Creating and maintaining high-performing collaborative research teams: the importance of diversity and interpersonal skills

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Collaborative research teams are a necessary and desirable component of most scientific endeavors. Effective collaborative teams exhibit important research outcomes, far beyond what could be accomplished by individuals working independently. These teams are made up of researchers who are committed to a common purpose, approach, and performance goals for which they hold themselves mutually accountable. We call such collaborations "high-performing collaborative research teams". Here, we share lessons learned from our collective experience working with a wide range of collaborative teams and structure those lessons within a framework developed from literature in business, education, and a relatively new discipline, "science of team science". We propose that high-performing collaborative research teams are created and maintained when team diversity (broadly defined) is effectively fostered and interpersonal skills are taught and practiced. Finally, we provide some strategies to foster team functioning and make recommendations for improving the collaborative culture in ecology.

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Ecologists frequently collaborate, and have been doing so increasingly over time. There are many examples of highly effective ecological research collaborations, which include small to moderately sized teams of productive scientists who have worked together for years (Parker and Hackett 2012), large networks such as the US Long Term Ecological Research Program (Robertson *et al.* 2012), and long-term transdisciplinary research efforts focused on critical problems (Pennington *et al.* 2013). Despite a paucity of research on how ecological teams work effectively together (but see Hampton and Parker 2011; Parker and Hackett 2012; Pennington *et al.* 2013), many studies have documented how teams of other professionals work together, including those in the disciplines of business and education. We assume that the characteristics of highly effective teams are similar across disciplines, and therefore propose that ecologists can learn from studies conducted on other types of teams and apply them to improve the research outcomes of ecological teams (eg generation of transformative knowledge, translation of research results to sound management and policy recommendations).

In a nutshell:

- High-performing collaborative research teams consist of diverse members who are committed to common outcomes
- Careful attention must be paid to the interpersonal skills of team members (eg social sensitivity, emotional engagement) and to team functioning (eg communication patterns)
- A greater focus on teamwork training should better position ecologists to successfully create, lead, and participate in high-performing teams to solve many current environmental problems

Collaborative research teams are a necessary and desirable component of ecology, and especially macrosystems ecology, which studies broad spatial and temporal scales and incorporates multiple disciplines and perspectives (Heffernan *et al.* 2014). Although most of our ideas apply equally well to disciplinary collaborations, interdisciplinary research teams offer additional challenges for collaboration (Pickett *et al.* 1999; Kostoff 2002; Cummings and Kiesler 2005). Effective interdisciplinary collaboration requires careful attention to processes and goals, and understanding and managing basic philosophical differences among team members (Benda *et al.* 2002; Eigenbrode *et al.* 2007). Unfortunately, training in how to collaborate effectively is rare in professional programs, graduate or otherwise.

When collaborations are successful, the outcomes surpass any one individual's accomplishments (Figure 1). These collaborations are referred to as "integrated research teams" (Bennett *et al.* 2010) or "high-performing cooperative groups" (Smith and Imbrie 2007); hereafter we use "high-performing collaborative research teams" (Figure 1 and WebPanel 1). Regardless of terminology, the characteristics of such groups are: positive interdependence of team members, effective communication,

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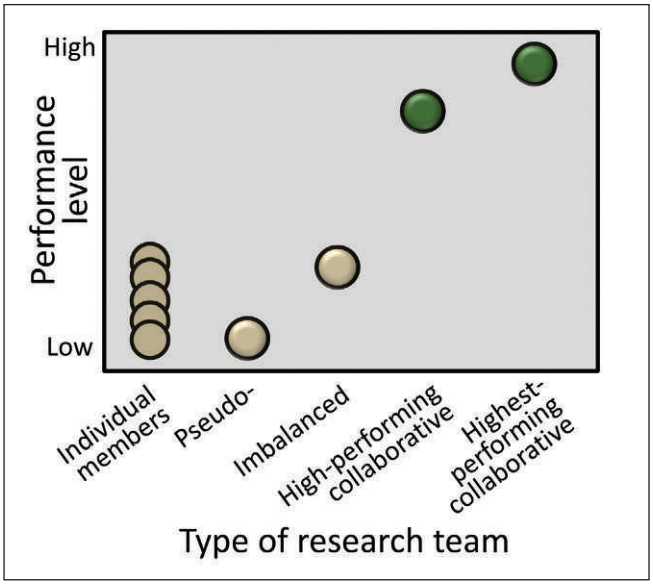

Figure 1. *The type of research team that scientists are part of plays a role in the performance level of those teams. Adapted from Smith and Imbrie (2007). See WebPanel 1 for details.*

and individual and group accountability (see WebPanel 1 for details). Such teams are highly productive and provide positive experiences for all participants, maximizing net benefits for both individuals and the team as a whole (Goring *et al.* 2014).

We share lessons learned from our collective experience as part of a wide range of collaborative research projects (some of which were high-performing). We structure those lessons within a framework developed from literature in business, education, and the relatively new "science of team science" discipline (Stokols *et al.* 2008a). Our thesis is that team diversity (broadly defined) needs to be effectively fostered and interpersonal skills need to be taught and practiced in order to create and maintain high-performing collaborative research teams (Figure 2). Interpersonal skills comprise two dimensions: social sensitivity and emotional engagement. Social sensitivity is the capacity to successfully navigate a full range of social relationships and interactions and has also been referred to as "people skills" or social intelligence (Albrecht 2006; Woolley *et al.* 2010). Likewise, emotional engagement is the presence and depth of feelings, both personal and professional, toward other team members and the project as a whole (Stokols *et al.* 2008b; Parker and Hackett 2012). Therefore, if a collaborative research team is made up of members with low interpersonal skills, that team will more likely experience tensions that require time negotiating relationships rather than conducting ecological research.

Team diversity and interpersonal skills strongly influence research outcomes by affecting critical aspects of team function such as communication patterns, problem solving, and group creativity (Bennett *et al.* 2010; Woolley *et al.* 2010). Various other factors also influence research outcomes, including the cognitive abilities and experience of team members, physical space, and funding level (De Long 1970; Sternberg and Wilson 2006; Leahey 2007). However, we argue that it is highly unlikely for a collaborative team to be high-performing without careful consideration and fostering of diversity and interpersonal skills. Growing evidence from a range of studies and disciplines, with different types of groups, indicates that teams with high social sensitivity, deep emotional engagement, and a high degree of diversity have positive research outcomes (Stokols *et al.* 2008b; Woolley *et al.* 2010; Pentland 2012; Parker and Hackett 2012). The rest of this paper describes the characteristics of these teams and their members, some strategies for creating and maintaining such teams, and future needs to make ecological teams highly effective.

Creating high-performing collaborative research teams

Diversity of team members

The creation of a high-performing collaborative research team requires consideration of overall group heterogeneity (Figure 2; Stokols *et al.* 2008b). Diversity has been found to increase team productivity as well as the quality of "end products" (Nemeth 1995; McLeod *et al.* 1996; Guimera *et al.* 2005; Leung *et al.* 2008). Diversity is a multidimensional factor (Uriarte *et al.* 2007) that includes not only gender, ethnicity, religious beliefs, career stage, personality, socioeconomic class, life experiences, viewpoints, and skills, but also how people represent and solve problems (ie identity and functional diversity; Hong and Page 2004). We identify five important dimensions of diversity that warrant consideration when building a macrosystems ecology collaborative research team: (1) career stage, (2) degree of team member incumbency or familiarity, (3) interaction mode of scientist, (4) type of discipline and the number of individuals per discipline, and (5) viewpoints. We define and explain each of these below; see WebPanel 2 for more resources and other factors affecting team diversity.

People at different career stages bring different perspectives and skills to ecological teams. However, when including members from multiple career stages, it is important to balance contributions across these stages and to recognize career-stage constraints and opportunities (Goring *et al.* 2014). Regardless of career stage, research teams with a mix of freshness and familiarity have had the best outcomes using traditional measures of team success: Whitfield (2008) synthesized publication and citation rates from four scientific fields and found that teams with 60–70% incumbents and 50–60% repeat relationships reach a "bliss point" where the team has the best outcomes.

Studies have demonstrated the importance of considering the different ways team members interact with each other (ie interaction modes of team scientists) when

forming a team. Although disciplinary specialization may benefit scientists in terms of research productivity and promotion (Leahey 2007), for interdisciplinary teams, the ability to bridge knowledge or approaches across disciplinary boundaries (ie brokering) is also important (Pennington 2011). In an analysis of 9000 articles, specialists who served as brokers produced the most highly cited papers (Panzarasa and Opsahl 2008). It remains to be seen how disciplinary boundaries are best crossed, given that there is a range of possible strategies (Pennington 2011). In addition, having at least one team member who is "outwardly engaging" can connect the team to other teams, thus increasing cross-fertilization of ideas and opportunities for new team membership (Pentland 2012). While the optimal team make-up to achieve high-performing team status will vary by team and problem (Figure 3), interaction mode seems to be an important factor to consider when creating collaborative research teams (Pennington 2011).

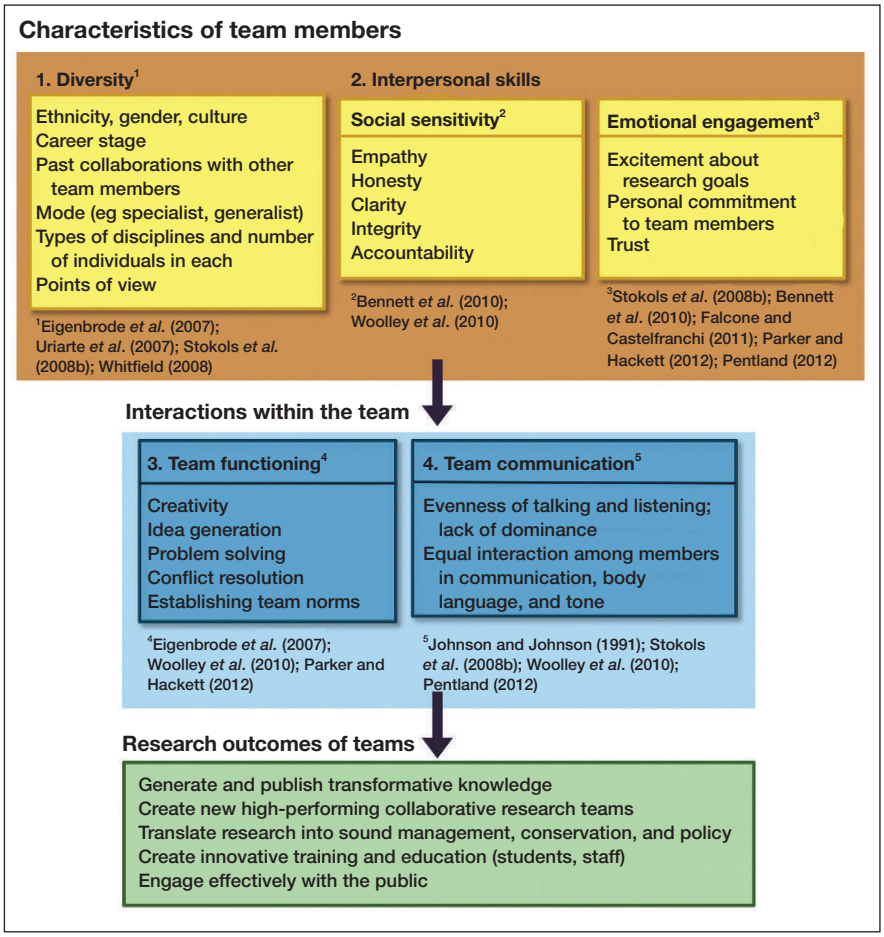

Figure 2. *Diagram depicting the influence of team member diversity and interpersonal skills on team functioning and communication, all of which influence research outcomes. Each of the five major categories of individual team member and entire team traits is strongly tied to all others; therefore, all possible arrows among categories are not depicted for the sake of clarity. For each category, supporting literature for the hypothesized relationships between the category and research outcomes for high-performing collaborative research teams is provided. Examples are shown for each category, but the lists are not exhaustive.*

Disciplinary diversity – in terms of both type and number of individuals per discipline – is desirable for macrosystems ecology research (Heffernan *et al.* 2014). Using citation rates as a measure of productivity, research suggests that teams with very high numbers of disciplines are the least productive (Whitfield 2008). This result may be due, in part, to the coordination costs associated with interdisciplinary teams, especially for teams with members from multiple institutions (Cummings and Kiesler 2005). How many disciplines are optimal will depend upon the goals of the team. On the basis of our collective experiences, we have also found advantages to having more than a single individual per discipline on the team, to provide a "critical mass" that ensures effective flow of ideas within and across disciplines.

Individual team members also have different points of view and philosophies (Eigenbrode *et al.* 2007). Such philosophical differences originate in the distinctive ways that scientists operate and include differences in: motivation for research, methodology, values, objectivity, and the amount and kind of evidence that they require for knowledge generation. Although fundamentally philosophical in nature, many of the challenges of cross-disciplinary research have been overlooked and may also arise within disciplines (eg between theoreticians and empiricists, or between modelers and experimentalists; Eigenbrode *et al.* 2007). In our experience, disciplinary assumptions are rarely made explicit within single-discipline collaborations, and likewise are rarely addressed in cross-disciplinary collaborations. Because these philosophical differences are fundamental to the way researchers operate scientifically, they are directly linked to the collaboration's success. Without clear sharing, communication, and appreciation of such differences, teams struggle to find common ground and are limited in their productivity.

Interpersonal skills of team members

High-performing collaborative research teams require members who have good interpersonal skills (social sensitivity and emotional engagement), which positively influence interactions among team members that then positively influence research outcomes (Figure 2 and ref-

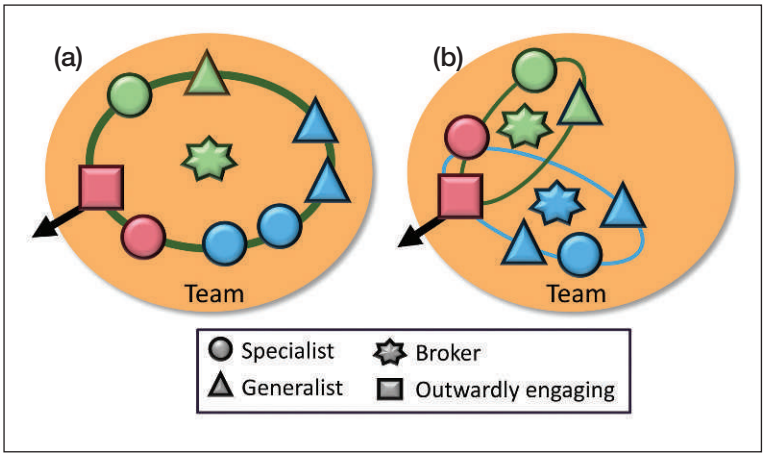

Figure 3. *Two examples of the combination of types of scientists that could result in a high-performing team. Team members are represented in two of five possible ways to depict some aspects of their diversity within the team: discipline (color) and one of four interaction modes (shape). In team (a), there is one member who serves as a broker among all of the represented disciplines and who facilitates communication and cross-fertilization across disciplines. In team (b), there are multiple members who serve as brokers across different disciplines. The ovals in both panels represent the connections the broker makes. The black arrow from the outwardly engaging scientist represents his/her engagement outside of the team for the benefit of the team. Refer to main text for more details.*

erences therein). The importance of these fundamental skills in a range of different contexts is well supported. For instance, measures of social sensitivity were the main predictor of group intelligence (ie ability to solve problems as a group), even more so than the cognitive intelligence of group members (Woolley *et al.* 2010). Such abilities also overwhelmingly influenced team project performance and productivity in a business setting (Pentland 2012), as well as the effectiveness and success of business leaders and the groups they supervised (Zenger and Folkman 2009). In an analysis of the qualities of US Presidents from Franklin D Roosevelt to Barack Obama, Goldstein (2009) found that emotional intelligence was the most important factor to predict "presidential success" as compared to political skill, vision, cognitive style, or ability to communicate. Regardless of discipline or question of interest, group problem-solving requires effective communication and collaboration at the *team* level in addition to the *individual* level. Honing such skills will likely be beneficial to ecologists working on teams.

The second type of interpersonal skill, emotional engagement, is sometimes ignored or undervalued in science, even though emotions are a central element of most – if not all – collaborations (Parker and Hackett 2012). Emotion metaphorically ignites and fuels creative collaboration, and often leads to productive research outcomes. Parker and Hackett (2012) found that reinforcing social bonds lowered the barriers to collaboration. However, teams must first develop the group culture and social practices to do so, and these must be supported by a foundation of trust (Falcone and Castelfranchi 2011). In the next section, we describe practices that teams can use to augment the culture and teamwork skills needed to improve interpersonal skills and thus improve team functioning and scientific productivity.

Building the culture and interpersonal skills of high-performing collaborative research teams

One strategy for building and maintaining high-performing collaborative research teams is to use teamwork exercises that improve the interpersonal skills of team members throughout the life of the project. Informal team outings (eg Figure 4) and formal teamwork exercises that build interpersonal skills, especially when they occur outside the workplace (eg in the field or in "inspiring" venues; Parker and Hackett 2012), can also help teams build trust relationships, establish shared research goals and standards of behavior, and create a shared vision for project management. These exercises can be a useful starting point for developing the policies for data collection, metadata creation, quality assurance/quality control protocols, data sharing, and co-authorship, which are essential for proper team functioning and high productivity.

In WebPanel 2, we describe some major categories of teamwork exercises. We provide detailed steps for implementing four of the examples provided in the panel in WebSupplements 2–5, along with general guidelines for using teamwork exercises in a workshop-type setting (WebSupplement 1). In our experience, many scientists are ill-prepared for or unexcited about participating in teamwork exercises; a colleague stated the following after reflecting on his participation in teamwork exercises:

> "As an early career scientist meeting with collaborators from other institutions for the first time, I did not know what to expect from the teamwork exercises that were listed on the workshop agenda. It was intriguing to observe the 'push-back' from, and severe anxiety of, some of the scientists on our team. The discomfort increased as these exercises progressed over the course of the week, and reached a 'boiling point' during a time management exercise during the last day…the process of completing this exercise together as a team allowed me to learn much about the demands on, and personalities of, several collaborators on the project. This exercise helped our team set realistic goals for science products as well as helped us to better understand and appreciate each other."

Teams may therefore benefit from discussing the importance of such exercises. Careful attention should also be paid to the sequence of these exercises. For instance, we

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Figure 4. *Picture of an informal team outing meant to foster interactions among team members and increase interpersonal skills. Photo depicts the research team "CSI-Limnology" (http://csilimnology.org/) kayaking on the Grand River in Lansing, Michigan, during their 2011 annual workshop.*

recommend that the first exercises should foster social sensitivity and emotional engagement, which will serve to facilitate later exercises on team functioning and communication (WebPanel 2). Furthermore, although using these activities when a team first meets is essential and can initiate discussions of individual and team expectations, goals, and needs, we have found that implementing these types of activities throughout the team's "lifetime" is important for that team to *stay* "high-performing".

We next provide a synopsis of WebSupplements 2–5, each of which describes a teamwork exercise:

- *Emotional engagement and understanding of and appreciation for team diversity (WebSupplement 2)*: Activities that stimulate conversations about both personal and professional topics can successfully start, build, and maintain the kind of personal and professional bonds that are necessary for high-performing collaborative research teams. These exercises help members get to know one another, appreciate similarities and differences in points of view, and generally stimulate emotional engagement.
- *Effective communication (WebSupplement 3)*: We recommend paying close attention to physical space by carefully arranging comfortable seating and then asking team members to change who they sit next to frequently in order to reduce hierarchically structured discussions (De Long 1970). This approach can help improve group habits that leaders should emphasize, such as: balancing each member's willingness to talk with their ability to listen, fostering equal interactions among all members, fostering open and encouraging body language, and paying attention to tone of voice (Pentland 2012). Face-to-face communication is very important for effective communication and has been shown to increase the number of peer-reviewed publications produced by ecological synthesis groups (Hampton and Parker 2011). However, we recognize that broad, interdisciplinary, multi-institutional teams may need to rely on technological resources that simulate these face-to-face interactions (WebTable 1 in WebSupplement 3). For multinational teams, communication issues that are related to differences in language, customs, and power structures can be particularly challenging. Solutions require careful thought and appropriate structure, and should be based on the philosophy that international partners are integral members of the team and should therefore share in the responsibilities, decision making, and communications (WebSupplement 3; WebPanel 3).
- *Team conflict (WebSupplement 4)*: It is important to help members understand that conflict is a normal and necessary part of becoming a high-performing collaborative research team (Tuckman and Jensen 1977). We provide an exercise that helps build awareness of the different ways in which members may respond to such conflict and that increases appreciation of team member diversity, problem solving, and conflict management skills. Indeed, one of our colleagues reflected:

> "Our two-nation biodiversity team used your materials about teamwork and conflict management at our first all-team meeting last month. The activities set the right cooperative tone at the [beginning], and I think everyone felt this was worthwhile. In fact, people [became so interested in] the conflict management instrument that one of the postdocs performed a cluster analysis on our individual scores to test the idea that the two nations differed in their way of resolving conflict. There was some numerical support for this."

- *Time management (WebSupplement 5)*: We suggest using an exercise that engages members in work and discussions both about themselves and the team as a whole. Such an exercise can improve team communication and functioning by helping members appreciate the

diversity of roles, responsibilities, and time constraints that are represented on the team. This exercise can be especially helpful in spurring honest conversations about which research outcomes to prioritize, who will lead such efforts, and what the timelines will be.

These teamwork exercises are designed to feed into the establishment of explicit standards for behavior (ie norms). These team norms can then result in team policies about important practices such as data sharing and co-authorship (WebSupplement 6 and WebPanel 3) that can create clear expectations and levels of trust among team members, thus improving research team functioning and productivity (eg Smith and Imbrie 2007). These policies should be viewed as "living documents" that evolve over time to reflect changing team membership and project goals.

Maintaining the team culture: team assessment

A characteristic of high-performing collaborative research teams is their frequent assessment of team functioning; they undergo periodic candid group processing, during which they celebrate what is going well and reflect on how to correct what is not (Smith and Imbrie 2007). While assessing progress in meeting their goals and timelines and in following their agreed-upon norms, team members continue to practice and develop their interpersonal skills. Being mindful of members' needs, and honoring the team's structure and processes, leads naturally to a set of activities that will maintain team cohesiveness and promote team functioning.

First, after a diverse collaborative research team has been formed and has undergone a series of initial team-building exercises (eg WebSupplements 2–5; WebPanel 2), we recommend that teamwork exercises continue in future face-to-face meetings. These exercises can further develop the interpersonal skills needed for effective team functioning. Second, teams should establish mechanisms and a timeline for periodic progress updates. Third, formal team assessment should be implemented to ensure that all team members voice their opinions about team functioning (eg WebSupplement 7). Such assessments can take several different forms. The least formal option is to conduct an anonymous online survey administered and debriefed by one of the team members (see WebSupplement 7 for an example survey instrument). A more formal assessment can rely on tools developed for use in education, in which each team member provides anonymous feedback about other team members and about team functioning. Each member then receives a summary of that feedback with research-supported suggestions for how they can specifically improve (eg CATME; www.catme.org; Ohland *et al.* 2012), and the team can collectively review future needs for best results. The most formal assessment is for an independent evaluator to review team procedures, policies, and interactions (Pentland 2012). Although maintaining team culture requires members to devote already limited time and energy to what appears to be non-research activities, the results of such efforts may substantially improve research outcomes.

Needs for future high-performing collaborative research teams

With scientific knowledge increasingly being generated by teams (Wuchty *et al.* 2007), scientists must carefully consider the extent to which their current collaborations are high-performing and whether they are achieving the "most successful" science outcomes possible. Graduate school is the training ground for scientists, and most, if not all, graduate advisors recognize how important it is for their students to learn skills in research methodologies, communication, and teaching. However, most dissertations are designed to be single-investigator-driven science, and formal teamwork training is nonexistent in most graduate programs. Conversely, most branches of knowledge, including ecology, are conducted by people working together. In fact, the most highly cited papers are increasingly being produced by teams rather than solo researchers (Wuchty *et al.* 2007) and the "ability to engage in cooperative learning and produce products with a team of people" is one of the top five nondisciplinary skills that conservation employers in the government, nonprofit, and private sectors are seeking (Blickley *et al.* 2013). Therefore, students must learn how to work with others to produce high-impact research products. One way to meet this need is for graduate programs to offer seminars, workshops, or entire courses on how to effectively collaborate in science.

We suggest that scholars use multiple forums to address teamwork challenges and to create solutions that will support teams generating innovative science. At the national/international level, publications such as those included within this Special Issue represent one way to foster dialogue. Funding agencies can support innovative training projects that specifically focus on team and collaboration training; train staff, panelists, and reviewers to reward and recognize teams as opposed to individuals; and redefine scientific success (Uriarte *et al.* 2007; Goring *et al.* 2014). Knowledge from emerging disciplines, such as the "science of team science" (Stokols *et al.* 2008a), can be used as part of those training projects. Professional organizations can develop programs to foster a culture that values and promotes collaborative training and the scientific outcomes of teamwork at all career stages. At the institutional and programmatic levels, administrators and leaders can: (1) incorporate teamwork training into their graduate programs, similar to programs that have been developed to train graduate students in pedagogy, and (2) more broadly define faculty research success to include individual contributions to the products of collaborative research teams (Goring *et al.* 2014). At the fac-

ulty level, graduate advisors should value such training, encourage their students to participate, and engage in teamwork training themselves. In short, developing the skills to build, maintain, and lead high-performing collaborative research teams must be recognized as one of the important skills to be learned in order to become a successful scientist.

Finally, additional studies are required – ones that quantify the factors leading to high-performing collaborative research teams in ecology and that use broad measures of success. Much of the published literature on collaboration in science has been conducted in other disciplines or by using fairly narrow definitions of research success that are easy to measure (eg publications, citation rates). Collaborative success should also be measured by outcomes that are equally important to ecology, such as the translation of research to policy, training/education, and engagement with the public (Frodeman *et al.* 2013). Broadening the definition of scientific value and the reward systems will require a cultural shift within the scientific community (Uriarte *et al.* 2007; Goring *et al.* 2014) and recognition of the importance of high-performing collaborative research teams for science and society.

Conclusion

We end with a question. Across your scientific career thus far, which collaboration have you been most excited about and most willing to prioritize above all others, and why? We anticipate that the most common response to this question describes a collaboration in which the team members worked well with and cared about each other professionally and personally, had a shared vision, were excited about the science being conducted, and made that science a top priority. This team likely had many important research outcomes as well. To realize this goal for most teams, members of the scientific community must redefine research success to include collaborative outcomes, promote teamwork training for ecologists at all career stages, and pay deliberate attention to and guide how teams are formed and maintained.

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