COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE	☐ Special Exception to Deadline Date Policy	FOR NSF USE ONLY
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University of Maryland College Park	**University of Maryland College Park** **3112 Lee Bldg 7809 Regents Drive** **College Park, MD. 207425141**

AWARDEE ORGANIZATION CODE (IF KNOWN)	
0021030000	

NAME OF PRIMARY PLACE OF PERF	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
UMD/SESYNC	**UMD/SESYNC** **1 Park Place, Suite 300** **Annapolis ,MD ,214013480 ,US.**

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)	☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS	☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **The National Socio-Environmental Synthesis Center (SESYNC): Advancing socio-environmental research through computational, theoretical, and interdisciplinary science**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **28,200,000**	**60** months	**09/01/16**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____
   PHS Animal Welfare Assurance Number _____
☒ FUNDING MECHANISM **Research - other than RAPID or EAGER**

☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____
   Exemption Subsection _____ or IRB App. Date _____
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
  XX
☒ COLLABORATIVE STATUS
Not a collaborative proposal

PI/PD DEPARTMENT **National Socio-Environmental Synthesis C**	PI/PD POSTAL ADDRESS **1 Park Place, Suite 300**
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Project Summary

Overview
In 2011 SESYNC was founded on the premise that progress toward a sustainable future requires new knowledge that arises from close collaborations across many disciplines and sectors including, the natural and social sciences, NGOs, and government agencies. Such collaborations and the involvement of knowledge users creates a research portfolio with the potential to identify solutions and inform decisions. The comprehensive set of research and education programs include: interdisciplinary team-based syntheses; a highly competitive Postdoctoral Fellowship Program; opportunities for undergraduates, graduate students, and sabbatical fellows. The computational support systems and education and training programs of SESYNC will continue to build capacity in multiple communities. These efforts will be linked through an iterative process to help researchers and students overcome the challenges inherent in interdisciplinary synthesis. SESYNC has supported over 2000 participants and 100 synthesis projects resulting in over 200 publications. Over the next 5-years, we will continue to advance computational, theoretical, and interdisciplinary synthesis. We anticipate providing opportunities for approximately 1000 participants/year through our programs at our facilities. Extensive computational, team science, and logistical support will continue to be a hallmark of SESYNC's approach to serving the many communities whom we engage in S-E synthesis research and problem solving.

Intellectual Scope
To accomplish our mission of fostering this actionable scholarship, we will address five core objectives: 1. Enhance the effectiveness of interdisciplinary collaborations among research teams focused on socio-environmental (S-E) problems; 2. Identify and support new communities of S-E researchers 3. Provide education programs to enhance interdisciplinarity and understanding of S-E synthesis; 4. Enhance computational capacity necessary to perform S-E synthesis; 5. Enhance relevance of S-E research to decisions and behaviors by involving knowledge users in co-development of research. Guided by these objectives, we will build upon our core programs with a series of innovations and enhancements. These include: fully implement an innovative program and associated computational infrastructure for facilitated data discovery and question formulation focused on the food-water-energy nexus; expand SESYNC's Postdoctoral Immersion Program to help early career scholars deepen their understanding of the theoretical foundations of multiple disciplines relevant to S-E research; develop a new undergraduate program in S-E science to provide training in synthesis methods, data science and related quantitative skills for under-represented students; double the size of the SESYNC Graduate Scholars research program; develop new networks between the scholarly and public policy sectors to expand actionable outcomes.

Broader Impacts
SESYNC takes a deliberate approach to fostering interdisciplinary scholarship and education at the undergraduate, graduate, postdoctoral, and senior scientist levels. This approach is designed to help find solutions to pressing societal problems that will enhance the sustainability of the environment as well as improve the well-being of the people that benefit from nature's resources. Toward this end, SESYNC engages leaders, members of the business community, natural resource managers, and citizens in identifying the most pressing research and education needs. We do this in both systemic and targeted ways and will expand this approach through training and network building. This project will not only train more than 60 postdoctoral scholars to take this solution-focused approach but will result in many useful products from interdisciplinary teams of senior scholars. Further, SESYNC will significantly increase participation by underrepresented minority scholars over the next 5-years. An enhanced communications and outreach capacity will also provide greater opportunities to extend the outcomes of SESYNC supported research.

Project Description

I. Center Philosophy

Environmental problems are by definition social problems and so it follows that in 2011 SESYNC was founded on the premise that progress toward a sustainable future requires new knowledge that arises from close collaborations across many disciplines and sectors including the natural and social sciences, NGOs, and government agencies. Further, a research portfolio with the potential to identify environmental solutions and inform decisions or behaviors benefits from participation by government, NGO, community, and business knowledge users. To accomplish our mission, we identified five objectives:

Objective 1. Enhance the effectiveness of interdisciplinary collaborations among research teams focused on socio-environmental problems;
Objective 2. Identify and support new communities of socio-environmental researchers;
Objective 3. Provide education programs to enhance interdisciplinarity and understanding of socio-environmental synthesis;
Objective 4. Enhance computational capacity necessary to perform socio-environmental synthesis;
Objective 5. Enhance relevance of socio-environmental research to decisions and behaviors by involving knowledge users in co-development of research.

Guided by these objectives, we created a highly adaptable center designed to serve the needs of a broad community of scholars and inform decision-contexts for a wide range of socio-environmental problems. The tremendous productivity, excitement, and size of our participant community makes us well-poised to enter Phase II of SESYNC – the second 5 years of its life.

Socio-environmental (S-E) research problems are highly complex, typically have multiple solutions, and are often socially charged, making them extremely difficult to study. So while all NSF synthesis centers must meet the challenge of supporting scholars in using synthesis methods to generate new knowledge, SESYNC leadership had to tackle additional and quite unique challenges to meet our objectives. In designing the center, we gathered input from the community, the literature, and our own experiences to identify barriers that represented the biggest impediments to accomplishing our mission.

We then adopted an experimental approach to formalize center design – its leadership structure, community engagement processes and forms of service (Box 1). We experimented with the design of center programs and the implementation of processes that target specific challenges and then reflected on outcomes using data collected both internally and by an external professional with expertise in formative and developmental evaluation. Our goal was to apply a progressive approach that would accelerate S-E synthesis discovery and solutions by providing vital support for teams of researchers, including expertise, tools, data, and active input by the leadership to assist with team formation, access to new scholarly fields, and access to individuals or organizations that represented potential users of the knowledge. The

> **Box 1. SESYNC ORGANIZATIONAL THEORY**
> *"the center as experiment"*
>
> Adopt a highly reflexive and adaptive experimental approach combined with a developmental evaluation to formalize center processes and organization.

challenges and the experimental and adaptive nature of our approach required that the leadership and staff be very engaged with research teams and adapt processes over time. This will continue. And while we will still evolve, we have arrived at a core set of practices that we now implement to meet those challenges, as described in the next section.

## II.   SESYNC Process to Foster Interdisciplinary S-E Synthesis

Interdisciplinary synthesis teams face a complex set of challenges that evolve over the course of their research. We designed an approach to help teams identify and overcome them using a set of practices designed to tackle the intersection of the three types of challenges most SESYNC teams face. The practices (Figure 1) were developed using an iterative, adaptive process that was informed by a body of scholarship on interdisciplinarity, organizational science, and team science and cognition (Klein 2010, Fiore, Rosen, Smith-Jentsch, Letsky, and Warner 2010, Bammer 2013, Cummings and Worley 2014). The theories and scholarship supporting the practices are summarized in Palmer, Kramer, Boyd, and Hawthorne (2016; Appendix I[1]*). Other research or synthesis centers face some of the challenges SESYNC practices were intended to overcome, but we know of no other center in which researchers face challenges from three sources simultaneously (Table 1).

Table 1. Three sources of challenges for SESYNC
Novel teams work only in short bursts
- Many team members have not previously collaborated   - Members only interact a few times a year and do so in intense multi-day sessions   - Teams must rely on existing data and knowledge, not original collection of "field" data   - Teams often face difficult computational challenges
The scope and complexity of socio-environmental research problems is immense
- Multiple ways to view problems and multiple solutions   - Disciplines needed for analysis may be difficult to identify and recruit   - Projects must be broadly relevant to sustainability solutions   - Aspects of problem are often mismatched in terms of spatial and temporal scales   - Integration of qualitative and quantitative data often required   - High degree of uncertainty is associated with data or needed data is unavailable   - Value-laden research topics can lead to philosophical conflict within teams   - Lack of understanding or respect for methods from different disciplines may be viewed as an incompatibility (e.g., grounded theory vs. falsifiable *a priori* hypotheses)
Socio-environmental synthesis requires strong interdisciplinary and cross-sector team skills
- Language/epistemological differences must be overcome to reach joint understanding   - Group size (too large/small) may impede progress in integrating across disciplines   - Too little/too much familiarity among participants (lack of team cohesion; cliques)   - Perceived or real power differences and/or disciplinary dominance within group   - Lack of flexibility or leaders pre-determine process and path forward   - Uncertainty over goals or lack of shared goal   - Inadequate communication and lack of clarity on each participant's role(s)   - Extended time/effort required to initiate research projects

Interdisciplinary teams are central to the success of synthesis research at SESYNC, and we have developed a flexible process to support and accelerate teams throughout a project's lifetime. Given the unique challenges of actionable S-E scholarship, SESYNC's process has been informed by research in diverse areas including: inter- and transdisciplinary studies, cognitive and learning studies,

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[1]***All appendices are in the Supplemental Documents**

organizational science, and the science of team science. We interact with teams across four general phases: engaging, priming, supporting, and outcomes. Feedback derived from formal and informal interactions, observations, and gentle interventions are essential throughout this process. The figure below outlines the various processes that we deploy.
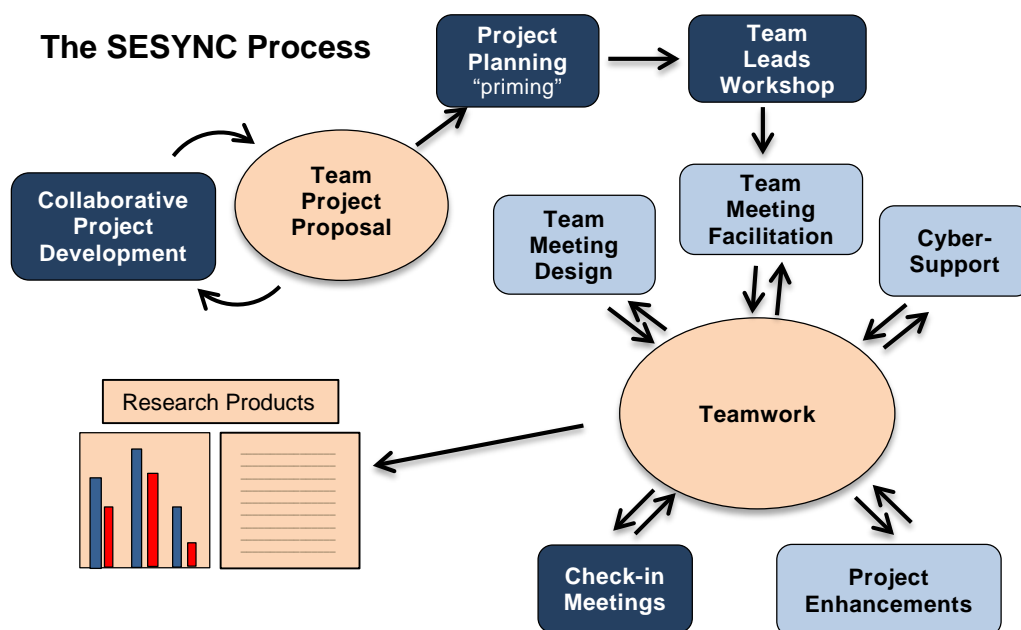
Figure 1. The SESYNC process is a set of practices that constitute an adaptive method for meeting the three challenges in Table 1. The process is designed to foster team progress and involves iterative engagement between SESYNC staff and team members over the life of a synthesis project. Each dark blue box indicates a group of SEYSNC practices that all teams have access to; light blue boxes are groups of practices that a subset of teams have utilized (see Methods below).

In this proposal, we identify which of the five center objectives (see *I. Center Philosophy*) are most closely associated with different aspects of the SESYNC process and with the portfolio of programs. However, most of our efforts contribute to meeting several or all objectives in some way. We think about our programs as a unified portfolio and manage our efforts in a coordinated way. This requires staff that are service oriented, able to contribute across programs, and are themselves creative and adaptable.

Methods

Lessons learned over our first 5 years have given us a strong foundation and methodology for helping S-E synthesis teams reach their research goals. The following set of practices together constitute the center's core approach to accomplishing *Objectives 1 and 2*. These processes are also employed at various times to enhance education *(Objective 3)* and actionability (*Objective 5).*

Collaborative Project Development
Given our mission to build capacity in S-E research, SESYNC staff discuss proposed projects with team leads prior to submission and provide feedback on optimal revisions following expert review. A highly interactive panel review process facilitated by SESYNC leadership is designed not only to identify the strongest proposals, but also to explore how projects might be improved by sharpening questions or considering new methods, clarifying conceptual frameworks, expanding or changing team composition (expertise, disciplinary diversity, and degree of prior collaboration), or considering additional data.

Project Planning

All team leads participate in a "priming" webinar with a core set of SESYNC staff that focuses exclusively on their project. This discussion gives all a better understanding of the scholarly problem and further introduces the PIs to the resources at the center. A set of standard queries is posed examining issues regarding data (access, amounts, quantitative or qualitative nature), logistics, and potential epistemological hurdles associated with interdisciplinarity. We emphasize the central role of leaders in articulating an early vision and in building effective team process.

Team Leads Workshop

PIs from SESYNC projects funded in the same time period come together for two days of interactive work. They share their research framework and early project management approaches as well as data and proposed methods. They discuss team composition and focus on the challenges of managing a transdisciplinary research effort. The workshop provides an opportunity for teams to discover joint interests, potentially form new collaborations, and engage in an explicit discussion of team dynamics.

Team Meetings Design

For a number of teams, advice on effective meeting structure is very useful. Discussions with SESYNC staff often focus on pre-meeting activities and specific goal-oriented agendas that balance group work with time for individual reflection and opportunities for flexibility.

Team Meetings Facilitation

Meeting facilitation is offered to all teams. In most cases, this requires a significant interaction between the facilitator and the team leads. The SESYNC facilitator becomes knowledgeable of the problem and language specific to the scholarship prior to the first meeting and tailors the facilitation process to specific team needs and preferences. Facilitation, particularly in projects' early phases, often focuses on the development of a shared conceptual framework and is designed to enhance the involvement of all team members and the sharing of diverse perspectives on the problem.

Cyber Support

A comprehensive overview of computational, analytical, and communication support tools are made available to all teams. A dedicated 8-member team of IT and computational experts is available to help in advance of or during team meetings. These experts work to understand the unique needs of each project and sometimes assist as participants, combining and analyzing diverse types of data. Ongoing engagement between these staff and team members is a key component of SESYNC's support structure.

Check-in Meetings and Project Enhancements

Staff and leadership utilize both informal and formal opportunities to gather information from teams and offer additional assistance. Casual conversations and shared lunches with teams in residence as well as structured webinars that engage multiple teams reveal both progress and ongoing or emergent challenges. In many cases, leadership and staff use this information to provide additional support (e.g., funding a new team member from a different discipline, providing computational support, training for a team member, or additional facilitation). These interactions also provide opportunity to link teams with potentially shared interests and invite new projects.

III. Implementing an Actionable Scholarly Portfolio

Fostering actionable scholarship (*Objective 5)* is critical if the research community is to effectively contribute to the solution of societal problems. "Actionable" has a very specific meaning in the context of SESYNCs goals (Box 2). It describes a characteristic of SESYNC's participants and our portfolio of

funded projects. Many synthesis teams directly engage non-academics, whom we refer to as potential "knowledge users." Other teams undertake projects that knowledge users have identified as important to our mission. In SESYNC's earliest years, the knowledge users provided input during development of SESYNC research themes; today input occurs in a continual and more comprehensive manner as they are fully integrated into our advisory boards (both the high-level External Advisory Board and the Scientific Review Committee; Appendix II). Participation of knowledge users is not a strict requirement for any specific SESYNC research team. Rather, it is a goal for our portfolio of teams.

The participation of knowledge users helps frame research questions that emphasize solutions to socio-environmental problems, stimulate creativity, provide guidance on policies and institutions affecting environmental decision-making, and communicate with broader audiences. SESYNC embraces a spectrum of actionable scholarship, from fundamental research needed before more applied research can move forward to research on broad, global socio-environmental issues, and to research that informs more specific policy questions. Policy-relevant research is only *one form* of actionable scholarship and has included, for example, a project that integrated concepts and methods from ecology and engineering to develop a new approach to enhance resilience of large water infrastructure projects in the face of climate change. This was designed to inform policies on what type of infrastructure projects are funded and how funders evaluate such projects; representatives from the World Bank as well as the Army Corps of Engineers participated in this synthesis effort. At the other end of the spectrum of actionability, SESYNC supports highly fundamental research projects such as one using cultural evolutionary theory to develop generalizable hypotheses and causal explanations for change in socio-ecological systems (Waring *submitted;* Bell *submitted*).

> **Box 2. Actionable Scholarship at SESYNC**
>
> Research of interest to or co-developed with individuals from both academic and non-academic (government, NGO, business) sectors. We embrace a spectrum of actionable scholarship from fundamental research needed to inform issues of global significance, to more applied research on specific policy questions.

Methods

Actionable scholarship is often under-rewarded within academia. Further, academic researchers often lack the training and experience needed to productively interact with knowledge users and to address public policy questions, as opposed to purely academic questions. Our mission is primarily geared toward the *academic* community's development of new skills for actionable research and partnerships. SESYNC therefore takes a deliberate approach to fostering actionable scholarship. We do this in both systemic and targeted ways:

Inclusion of knowledge-users in the SESYNC community and on research teams. Individuals from agencies, NGOs, businesses, and other sectors have been a part of the SESYNC community since the center's opening and will continue. We require all proposals include a section on actionability and our review committee takes this seriously as a criteria for evaluation. We have made a concerted effort to increase representation of knowledge-users on our External Advisory Board (Appendix II). Of those reporting demographic information from our core programs, 24% of SESYNC participants come from outside academia and 70% of the 97 research teams reporting include knowledge users.

Integrated in team facilitation. For those synthesis teams that use our facilitation services, we deliberately include a component on the relevance of the project to policy, decision-making, and/or resource management and encourage integration of decision-making and knowledge user relevance into

conceptual models and question formulation. An emphasis on geospatial data and informatics is currently and will increasingly be part of this interaction due to spatial information's importance to decision-making and science communication.

Pro-active recruitment of projects. SESYNC leadership will continue to seek and fund projects specifically targeted at actionable scholarship, such as our Foundations projects focused on topics like "Large-Scale Natural Resource Conservation and Restoration", "Sociological Perspectives on Non-State Actors in Environmental Governance", and "The Limits of Environmental Governance."

IV. Providing Synthesis Opportunities

During SESYNC's second phase, we will continue to enhance support of inter- and transdisciplinary teams using the set of practices described and a comprehensive set of programs (Table 2) designed to build and sustain the growing community we have nurtured. With approximately 100 synthesis activities initiated since 2011, we have built a community composed of a broad cross section of disciplines, academics at different career stages, and individuals and organizations that work at the boundary of science and decision making. We now average 900 visitors to the center each year. The programs are managed as a comprehensive portfolio of opportunities. We provide support for short-term catalytic Workshops and longer-term syntheses called Pursuits. We initiate new interactions and engage new disciplines through Foundations projects and support individual researchers, particularly at the postdoctoral level, who work to expand their scholarship and fluency in interdisciplinary S-E science. SESYNC leadership and staff actively look for ways to link and leverage programs to achieve productive and novel outcomes. For instance, workshops often lead to new proposals for Pursuits; facilitated interactions among members of different synthesis teams lead to wholly new collaborations; and, postdoctoral fellows are encouraged to interact with and subsequently become key members of synthesis teams. Taken as a whole, we manage our programs to build new collaborative networks and new research capacity.

Methods

General Programs
Our Pursuit, Workshops, and Fellows programs include opportunities for team-based and individual projects that contribute not only to the production of important scholarship, but also to meeting *Objective 2.* Since all provide access to the array of support systems offered by SESYNC (Figure 1) these programs also help advance *Objectives 1, 4,* and *5*.

Pursuits and Workshops**.** SESYNC projects are solicited via RFPs issued on a biannual basis. Pursuit and Workshop applications benefit from SESYNC's process of "Collaborative Project Development" (Figure 1). Proposal review is conducted by the Scientific Review Committee, a highly interdisciplinary, long–lived (2-3 year terms for members) body composed of 24 scholars (Appendix II). SESYNC's review process is both rigorous and highly iterative; it is built around discussions on the likelihood of success and project outcomes and in all cases lead to detailed recommendations for improving proposals that demonstrate promise. Post-review revisions are common for most proposals. The iterative nature of our funding process is designed to address our second core objective of building capacity and new communities. The very disciplinary-diverse SRC is critical in providing advice to PIs – particularly those new to S-E research – and directing them to resources and potential collaborators. There is a great breadth of synthesis activities conducted by Pursuit teams and in Workshops (Appendices III and IV).

Table 2: Core SESYNC Programs	
GENERAL PROGRAMS	
Pursuits	Projects conducted by teams meeting 3-4 times over SEVERAL years, often including knowledge users
Workshops	20-30 participants at one meeting focused on rapid synthesis of data, new approaches/tools, an emerging or critical problem, or engaging previously unlinked communities or disciplines
Foundations	Invited projects that explore novel ideas or how different disciplines can contribute to new S-E research areas; generally include 6-10 participants for 1-2 meetings
Research Fellows	Sabbaticals, short-term/visiting fellows, journalism fellows, policy and practice fellows
EDUCATION PROGRAMS	
Postdoctoral Fellows	12-15 fellows in residence, each with external domain collaborating mentors and access to an extensive professional mentoring program at SESYNC
Graduate Scholars	Workshops and training leading to Pursuits led by advanced graduate students
Undergraduate Synthesis Scholars	Summer Internships and a newly proposed initiative to engage under-represented students and their faculty mentors in S-E synthesis
Short Courses	3-10 day, hands-on training on topics including: Case study approaches, Bayesian analysis, network analysis, computing (database management; R programming, GIS, etc.)

Foundations. SESYNC leadership has proactively recruited 8 Foundations projects; the majority were in the first two years in order to stimulate initial engagement of policy scholars and leaders, environmental psychologists, political scientists, philosophers, and sociologists. We will continue this program as we see novel opportunities arise or as leadership and external advisors identify important topics.

Research Fellows. SESYNC will continue to fund a limited number of sabbatical fellows each year based on a competitive application process. We require that interested people contact us prior to submission of a proposal to ensure they are eligible given their topic and status; proposals are generally reviewed by the most relevant external experts. Other types of Fellow applications (Short-term, Journalism, etc.) are generally reviewed by the leadership.

Education Programs
The SESYNC Education portfolio includes the following programs: Postdoctoral, Graduate Scholars, Undergraduate Scholars, and Short Courses. While this portfolio is specifically designed to meet *Objective 3*, individual programs target additional objectives.

Postdoctoral Fellows Program. This supports outstanding early career scholars to conduct synthesis research in residence at SESYNC for two years. Fellows build the skills and dispositional attributes needed for S-E synthesis research through structured and informal programmatic offerings. We strive to achieve a diverse pool of 12-15 fellows at all times (Appendix IV) which has contributed to the strong sense of community for them and also encourages collaborations that extend beyond each individual's synthesis project. Our mentoring program will continue to expand our four-fold approach of providing: 1) time and funds for one-on-one interactions with external domain mentors as well as personalized advice and support from onsite "professional mentors"; 2) training and engagement in interdisciplinary team work; 3) organized activities and workshops career skills; and 4) embedding the scholars in the processes that more senior scholars routinely engage in ("dispositional mentoring"; Table 3).

Table 3. Postdoctoral Mentoring Plan	
1. Collaborating Mentors	Fellows select up to two mentors from anywhere in the world that serve as their domain collaborating mentors. SESYNC provides funds for travel by the fellow and mentor to interact and encourages regular remote interactions.
Professional Mentors	Palmer is the primary on-site mentor who interacts regularly with the postdocs and organizes activities with help from other education staff. Annual evaluations and individualized input from the entire leadership provide ongoing feedback to fellows.
2. Scholarship and Training in Interdisciplinarity	The Immersion Program aims to increase Fellow's knowledge of core disciplines beyond their own, and engage them in interdisciplinary discussions. The focus is on theories and methods foundational to S-E disciplines (Appendix V). Eminent researchers lecture and engage in discussions facilitated by external scholars who support the Fellows through the program Lectures are live-streamed and video-taped to share broadly.
3. Skills Mentoring	SESYNC organizes activities for the fellows to build specific skills; these have included: • Communication workshops – communicating with the public, policy makers, etc. • Workshops on research funding sources and writing strong proposals • Lecture-discussions on the science-policy link • Visit to NSF to interact with program officers • Writing workshops • Data Carpentry workshops and weeklong Computational "Institutes" • 10 day Bayesian workshop • 5 day workshop on Network Analysis
4. Dispositional Mentoring	Much of the mentoring that is intentional on the part of the leadership may not always be transparent to the fellows: experiential or immersion type learning occurs as fellows are embedded in activities/settings representative of their professional future or their future as a practitioner of socio-environmental research and interdisciplinary collaboration. While individuals can be introduced to professional practices through traditional means (e.g., lectures or readings on how best to engage in interdisciplinary settings), we believe these practices are best learned experientially. Thus we immerse postdocs in a variety of setting in which the values, collaborative attitudes, and practices are negotiated by each individual. Examples include: • Serving on a SESYNC search committee • Serving on a SESYNC proposal review panel • Participating in postdoctoral candidate interviews • Hosting visiting scholars and organizing symposia • Leading a synthesis team • Developing curricular materials • Giving lectures in SESYNC courses • Preparing an annual accomplishments packet and undergoing annual review

Graduate Scholars Program. In 2015, SESYNC developed a unique opportunity for teams of doctoral candidates to conduct S-E synthesis. The program provides the support services given all other teams, but tailored to the specific needs of emerging scholars. It is designed to foster S-E synthesis and interdisciplinary team science competencies through an authentic research experience. The program starts with a hands-on workshop for ~30 students and provides an introduction to S-E synthesis, proposal writing, teamwork skills, and networking across natural, biophysical, and social science disciplines. A widely distributed RFP then invites applications from teams of 5-7 students to work together at the center. Many who attend the initial workshop go on to apply. The leads of successful proposals return to SESYNC for additional training and proposal refinement prior to initiating a series of three working team sessions over the following 18 months. SESYNC provides an enhanced level of support during this period including: process mentoring before and after each team meeting, additional check-ins, and professional development on an as needed/requested basis. This support is led and

primarily provided by Dr. Jonathan Kramer, Director of Interdisciplinary Science at SESYNC. Graduate teams are also given opportunities for technical training and/or expertise as needed (e.g., data and software carpentry, modeling, etc.).

Early feedback from the first graduate cohort was very encouraging (Appendix VI). Participants felt that the experience gave them a new appreciation for disciplines other than their own, driven in part by the opportunity to benefit from a structure that fostered shared learning in a setting that was not driven by a more senior leader. Most felt that the experience exceeded their expectations. Each of these teams has now completed the bulk of their work and 5 of 6 already have submitted at least one manuscript for publication.

Undergraduate Programs. This program offers students summer internships for hands-on S-E research with faculty. In the past we have had students from the University of Maryland, Coppin State University, University of Maryland Baltimore County, and Dartmouth; faculty mentors are at local universities. Interns work on projects at the mentor's institution and attend weekly day-long program events at SESYNC to bolster S-E synthesis skills and knowledge. The program has supported 53 undergraduates to date, and feedback from interns and mentors has been very positive. Priorities for continued improvement include involvement of students and mentors from additional local historically black colleges and universities (HBCU) and increasing the depth of S-E science skill training.

Advancing Teaching and Learning of Socio-Environmental Synthesis. SESYNC is committed to advancing undergraduate and graduate level teaching and learning of 1) fundamental concepts associated with socio-environmental systems, and 2) competencies needed to apply the synthesis method to a problem at the interface of people and the environment. This is accomplished via two primary programs.

Teaching S-E Synthesis with Case Studies Program: An annual weeklong short course for college-level instructors offers a guided experience in designing and writing a S-E synthesis case studies for classroom use, and engages participants in broader discussions of teaching about S-E synthesis. Participants have developed 43 cases and have taught over 900 students with them; cases are made freely available via the SESYNC website. Additionally, workshops focusing on synthesis of best practices, development of tools and resources, and deeper exploration of relevant issues in teaching S-E synthesis are organized. Presentations about these teaching case studies by SESYNC staff and short course participants have expanded the reach of this program. A community of educators engaged in the teaching of S-E synthesis continues to grow as a result of these efforts. The primary goals for the Case Studies Program are to: 1) provide effective professional development for participants to teach S-E synthesis; 2) engage participants in broader discussions of teaching about S-E synthesis to help build a community of practice; 3) enable participants to develop a portfolio of high quality teaching case studies; 4) adapt the case study method for teaching about S-E synthesis; and 5) develop a quality collection of case studies that is useful to a large audience.

Online Education Resource Program: SESYNC will use a variety of approaches to increase the education resources that we make available to the learning community and broad public. A set of lecture notes on the fundamentals of S-E systems has been developed and is available online; we will continue to add to this. We will enhance the reach and usability of the case studies by translating some into Spanish and by distributing many through networks including Verde Elemental and the American Museum of Natural History's Network of Conservation Educators and Practitioners (AMNH-CBC). All of the lectures filmed during the postdoc Immersion Program will be shared via the SESYNC website.

Computational and Cyber Support Programs

SESYNC seeks to provide the best cyber infrastructure (CI) for facilitating computation and data related synthesis activities; the CI programs also include extensive services by our computational personnel to assist teams with database development, data integration, analysis, and visualization (Figure 2). SESYNC staff perform many CI tasks directly for teams; however, because we strive to build CI capacity (*Objective 4*), we prefer to work with team members so they can learn how to perform the tasks themselves. Since SESYNC teams are quite diverse in their approaches to synthesis and in the types of data they bring to a problem, our CI staff include individuals that span a broad range of disciplinary backgrounds and expertise. Through an array of integrated services, the staff and infrastructure enable researchers to collaborate; to address research problems at unprecedented scales; and to build their own capacity to do computationally-enabled, socio-environmental analysis (Figure 2). In order to support the variety of groups, the CI staff has developed procedures to actively engage projects and ensure their CI needs are met throughout their lifecycle, from pre-award through completion.
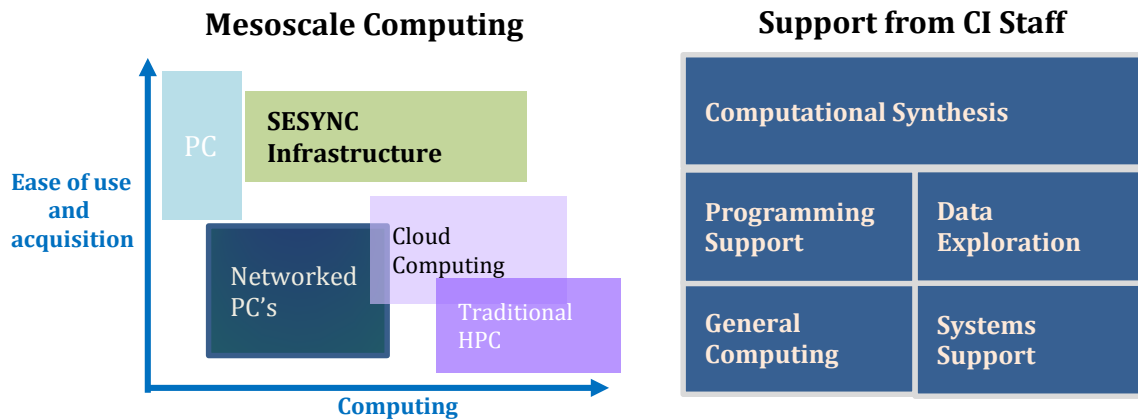
Many SESYNC synthesis teams focus exclusively on highly quantitative data (biophysical, social, or both). While this is reflective of the social sciences becoming increasingly quantitative (King 2014; Mann 2016), survey data, interviews, and case studies remain very important to understand how behaviors, attitudes, decisions, and local context interact with or drive changes in the environment and vice versa. Teams relying on both quantitative and qualitative information can employ mixed methods analyses (Nuijten 2011; Molina-Azorín and López-Gamero 2014), meta-studies approaches (Magliocca, Rudel, Verburg, McConnell, Mertz, Gertsner, Heinimann, and Ellis 2015 see Table 1 therein), or agent based modeling to analyze interactions among variables as well as outcomes across diverse scales. Many groups seek to integrate theoretical frameworks with modeling (e.g., combine Ostrom's diagnostic approach with hierarchical statistical models; MacNeil and Cinner 2013). Some teams are well equipped to undertake mixed methods analyses, but we have found that most natural scientists are not familiar with such methods and may struggle over how to incorporate qualitative data into the synthesis. We provide advice, courses, and one-on-one assistance to help participants overcome these and other barriers.

Computing Infrastructure. The suite of hardware and software we offer is designed to provide maximum computing power with minimal barriers to entry. Large data storage (75 TB), database servers, and a 16-node computational cluster can be accessed by group members via SSH, a web file gateway, virtual desktop, or SESYNC's RStudio Server.[2] All services have been tightly integrated so that researchers have seamless, remote access to all of their group's resources regardless of which SESYNC service they are using. SESYNC's infrastructure is fully virtualized allowing CI staff to reconfigure and redistribute resources as necessary depending on research needs. We anticipate more than doubling our computational and storage capacity as the sophistication of resources our groups need and know how to use continues to grow. As necessary, SESYNC will pursue partnerships with UMD-based resources and national groups, such as CyVerse, to support the computing needs of our teams and researchers.

In-House Expertise. The eight-member CI staff are dedicated to solving problems and developing tools for SESYNC supported researchers. We offer a wide range of expertise crucial to successful synthesis research, including statistical programming and advanced statistical methods, simulation and analytical modeling, database design and administration, geospatial data handling, and parallel computing. Half of the CI team are domain scientists, and the remainder computer scientists; this diversity allows us to bridge the diverse objectives of the researchers we support to appropriate computing resources.

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[2] These services were developed and deployed to accelerate research based on our observations of common needs and challenges across projects.

Mesoscale Computing

Support from CI Staff

Mesoscale Computing diagram:
- Ease of use and acquisition (y-axis)
- Computing (x-axis)
- PC
- SESYNC Infrastructure
- Networked PC's
- Cloud Computing
- Traditional HPC

Support from CI Staff table:
- Computational Synthesis
- Programming Support
- Data Exploration
- General Computing
- Systems Support

Figure 2. SESYNC cyber infrastructure is ideal for scientific problems that require more than a high-end desktop but less than traditional High Performance Computing (HPC). This mesoscale CI accelerates scientific discovery by providing maximum productivity with minimal barriers to entry. Equally as important as the physical infrastructure are the services SESYNC computational staff provide.

Computational Training and Community Capacity Building. Recognizing the urgent, largely unmet need domain S-E researchers have to acquire and apply data science skills in their work, SESYNC regularly offers hands-on short courses combined with research-focused hack-a-thons to familiarize our community with tools like R, command line (shell), collaborative code development (git), SQL, and more. This instruction not only accelerates progress on SESYNC projects, but also connects the Center's education mission to CI by preparing researchers for future work on computationally demanding S-E problems. SESYNC is a leader in training scientists to apply data science skills in their work, leading and participating in multiple workshops with a network of like-minded organizations to develop instructional methods and materials.

V. INNOVATIONS

The first five years have been extremely productive, and the community has responded well to our program and activities (see, *Section X. Results from Prior Support*). For the second five years, we propose the addition of "new" programs and the expansion of several others as described next.

Methods

New: Activities to foster actionable scholarship

The concept of actionability is often assumed to mean that research leads directly to policy. As noted earlier, this is not the philosophy SESYNC embraces; scholarship may inform policy, but it also may be actionable because it has the potential to contribute to the solution of a problem of societal interest or it provides information needed before potential solution paths can be identified. For example, research that can lead to better management practices for species at risk from climate change may first require the development of a general classification scheme to assess the extinction risk to climate changes for a broad range of species living in fragmented landscapes. Such a project is ongoing by a SESYNC postdoctoral fellow; she is developing novel mathematical approaches to synthesize dispersal and demography data. These approaches can then help others develop tools or other products for the non-academic community. Understanding and identifying the link between research and its potential use in a solution context has been difficult for many scholars engaged with SESYNC. They have requested more information/training on how to move their work along the actionable continuum and on the

mechanisms by which policy/behaviors/decisions can make use of research knowledge. To help meet these needs, we plan several things:

Public Policy/Actionable Research Training. A course will be developed to introduce content on actionable research to our postdoctoral fellows, graduate student participants, and potential research teams. It will provide instruction on the variety of institutions that use S-E science, the kinds of research pertinent to decisions made by those institutions, and ways to connect and communicate with non-academic partners.

Match-making Efforts will be initiated in which we will begin matching supported researchers with knowledge user and policy audiences. We will financially support researcher travel to participate in policy related workshops, briefings, and other meetings where their expertise is relevant. This can be thought of as both actionable synthesis and communications/outreach strategy and is something the community of scholars and knowledge users has requested of us.

Exploratory Roundtables will be organized in which we will bring knowledge users together with researchers to inform future requests for project proposals. Akin to, but more topically focused than the Theme Identification meetings we conducted in year 1, these roundtables will help us identify research needs likely to be relevant to decision audiences and strategies to encourage new synthesis projects around those needs.

New: Diversifying the socio-environmental synthesis community
In collaboration with Coppin State University we will develop a program for junior level undergraduates from four HBCU institutions (Coppin, Delaware State University, Virginia State University, and University of Baltimore). The goal of the program is to introduce undergraduates and their campus mentors to S-E synthesis research. In addition to structured workshops, we will connect them with and explore potential ideas for team research projects. The program will provide a highly interactive curriculum on S-E science, the use of synthesis methods, and training in associated competencies including data science and related quantitative skills. Because the program will also engage their faculty mentors, it will also provide HBCU faculty with new teaching modules and the skills to use them in their classrooms.

The program will begin with a series of three workshops over the course of a year: "Introduction to S-E Systems and Synthesis Research", "Interdisciplinary Team Science on S-E Problems", and "Data-based Syntheses." A combination of lectures, presentations by researchers conducting S-E synthesis, interactive case study exercises, discussions, and other hands-on activities (e.g., a GIS demo) will be used. Throughout the workshops and beyond, students will be developing their own independent research project. SESYNC staff will organize and lead the workshops, but given the great interest on the part of our postdoctoral fellows in engaging in teaching and training, we anticipate many of them will provide assistance and additional mentoring to the student-mentor teams.

New: Synthesis educational video project
SESYNC will develop 3 videos (30 – 40 minutes each) that focus on: "Synthesis as a Research Method", "Interdisciplinary Best Practices", and "Computational Aspects of Synthesis Projects." Videos will target graduate, postdoctoral, and senior scholar levels; however, we believe parts of them will be suitable at the undergraduate level as well. The content has been outlined; the story boards will be written in the near future and production plans will be finalized with a professional video team we have previously engaged.

Expand: the "Data to Motivate Synthesis" (DTMS) program

With supplemental funding from NSF in 2015, SESYNC initiated a pilot project to engage and support early career scholars in an unconventional process of facilitated data discovery and team science workshops designed to spark new project ideas and foster new interdisciplinary collaborations. The focus is to explore one or more links between food, water, and energy. SESYNC is now developing the components of a cyberinfrastructure platform to support data discovery and analysis and lower the barriers to entry for data-driven research. While the primary objective of the program is to foster new collaborations and important scholarship, additional fundamental knowledge will be sought on how best to foster team work among highly heterogeneous disciplines as well as how to help foster computational skills. The cyberinfrastructure platform is critical to the four main objectives of the DTMS program: 1) Flip the conventional synthesis process from a theory-to-question-to-data workflow to a process that begins with facilitated data exploration and discovery to catalyze formation of novel research questions and testable hypotheses based on existing data (Figure 3); 2) Accelerate research by fostering new collaborations and scientific inquiry on feedbacks between systems by linking concepts and data from previously disparate sources and problem domains; 3) Build new scientific communities among the social, natural, and computational/data sciences through real-time data discovery, analysis and joint question formulation; and 4) Enhance interdisciplinary collaboration skills and strengthen data and computational literacy among early-career scholars.

Data-Driven Scientific Workflows
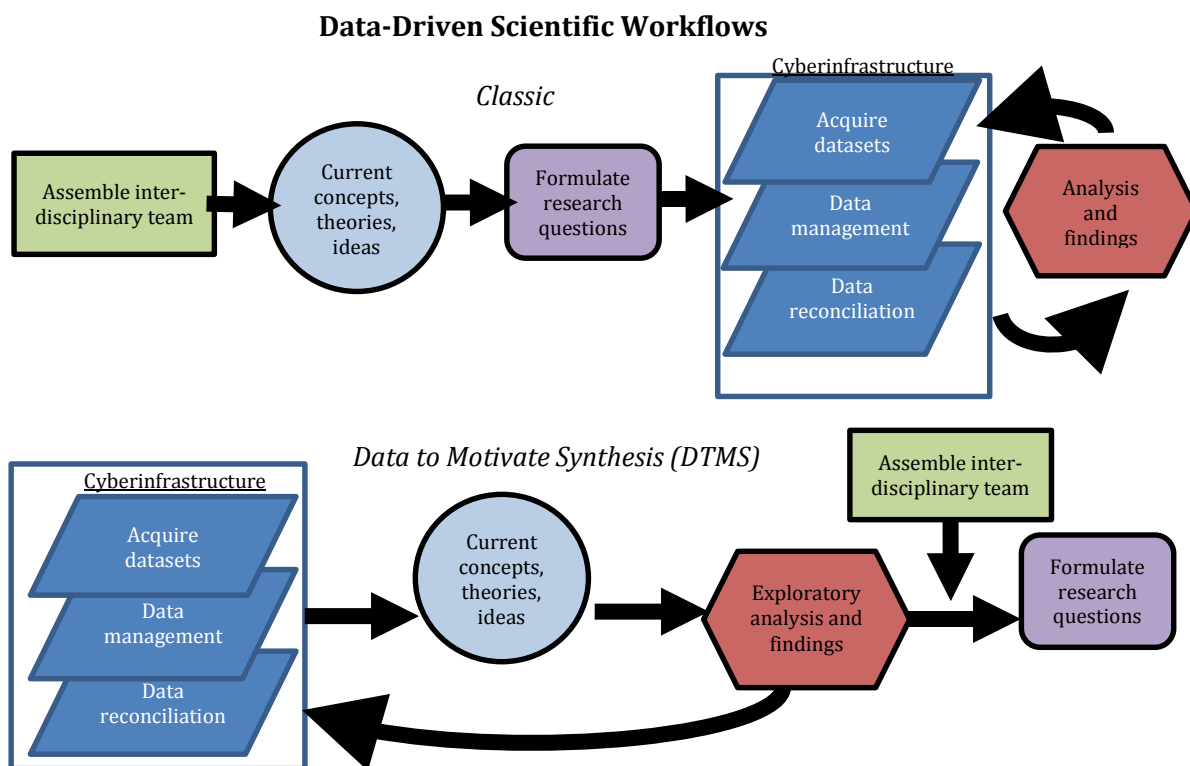
Figure 3. The DTMS program is designed to flip the classic process used to build synthesis teams and develop research questions. The program will test if group facilitated processes that begin with data discovery and iterative exploration and end with team formation and final research questions will result in novel high impact syntheses.

Motivating new teams and new questions. In the second half of 2016 we hope to bring the computational platform and its fully integrated user interface to a level which will allow researchers to find and interact with data through a searchable data catalog and a food-water-energy S-E ontology. The

tools will be linked to a general workshop facilitation process. We will test this entire system with a series of focus groups to help us assess functionality and make needed improvements. Moving into 2017, we will host workshops for early-career scholars to provide preliminary test of our underlying proposition that team use of the software combined with facilitated discussions will accelerate interdisciplinary collaborations. The participants will leverage the data catalog, ontology and analysis components of the platform as boundary objects to link disparate disciplinary conceptualizations of research issues. We hypothesize that search paths and data identified through the joint data discovery process will act as common reference points for bridging disciplinary and epistemological divides, as well as fostering communication between more theoretically- or technically-oriented researchers. The outcome of the preliminary workshops will be evaluated qualitatively to determine if we move to the next phase of full platform development. Ensuring that the platform is reliable, highly usable, flexible and maintainable is essential if we are to fully implement this "flipped" approach in numerous workshops that engage a greater number of participants. We will collect data on their processes of engagement and the collaborative outcomes.

Participants in the DTMS workshops will be encouraged to develop full synthesis proposals to SESYNC, and we hope to support several clusters of these, refining the process after each workshop. At the same time, we will independently solicit synthesis proposals associated with the food-water-energy topic from the broader external scientific community. We will compare proposals from the two sources (workshops vs. open calls) based on their utilization of data (e.g., number, size, and diversity of data sources), integration of multiple and diverse disciplines (e.g., number and breadth of disciplines), and novelty of research questions (e.g., competitiveness ranking) to assess the role of a facilitated and cyber-enabled team science approach to synthesis research versus the convention research development model. The DTMS project presents a unique opportunity to advance the science of team science through a comparative natural experiment. Will facilitated discussions motivated by data discovery and discussion of how members navigated the cyber ontology lead to more creative or actionable synthesis research?

Expand: the Immersion Program

The Postdoctoral S-E Immersion Program kicked off in September 2015 with the arrival of the first cohort of Postdoctoral S-E Immersion Fellows at SESYNC and the beginning of a year-long workshop series. Twenty-two postdocs are engaged in each workshop – 15 of them SESYNC postdocs and 7 from other universities around the country (Figure 4). The series aims to build capacity in young scholars to work with and across disciplines that are core to socio-environmental research, by providing them the resources and opportunities to learn about concepts, theories, and methods that are foundational to specific disciplinary perspectives. During the 2015-2016 academic year, five four-day workshops were organized, each focusing on a different core discipline: ecology, economics, sociology, anthropology, and the science of change. The workshops are based on the immersion principle that diving into new ideas in the context of problems familiar from one's own disciplinary tradition will support learning and later application of the new ideas. Eminent scholars from their respective discipline are invited to each workshop to present lectures and engage in discussion with the Immersion Fellows. The workshops are facilitated by two scholar-mentors who travel to SESYNC for each workshop and support the Immersion Fellows in in-depth learning, discussion, and application of methods and theories during and after the workshops. Synthetic products are being produced by the postdocs. The program goals are to: build capacity by increasing Immersion Fellows' knowledge of core disciplines that are outside of their own training; create a community of young scholars engaged with questions about how to bring together theoretical and methodological perspectives in S-E research; and broaden the resource and knowledge base of the S-E research community more generally.

Figure 4. The 2015-16 Immersion cohort and scholar lecturers from one workshop. Sociologist Simone Pulver from UC-Santa Barbara and fisheries biologist Olaf Jenson from Rutgers University are facilitating all of these postdoc workshops and working with the postdocs to develop papers and products.

Immersion alums enhancing support of S-E networks. For the next phase of SESYNC, we will introduce support for past and current cohorts of postdocs to engage with past and current SESYNC-funded synthesis teams. Former postdocs as well as the broader S-E community have expressed a need for activities to help sustain S-E research communities after their SESYNC work ends. The current cohort of Immersion postdocs have been very enthusiastic about organizing symposia and networking forums that build but also extend their experiences during the Immersion program. SESYNC will support their plans to organize multiple symposia with a thematic focus and link these together into a larger conference that is either open to the broad community or available to a smaller number on an application basis. We anticipate the first of these will be in late 2016 and into 2017. The expanded Immersion Program described here will include opportunities for similar activities catalyzed by the participants.

Engaging the broader community. All of the lectures and panel discussions given throughout each workshop have been live streamed and video-taped and we are currently editing these to produce educational videos that will be freely available on our website (see http://www.sesync.org/immersion-program-lectures-related-resources for progress to date). Additional short video products, originating from the first Immersion Program, will also be produced that can be used to generate interest in STEM education and demonstrate how specific scientific fields and disciplines engage in S-E research. Going forward into Years 6-10 we will invite new scholars to add new material and different perspectives to the core disciplinary domains involved in S-E research. We will also add topical research areas that span domains (e.g., theories of behavior change, socio-ecological resilience).

Expand: the Graduate Scholars Program
Based on the strong results of our first cohort of graduate student teams, we will expand the program from 6 to 12 teams (two cohorts) supported per year for the next 5 years. We will provide teams with a full offering of computational and team process support to match specific training to their needs. Based on input from our first cohort, we will expand our on-site mentoring to include a higher level of interactions with team members in addition to project leaders. In addition, we will initiate post-program tracking of career trajectories and provide opportunities for long-term networking through communications and presentations and gatherings at conferences. These cohorts of young scholars provide a wealth of information on the emergence of interdisciplinary teamwork competencies. We will obtain institutional review board approval to study their progress over time.

Expand: Cyberinfrastructure services and products

The experience gained during SESYNC's first phase has uniquely positioned us to develop transformative technologies and rapidly increase the capacity of our community to use the best tools for their research problems. In particular, we will make the DTMS platform accessible to all interested researchers for data discovery and metadata exploration. We will also continue to grow our computational education efforts by increasing the variety of topics covered in response to community demands (e.g., introducing workshops on GIS and parallel processing).

We will continue to work with researchers to identify common computational barriers, then develop and disseminate tools and best practices to overcome them and accelerate research. For example, in response to the increased demands from new data-intensive projects, we deployed a scheduled cluster and are making continuous improvements to ease researcher access to it, including developing an R package to allow direct interaction with the scheduler and deploying a queueing policy to balance and distribute the increasing demands on the system. In addition, SESYNC cyberinfrastructure staff are developing an R package to connect R to PostgreSQL hstore data for more efficient storage and retrieval of large, complex data formats.

As the demand for web-based visualization continues to grow, we will support our researchers in using the most appropriate technologies for their visual analysis and dissemination needs. Using tools like RShiny and GitHub pages, we will empower researchers to frame their findings in compelling narratives that integrate text and visualizations for dissemination. Providing and supporting such "do-it-yourself" tools reflects our mission to enable the adoption and application of new technologies for S-E synthesis among the research community.

Expand: Communications Program

SESYNC's communications program translates and disseminates research results, promotes the Center's programs, and builds the capacity of the Center's research community to engage with a broad audience outside of academia. Our strategy is based on producing high-impact digital communication products disseminated through multiple channels and actively developing networks to connect researchers to key knowledge users and decision makers. Two full-time staff members meet the Center's communications goals by working to produce content for SESYNC's website and social media channels; writing press releases; organizing seminars; contributing to publications such as the *New York Times*, the *Guardian*, and *Yale Environment 360*; and developing outreach channels at venues such as the Wilson Center and the Council on Foreign Relations (see Appendix III for a complete list of communications products).

Leveraging the networking capacity of communications staff in coordination with SESYNC leadership, we will integrate communication efforts with the actionability of supported projects and engage in a more active media outreach strategy by: 1) Expanding existing connections with high-visibility media venues – such as, Wilson Center's *New Security Beat*, *Nautilus*, and *The Conversation* – to help SESYNC researchers develop content based on their results for these and other outlets with broad reach; 2) Increasing targeted outreach to journalist contacts and provide the support to place meaningful and representative stories from our Center in regional, national, and international news outlets. For example, direct outreach to the *New York Times* recently resulted in a feature story; and 3) Developing interactive communications training materials for project leads and teams to aid them in identifying and connecting with potential audiences outside of academia (decision makers, the interested public, etc.). Training materials will cover topics, such as how to place feature stories in high profile media outlets, distilling information for policy makers, and strategies for effective press releases. Communications staff will systematically interact with teams as they work at SESYNC and after projects are completed to

provide support and alert them to emerging opportunities for outreach. This same training and assistance will also be provided to SESYNC's postdocs as a professional development opportunity.

VI. Partnerships and Collaborations

For the next 5 years of SESYNC's life, we will take on fewer collaborations and establish clear and unambiguous goals for each. Our collaboration with **Resources for the Future** (RFF) has been very useful and resulted in joint workshops, panels, and co-sponsoring of events. Dr. Jim Boyd remains very active at SESYNC and has helped us engage a number of senior scholars from RFF in various events; we will continue this collaboration. Our collaboration with **Helmholtz Centre for Environmental Research** and the **Synthesis Centre for Biodiversity Sciences (sDiv)**, has been excellent. We have jointly funded multiple teams that met alternately at the centers, and exchanged ideas among the center leaders over three in person meetings and multiple e-exchanges. We are currently in discussion with both German centers about future collaborative opportunities. We have also partnered with **NCEAS, NESCent, NIMBioS**, **and the Powell Center** to co-fund synthesis projects. SESYNC is a founding member of the International Synthesis Center Consortium and fully supports the efforts of this new organization. In addition, we have offered to partner with Future Earth by hosting a synthesis team focused on a topic related to coupled human natural systems.

Our collaborations with **Gallaudet University** and **Coppin State University** have resulted in the engagement of under-represented students and faculty in synthesis activities. Synthesis work co-led by faculty from these and other institutions resulted in the development of common methods for course modules to teach undergraduates about socio-environmental systems and interdisciplinary synthesis research. Modules are being implemented and learning outcomes compared at Gallaudet, Coppin State, University of Washington-Vancouver, Widener University, and University of Maryland.

Relatively new but very productive partnerships were established in late 2014 with **USDA** (Agricultural Data Common) and **USGS** (Center for Integrated Data Analytics) for the sharing of data, development of data discovery tools, and metadata standards. Both agencies have provided staff support to facilitate our interactions and help move forward the DTMS project that described in the prior section.

Methods

In addition to continuing the partnerships described above, we propose several new collaborations and partnerships that have been in discussion over the past year and very briefly describe the goals in this section. The addition of new collaborations with three HBCUs that extend beyond our ongoing relationship with Coppin State was described earlier in the Innovations section ("Diversifying the S-E Community").

Georgetown University

We will implement a new program with Georgetown University focused on environmental policy. Georgetown has recently launched a new "Environment Initiative" to advance interdisciplinary study of the relationship between the environment, society, scientific understanding, and sound policy. Georgetown brings strength in a variety of areas relevant to SESYNC including programs and faculty from their top ranked law school, environment clinic at the Law Center, Georgetown Climate Center, McCourt School of Public Policy, and the School of Foreign Service. We will co-mentor and co-fund four postdocs to conduct synthesis research on science-policy linkages. Recruited through a national competition, they will reside at SESYNC fully integrated into our postdoctoral program with the option of spending time at Georgetown working with faculty and/or participating in workshops and seminars. The

collaboration will also include training and experiential opportunities for SESYNC's full postdoctoral cohort. Additionally, Georgetown faculty will contribute to SESYNC short courses and training efforts in environmental policy.

Brazilian National Synthesis Center

As part of our continuing effort to engage with other synthesis centers and with the International Synthesis Consortium, we will collaborate with faculty from the Pontifical Catholic University of Rio de Janeiro to provide advice and input as they develop the national synthesis center for Brazil. This is only now emerging and has the initial backing of Brazil's Ministry of the Environment. Dr. Bernardo Strassburg will serve as the synthesis center director and it will be closely affiliated with the International Institute of Sustainability (http://www.iis-rio.org/en/). The projects and research Director, Dr. Agnieszka Ewa Latawiec, is also pivotal to the collaboration. We anticipate postdoctoral exchange programs and potentially the co-funding of synthesis projects, much as we did with the Helmholtz Centre and sDiv during our first five years. International perspectives are critical for postdoctoral training.

VII. Evaluation and Assessment

Over the past 5 years, SESYNC has utilized a formative evaluation to understand the efficacy of our programs and processes. The evaluation, conducted by an external, independent expert was essential to the design and refinement of programs (Appendix VII). SESYNC also continuously monitored the productivity of synthesis teams (publications, presentations, student support, etc.), participant demographics, as well as activities and products directed toward making research outcomes more actionable (Appendix III). Steady growth in the interdisciplinary community conducting S-E synthesis, accumulation of scientific outputs of high caliber, and a growing list of actionable outcomes are indicative of the maturation of the Center's approach over our first 5 years. While our next evaluation will be more summative in nature, formative techniques will still be a valuable component in our comprehensive approach to informing decision making and program evolution, all supporting our continuing commitment to experiment, refine, and improve SESYNC.

Methods

In Years 6-10, SESYNC will contract with an external, independent evaluator (Dr. Edward Wilson, Wilson Consulting) who will work with Center leadership and staff to develop the summative evaluation.

Core Research Programs

Surveys and interviews. Beginning in 2016, the evaluator will work with SESYNC leadership to develop a new strategic plan for the next 5 years. The Center's program theory will be refined as will evaluation goals with specific emphasis on how SESYNC accelerates the S-E synthesis process and builds S-E synthesis capacity among multiple communities. This portion of the evaluation will be focused on outcomes at the individual and team levels and will employ a mixed methods approach including semi-structured interviews, surveys, and other data collection techniques. Summative findings will be presented to SESYNC leadership on an annual basis; however, we anticipate that interim results and interactions with the evaluator will be used to inform decision making on an ongoing basis. We have implemented a new center-wide system that allows staff to annotate, share, and archive information on interactions with teams and individuals. This provides a comprehensive data set to inform the evaluation as well as other studies of team dynamics.

Science metrics. Collection of data pertinent to science metrics will allow us to conduct advanced analyses that go beyond measures of citation rates and journal impact factors. We will recruit a member

of the external research community to conduct bibliometric and network studies (e.g., Borrett, Moodey, and Edelmann 2014) focusing on SESYNC's impact on participant scholarship and in a broader sense, the emergence of S-E synthesis as a discipline. These studies will examine if publication patterns are changing among SESYNC participants and if there is evidence that new concepts are being developed, shared language used, and new research networks emerging. We are particularly interested in seeing if sustained interdisciplinary collaborations emerge after researchers work at together at SESYNC. We will also examine whether AltMetrics are of value to understanding the broader dissemination and impacts of SESYNC supported work (Bornmann 2014).

Impact Evaluation *(Actionable Philosophy)*
Like all organizations with a goal of informing behaviors or policies, we believe that changes in decisions or behavior can rarely be traced to a single driver or research program. Thus, we will continue to use both quantitative and qualitative measures of how our sponsored research contributes to discourse and decisions outside academia. We will continue to collect information from participants regarding how their work has been extended to audiences beyond their scientific peers. This will involve interviews after teams have completed their work; we will also survey non-academic participants to determine if and how synthesis outputs are being utilized.

Advancing teaching and learning
The education programs will be evaluated using both formative and summative assessments. The former is used to iteratively improve the Case Study short course itself and the latter to evaluate the effectiveness of the case study approach for teaching about socio-environmental systems. The indicators of "effectiveness" are numerous but include, for example: participant reports of specific learning strategies gained and extent of use in the classroom; changes in participant engagement in activities that involve sharing knowledge gained with other teachers or at conferences; number of completed case studies meeting set criteria compared to number of participants in courses; and feedback on cases from users. Evaluation of the online education resources will be through tracking of downloads and surveys on their use. Evaluation of the postdoctoral program will be based on quantitative data related to publications, types of activities they engage in, and positions obtained after SESYNC. Part of the core program evaluation (above) will include interviews with past postdocs to gather qualitative information on the effectiveness of the training programs and mentoring.

Cyber and Computational
Continuous evaluation and improvement of cyber infrastructure and related services is facilitated by the use of Redmine project tracking software. The software enables SESYNC to record qualitative information about multiple types of interactions with teams and provides a database for examining what types of computational support teams are receiving. Types of computational support are broadly classified into hardware/software provisioning, customized solutions and consulting, and education on best tools and practices for scientific computing. To date, 46% of teams and 95% of postdocs have benefitted from one or more of these forms of support. One hundred percent of respondents in surveys indicated that their work and/or skillset benefited from attending SESYNC's computational institutes.

VIII.   Leadership, Staffing and Management

The leadership and staff of SESYNC foster synthesis discovery and capacity building through the Center's disposition, processes, and programs. We work to seamlessly integrate our mechanisms for supporting research with the provision of participant support (group and one-on-one) such that project teams are empowered to move forward as quickly and creatively as possible.
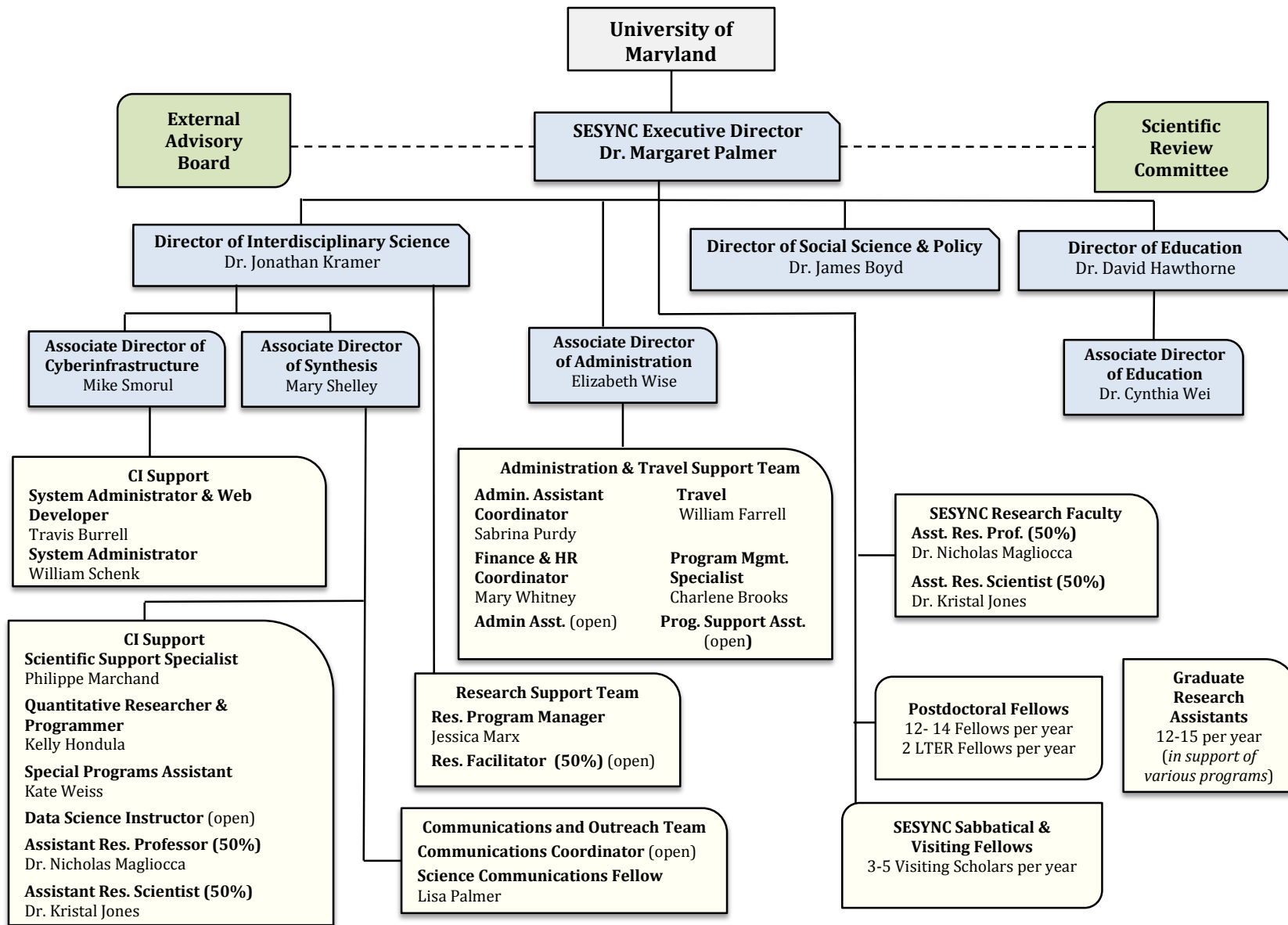
University of Maryland

External Advisory Board

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System Administrator & Web Developer
Travis Burrell
System Administrator
William Schenk

Administration & Travel Support Team

Admin. Assistant Coordinator Sabrina Purdy	**Travel** William Farrell
Finance & HR Coordinator Mary Whitney	**Program Mgmt. Specialist** Charlene Brooks
Admin Asst. (open)	**Prog. Support Asst.** (open**)**

SESYNC Research Faculty
Asst. Res. Prof. (50%)
Dr. Nicholas Magliocca

Asst. Res. Scientist (50%)
Dr. Kristal Jones

CI Support
Scientific Support Specialist
Philippe Marchand

Quantitative Researcher & Programmer
Kelly Hondula

Special Programs Assistant
Kate Weiss

Data Science Instructor (open)

Assistant Res. Professor (50%)
Dr. Nicholas Magliocca

Assistant Res. Scientist (50%)
Dr. Kristal Jones

Research Support Team
Res. Program Manager
Jessica Marx
Res. Facilitator (50%) (open)

Postdoctoral Fellows
12- 14 Fellows per year
2 LTER Fellows per year

Graduate Research Assistants
12-15 per year
(*in support of various programs*)

Communications and Outreach Team
Communications Coordinator (open)
Science Communications Fellow
Lisa Palmer

SESYNC Sabbatical & Visiting Fellows
3-5 Visiting Scholars per year

Figure 5. SESYNC Organizational Chart.

IX. Allocation of Funds

In our first proposal, SESYNC allocated funds based on anticipated needs; today we have a far better sense of those needs and this is driving our proposed allocation for years 6 – 10. In our initial proposal, we underestimated staffing needs that would best facilitate interdisciplinary scholarship, new team formation, and computational challenges of synthesizing the diverse types of data our participants bring to research problems. SESYNC provides more support for teams than any other synthesis center ever has and we believe that has been critical to our success.

Methods

General expenditures

Our budget justification provides details on our proposed funding model, but in general, we request funding be allocated in the following ways: 24% participant support (teams, sabbaticals, and visiting scientists) and 21% Postdoctoral Fellows. Just over 45% of SESYNC's budget is allocated to participants. An additional 13 % of the budget goes to staff who work in direct support of participants (e.g., our computational team, etc.). We emphasize that all NSF funded staff are engaged in participant support in some manner: from leadership to administrative staff. The remaining funding will be distributed amongst consulting, materials/supplies, advertising RPFs/publication fees, travel, and subawards. Our budget includes an overall reduction by 10% in year 9 and then by 20% in year 10 as we prepare to ramp down NSF funding. The University of Maryland will continue to support a major portion of our cyberinfrastructure needs, a portion of staff/leadership salaries, and facilities expenses, as well as annual maintenance contracts. The University of Maryland Center for Environmental Science (UMCES) will continue to support the lease in Annapolis, as well as a portion of internet connectivity fees.

### *Sustaining SESYNC into the Future*

As outlined by University of Maryland administrators during the initial site visit that determined NSF funding beginning in 2011, the university is very committed to SESYNC's success. They have been and will continue to be extremely supportive financially: between 2011 and 2016, the combined support from the University of Maryland, the University of Maryland Center for Environmental Science, and the University System of Maryland totaled $8.4M. For the next five years of SESYNC (2016-2021), the combined Maryland support will remain at roughly the same level minus the very generous start-up funding the University provided – the total committed support is $7.8 M which covers salaries for staff, lease costs for our facilities in Annapolis, and internet connectivity.

SESYNC has begun to work with the both the Office of the Vice President for Research and the Office of University Relations (responsible for development and fundraising) to initiate a strategic approach to sustaining the Center after NSF support ends. We are currently focused on a funding plan that they intend to implement over the next 1-3 years. Development officers led by Eric Chapman from the Office of the Vice President for Research are committed to this proactive approach and are optimistic they can raise funds to continue to support SESYNC at or near its current capacity. They see great benefit in and promise for alternate funding for SESYNC's organizational structure and objectives. They agreed that support for the broad external research community in seeking solutions to pressing socio-environmental problems is an essential aspect of a future funding strategy. We fully expect there may be more engagement of University of Maryland researchers; however, the intent is to continue the center as an outward looking and outward funding synthesis research center.

X. Results from Prior Support

Team composition and participant demographics

With approximately 2050 participants involved in over 100 synthesis efforts between 2011 and 2016, SESYNC has been effective in attracting new communities of collaborators to the center. Their disciplines represent a broad cross section of expertise relevant to S-E problem solving (Figures 6 and 7). About 24% of participants at SESYNC come from non-academic settings (government, NGO, business). Support for young scholars, especially postdoctoral fellows and graduate students, has been a priority at SESYNC. Seventy-eight postdoctoral fellows and over 150 graduate students have participated in various programs including leading their own team synthesis projects. The young scholars span anthropology, economics, ecology, engineering, hydrology/earth science, political science, sociology, and geography.


Academics' Domain Expertise

N = 776
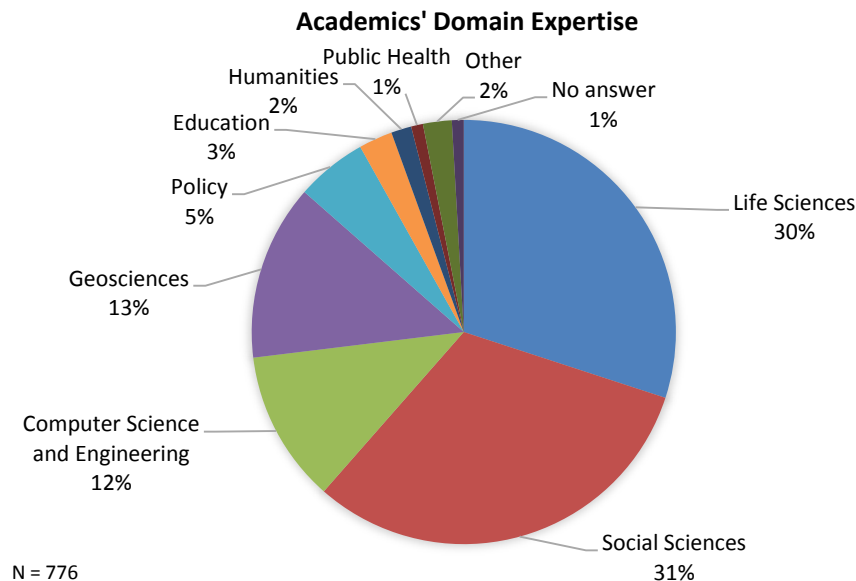
Figure 6. Domains of academic participants in SESYNC research teams based on center data through 2016. Within these, the dominant disciplines include: Life Sciences – Ecology, Conservation Biology, Disease Ecology & Epidemiology, Ecological Modeling; Geosciences – Earth Sciences, Hydrology, Ocean Sciences; Social Science - Sociology, Economics, Geography, Psychology, Anthropology; Computer Science & Engineering – General Computer Science, Civil and Environmental Engineering, Electrical and Computer Engineering; Policy – Public Policy, Planning, Environmental Policy. Appendix IX has further demographic analysis of domains and disciplines.
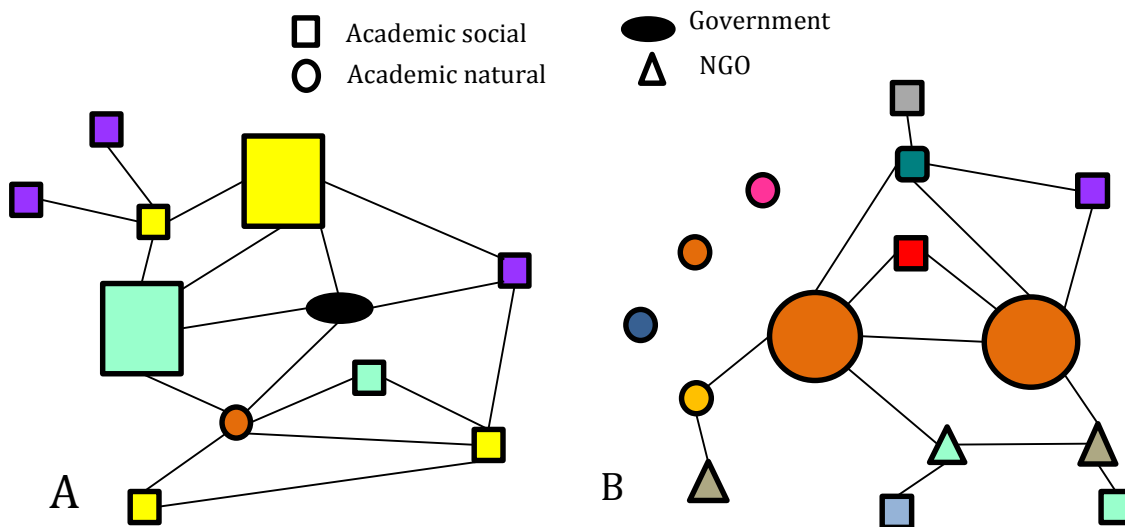
Over time, the disciplinary diversity of team leads has increased (Figure 7). We believe this is related to the 2012 implementation of an outreach effort to increase applications from social scientists along with word of the center simply spreading as the number of participants grew. SESYNC is still not at parity in terms of social vs. natural science PIs. This may mean more proactive outreach efforts are needed.

Many SESYNC participants report that they have had some exposure to inter- or transdisciplinary activities prior to coming to the Center. Of those responding to the survey 65.7% reported frequent engagement in such work, 32.2 % reported occasional; and 2.1% had never done this type of activity. In addition to interdisciplinary diversity within teams, SESYNC encourages the development of new collaborations among funded participants. An example of the network of collaborations that existed prior to the formation of two SESYNC research teams can be found in Figure 8.
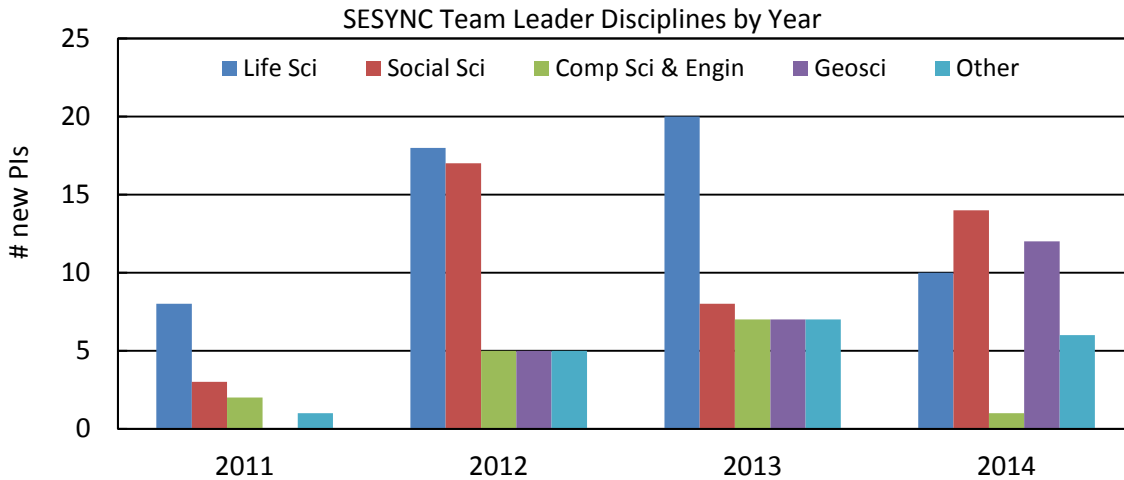
Figure 7. Disciplines of team leaders of SESYNC projects for Years 1-4. The spike in social scientist participation in 2012 reflects a special effort that year to engage scholars from disciplines under-represented on SESYNC research teams (psychology, environmental ethics, development sociology, environmental policy, political science). In the subsequent years, the number of projects with social science PIs grew relative to that prior to the 2012 effort (compare red bars in 2011 to bars in 2013 and 2014).

Figure 8. To illustrate the sector and disciplinary diversity of teams we provide two examples showing the range in the networks of collaborations that **existed prior** to the formation of these two synthesis teams. The shape of each node represents an individual team member characterized by sector; the largest are the team leaders. A) This 11-member team includes individuals from: ecology, geography, law, management, political science, and psychology. The team's project was designed to recruit multiple sub-teams of social and natural scientists with each sub-team having previously studied a different geographic region. Less than half of the individuals had previously collaborated yet this team had more prior collaborators (mostly within sub-teams) than most other SESYNC teams. B) This 13-member team included individuals from: anthropology, climate science, conservation biology, ecology, economics, environmental health, epidemiology, geography, human demography, hydrology, natural resource governance, NGOs, public and policy.

Overcoming challenges

Data on the types of support various teams requested and our own observations or conversations with teams revealed that most have had to address multiple challenges from among those listed in Section I of the proposal. All experienced the challenges of only meeting intermittently and across several years, collaborating with new investigators, and tackling a problem relevant to sustainability that could be framed in different ways and often with aspects that were mismatched spatially or temporally. The rest of the challenges were experienced to differing degrees by different teams. Almost all of the teams took advantage of SESYNC support to help overcome challenges. This included computational assistance (46%), individualized support for meeting design or for resolving problems that hindered team progress (38%), and direct facilitation of one or more team meetings (21%). The amount and type of computational assistance teams received varied; some participated in SESYNC's computational workshops for help developing or analyzing databases while others received individualized support in the use of software, coding, or cloud computing.

The vast majority of teams – facilitated or not – have self-reported good progress and positive collaborative experience. The minority that struggled do provide interesting insights. One team reported conflicts or incompatibilities due to issues of power or inflexibility on the part of some team members. A second experienced high turnover rate of members and has struggled due to poor communication between team leads and members. Problems persisted for both of these teams despite extensive input from SESYNC. One team leader wrote to us that it had never taken him/her this long to do a synthesis project with ecological colleagues; this person was leading a highly interdisciplinary team and happened to be one of only a few team leads that declined team support from SESYNC.

Of the projects that have reached their final year, one-third have requested funding for an additional meeting suggesting that projects did take longer to initiate and move forward than expected.

Team productivity and actionable science

SESYNC has supported over 100 projects and hosted over 2050 participants (many for multiple visits) in its first 4.5 years. The productivity of synthesis teams and individual researchers has been exceptional and has grown as early projects have now come to fruition. We provide details of all the research products reported to us by SESYNC participants in Appendix III. Here we provide brief highlights of some of the more notable results of the syntheses done since 2011.

Synthesis Teams. Synthesis teams, fellows and staff produced 206 peer-reviewed journal articles since 2011 (Figure 8). The publication outlets for these articles include some of the highest quality journals that span many disciplines including: Science, Nature Climate Change, Social Networks, Behavioral and Brain Research, Conservation Letters, Current Anthropology, Ecological Economics, Ecology, and Landscape and Urban Planning. In addition to publications, other products of team efforts from our core programs include 8 books/book chapters, 258 presentations, and 64 proposal submissions for grants or follow-on funding. 186 graduate students were included as participants within our core programs.

While these numbers tell a certain story, they don't fully represent the nature, success, and diversity of SESYNC teams. For example, philosopher Dr. Baird Callicott led a team comprised of legal scholars, economists, ecologists, conservation scientists, and political ecologists to synthesize diverse data and to understand the implications of shifting the goal of ecological restoration from achieving a particular ecosystem state to producing specific ecosystem services. Led by Kate Suding, The team published their first manuscript in *Science* less than a year after their first SESYNC meeting.

Figure 8. Journal articles generated with SESYNC support.
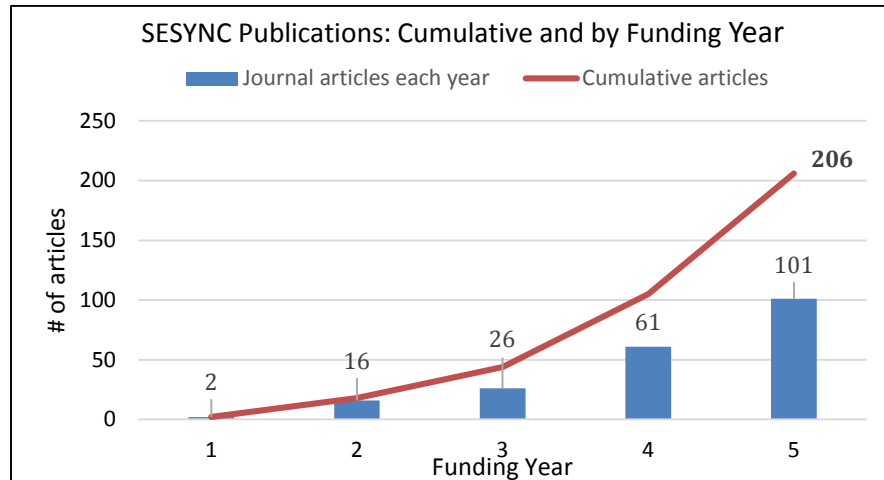
In a second example, Dr. Susan Clayton, an environmental psychologist, led a project that explored the intersection of the fields of environmental science and psychology. This work led to a publication in *Nature Climate Change* (Clayton, Devine-Wright, Stern, Whitmarsh, Carrico, Steg, Swim, and Bonnes 2014) that highlights the links between individual behaviors and perceptions of climate change and how this in turn influences responses to climate change response and mitigation. Dr. Wei-Ning Xiang (East China Normal University) and Dr. Joan Nassauer (University of Michigan) led a Pursuit focused on the Shanghai mega-region. They synthesized knowledge of ecological functions and patterns, land use, and human population distributions. The team produced 14 publications in a special issue of *Landscape and Urban Planning* (Nassauer, Wu, and Xiang 2014). These papers have implications for urban ecology, landscape planning, governance, public health, environmental justice and most broadly the sustainability of cities.

Postdoctoral Fellows. SESYNC postdoctoral fellows produced 59 publications. The following two publications illustrate the diversity of their work. Dr. David Gill published a study on reef fish communities and tourism in *Ecological Economics* (Gill, Schuhmann, and Oxenford 2015). He synthesized data to quantify how the loss of reef fish communities could impact the Caribbean's tourism economy. The study demonstrates why conserving coral reefs should be both an economic and ecological priority and provides policy makers with a possible roadmap for sustainably financing that conservation. Dr. Neil Carter worked with two collaborating mentors to develop a novel, spatially explicit agent-based model of tiger population dynamics and applied it to a global biodiversity hotspot with a large tiger population (Carter, Levin, Barlow, and Grimm 2015). The model successfully matched observed patterns of reproduction, mortality, dispersal, resource selection, territory size, and spatial distribution of the actual tiger population and is a useful tool for decision makers with respect to human-tiger interactions.

Knowledge Users and Actionable Scholarship. SESYNC encourages teams to involve knowledge users in the co-development and execution of research, to provide guidance on policies and institutions affecting environmental decision-making, and to facilitate communication with broader audiences of decision-makers. For example, a Workshop entitled "Interdisciplinary best practices for ecosystem services methods in federal agency decision making" brought together a group of 6 academics from different institutions and 15 knowledge users from Federal agencies and NGOs including the U.S. Forest Service, the Office of Management and Budget, the U.S. Environmental Protection Agency, The Nature

Conservancy, and the Council on Environmental Quality (CEQ). The team's work was input for subsequent guidance from the CEQ related to ecosystem services and federal decision making.

Another project, "Using spatial data and analysis to understand the human impacts of ocean acidification," consisting of 8 academics and 13 knowledge users, published a study in *Nature Climate Change* (Ekstrom, Suatoni, Cooley, Pendleton 2015) that similarly produced research that could inform more specific policy questions. The authors presented a spatially explicit, multidisciplinary vulnerability analysis of coastal human communities in the U.S. highlighting regions most vulnerable to ocean acidification. They also provided knowledge and information gaps relevant to local adaptation options. The team worked closely with managers and policy makers to enhance project relevance for decision making. The project yielded input to several policies, such as a decision by the federal Ocean Acidification Program at NOAA to establish an RFP for regional vulnerability assessments with respect to ocean acidification.

Computationally Intensive Products. Several examples serve to illustrate the high productivity of data and computationally-intensive projects. A Pursuit team of researchers from nine institutions led by Rob McDonald, senior scientist with the Nature Conservancy, constructed the first global database of urban water sources and stress. The team surveyed and mapped the water sources of more than 500 cities globally, providing the first global look at the water infrastructure that serves the world's large cities. They used computer models to estimate water use based on population and types of industry for each city, revealing that many of the fastest growing cities are also economically stressed and will find it difficult to deliver adequate water to residents without international aid and investment.

Working with a Pursuit team studying the links between conservation governance, ecological, and human health outcomes, SESYNC cyberinfrastructure staff built a prototype database assembling millions of records from USAID Demographic and Health Surveys around the world and combined those surveys with biophysical data on the location of > 53,000 village clusters that surveyed. The database is accessible via our R Studio server to researchers who have been approved to use the data by USAID for exploration and analysis.

Postdoctoral Fellow Dr. Mary Collins integrated 8 million census blocks and 1 billion toxic release data points from an EPA database; the resulting analysis is the first to cross-link the toxic releases of more than 600 chemicals by 16,000 facilities nationwide to the race and socio-economic status of local communities. Her resulting paper was published in *Environmental Research Letters* (Collins, Munoz, and JaJa 2016) revealing that a small minority of polluters are responsible for a high proportion of toxic releases that disproportionately impact minority and low-income neighborhoods. The study suggests that targeted enforcement of super-polluters may produce the most cost-effective improvements to environmental quality in areas with low economic and political capital.

Formative evaluation results
SESYNC's formative evaluation was designed to gather information about the effectiveness of center processes (Appendix VII). The external evaluator observed multiple activities and conducted semi-structured interviews with 37 participants (22 team leads and 15 team members) from 19 teams. Transcribed notes and audio files from interviews were coded based on the evaluative questions and analyzed by the external evaluator using NVivo software. The evaluation focused chiefly on early participants during the period when center processes were being actively developed and adapted.

The report from the evaluator reinforced many of the decisions SESYNC leadership had made in designing programs, activities, and organization – interviewees had many positive things to say. Rather than repeat those here, we briefly highlight some of the findings from the formative evaluation that led us to adapt our practices. Some interviewees noted that nascent connections within teams may be fragile and hoped that SESYNC could go beyond convening and catalyzing collaborations to help sustain new collaborative S-E networks. Numerous comments were made about the lack of sources for follow-up funding to support a bigger project. SESYNC cannot create new sources of funds for the community, but to enhance connections, we implemented new communication practices including regular blogs, newsletters, and individualized emails. Other interviewees commented on the need for salary or dedicated staff support to help teams with databases and analyses. We thus instituted a practice of identifying teams with computationally intensive projects and allocated more staff time to them; for some teams we provided modest support for a graduate student or part-time postdoc.

Some interviewees noted that when facilitation was used it was very effective but many reported that they were not aware of all the services SESYNC provides and/or could have used a facilitator. We knew there was a greater demand for facilitation than we could meet so we advertised to hire an additional facilitator; we were not successful despite interviewing the top candidates. Currently, we are in conversation with a potential candidate, a past SESYNC participant who has the requisite skills and is interested in working with us in this capacity. To increase teams' awareness of our portfolio of services, we modified our "priming" procedures with team leads to better emphasize services and ongoing interactions with teams across the lifetime of a project. We also began briefing teams during their first meeting at SESYNC. Interviews also indicated that SESYNC could improve team linkages and overall communication about the progress, processes, and outcomes of teams. In response, we developed a practice of meeting with PIs or listening in on team sessions to better track the scholarly directions of teams; then we followed up with emails alerting PIs to projects by other teams that may be synergistic. Finally, interviews suggested that many of the teams would like guidance on what it means to be actionable and how they could better link their work to policy. This led us to develop plans for a stronger emphasis on the science-policy link that we described in our innovations section of this proposal.

Lessons learned
We have found it is not at all unusual for a team's research methods, final products, and even the nature of questions addressed to change from what was envisioned at the onset. This was due in part to "negotiating the interdisciplinary team process", but often the change was because the data they needed was not available or was in an unsuitable form. This has been more common for teams seeking relevant social data on, for example, human health, well-being, or behavior than for teams relying primarily on environmental data. While some participants expressed initial discomfort with uncertainty over their group's direction, many later reported enjoying the learning that came from integrating ideas across disciplines with different languages and epistemologies.

The wide use of SESYNC services suggests the need to maintain those services, if not expand them, for example, by providing large multi-day training workshops. Computational capacity to build, harmonize, and work with heterogeneous datasets is a major impediment to synthesis work across the social and natural sciences. A focus on computational skills has been catalytic but other efforts around S-E systems, interdisciplinarity, team science, and education all contribute to building capacity of participants.

Facilitation can enhance problem solving when deployed across several phases of a project including pre-planning to help teams develop congruent goals, agendas, and processes as well as strengthen

motivation, trust, and attention to team dynamics (McFadzean 1999, 2002). Highly skilled facilitators with environmental sciences expertise have proven to be effective at working with SESYNC teams, but those with such skills are few in number and thus far Jonathan Kramer remains our sole facilitator.

While SESYNC has a wide variety of resources that can be deployed to assist teams, many of them are reluctant to ask for support or don't understand options available to them. Our ability to appropriately and constructively intervene across a project's lifetime has evolved over time and must continue to do so if we are to advance interdisciplinary S-E science. Despite our large professional staff, we are challenged to meet all the teams' needs because of the time-consuming nature of such support.

Strong team leadership is necessary but works best in combination with a commitment to flexibility and shared learning. To be effective, team leaders need to take an integrative approach that focuses on orchestrating expertise, individuals and relationships in a manner that supports problem definition and progressive refinement and extension of ideas. Successful team leadership relies less on power than on the ability to manage the ideation process (generation, structuring, and promotion) and provide incentives (Mumford, Scott, Gaddis, Strange 2002). Because SESYNC projects involve new intellectual and social relationships, the reality or even perception that leaders are not listening or adapting to others' language, philosophies, methods, and goals can be detrimental. Attention to the creative process' antecedents (e.g., developing shared goals, defining interdependent tasks, team attitudes and socialization) is essential (Gilson and Shalley 2004).

XI. Increasing Participation of Under-represented Minorities

SESYNC is committed to broadening participation of under-represented minorities (URM) in the socio-environmental research community. The members of the fourth year review team encouraged us to expand our efforts and we have already begun to do so.

Recruitment and Engagement

SESYNC has recruited a number of new members to our advisory groups: just over one-third of the 24 member Scientific Review Committee is from an under-represented group and just under one-third of our 14 member External Advisory Board are from an under-represented group (Appendix II). Additionally, SESYNC leadership initiated a workshop of East African scholars to identify opportunities for collaboration and build capacity for doing S-E synthesis work. We have begun to target minority-serving email lists and specific individuals to pass along to their networks when distributing calls for applications. We also recognize that very proactive approaches are required as indicated next.

Innovations to Sustain and Build Capacity

Recognizing that there are few graduate programs at historically black colleges and universities, we will employ our short courses, web resources, and computational training workshops to build and accelerate capacity for S-E synthesis research by members of under-represented groups. In addition, we have developed a new collaborative program with four historically black colleges and universities within the region; this program is fully described under the Innovations Section. We will also focus on diversifying our speaker series both through our weekly SESYNC Seminar and our Café Scientifique. We have already begun to include diversity and stigma consciousness as a topic in the informal discussion series of ethical issues in science that is part of the postdoctoral mentoring program. Additionally, we will lower the financial barriers to entry of existing programs that may be otherwise unfeasible to participate in for under-represented groups – for the few workshops and short courses in which we do not typically cover

the full costs of participants, we will commit to providing full coverage of costs based on a statement of need.

XII. Broader Impacts

As with the first five years of funding, SESYNC will continue to take a deliberate approach to fostering interdisciplinary scholarship and education at the undergraduate, graduate, postdoctoral, and senior scientist levels. This approach is designed to help find solutions to pressing societal problems that will enhance the sustainability of the environment as well as improve the well-being of the people that benefit from nature's resources. Toward this end, SESYNC engages leaders, members of the business community, natural resource managers, and citizens in identifying the most pressing research and education needs. We do this in both systemic and targeted ways and will expand this approach through training and network building. This project will not only train more than 60 postdoctoral scholars to take this solution-focused approach but will result in many useful products from interdisciplinary teams of senior scholars. Further, SESYNC will significantly increase participation by underrepresented minority scholars over the next 5-years. An enhanced communications and outreach capacity will also provide greater opportunities to extend the outcomes of SESYNC supported research.

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