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Centennial Survey: Introduction, methods, respondents

Survey background and goals:

The Centennial of the Ecological Society of America is a time to reflect upon ecology's successes and shortcomings, and the opportunities and challenges that lie ahead. ESA's Science Committee conducted three parallel surveys- one for researchers, one for environmental managers, and another for environmental policy makers. The goals of these surveys are to summarize:

- the most interesting and important advances in ecological science (poster 3)
- the key unanswered/ partially answered ecological questions (poster 3)
- the most significant contributions of ecological science to policy and management (posters 4, 5)
- the most pressing environmental challenges that need to be addressed (poster 2)
- the key scientific gaps that limit: our ability to address environmental challenges, and application to environmental management and policy (posters 4, 5)
- the key opportunities and obstacles in integrating ecological research, management, and policy (posters 4, 5, 6)

Methods:

Survey participants were recruited through emails to ESA members and postings on Ecolog and ESA's Twitter and Facebook feeds. In addition, emails were sent to individuals whose email addresses were available through web searches associated with: US federal environmental agencies, US state environmental agencies, US state and national legislators on environmental committees, US state and national legislators on the national caucus of environmental legislators, and a broad spectrum of NGOs associated with environmental management and policy.

Most questions in the surveys were free-response (rather than ranking pre-determined choices) in order to gain more in-depth answers and to determine which issues were "front and center" for the respondents. We felt that this free response approach provided a truer ranking of priorities.

These surveys reflect the perspectives of a small subset of each professional community (especially policy), and likely are biased to those most interested in facilitating collaborations across communities.

Acknowledgements:

The ESA Centennial Survey Committee designed, implemented and analyzed the surveys. Committee members include:

Valerie Eviner (Chair)
Evan Batzer
Elena Bennett
Kelly Garbach
Leah Gerber
Daniel Scholes

The survey was conceptualized and edited through conversations with ESA's Governing Board and ESA's Science Committee and Office of Science.

The survey was supported through funding from ESA's Long-Range Planning Grant as well as through a grant from ESA's Centennial Implementation Funds.

We would like to thank all of those who responded to the surveys, and who distributed the surveys to colleagues.

Contact information:

Sign up for the listserv if you would like to be updated on products through this effort (papers, white papers, web summaries):
https://lists.ucdavis.edu/sympa/subscribe/esacentennialsurvey
Or follow us on twitter: @ESASurvey100

For more information, or if you are interested in collaborating with ESA's Science Committee on efforts to enhance integration of science into policy and management, contact:
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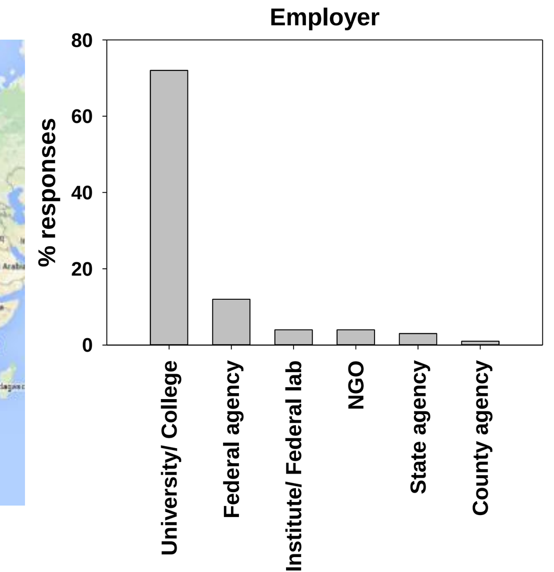
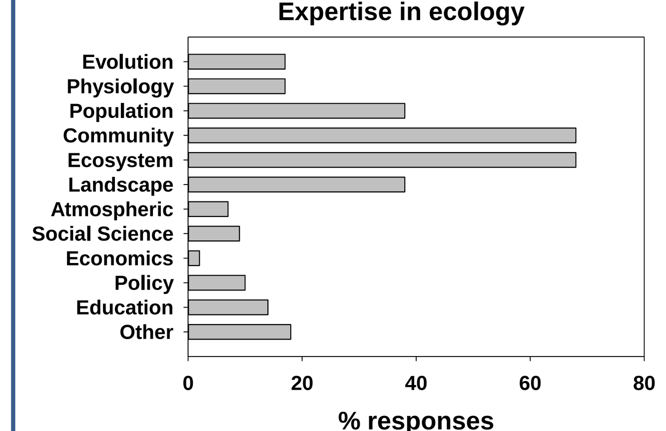
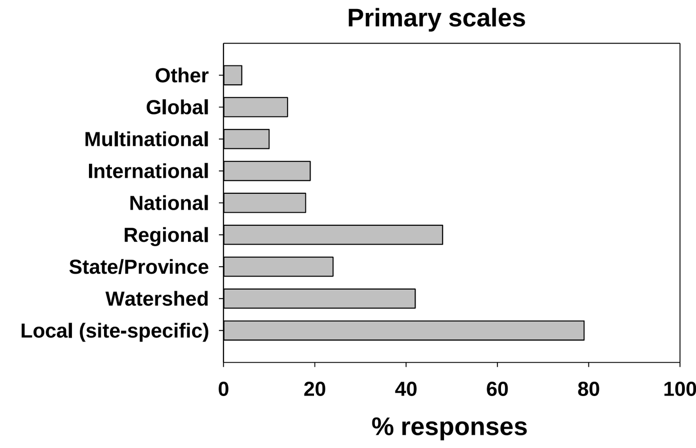
Summary of respondents:

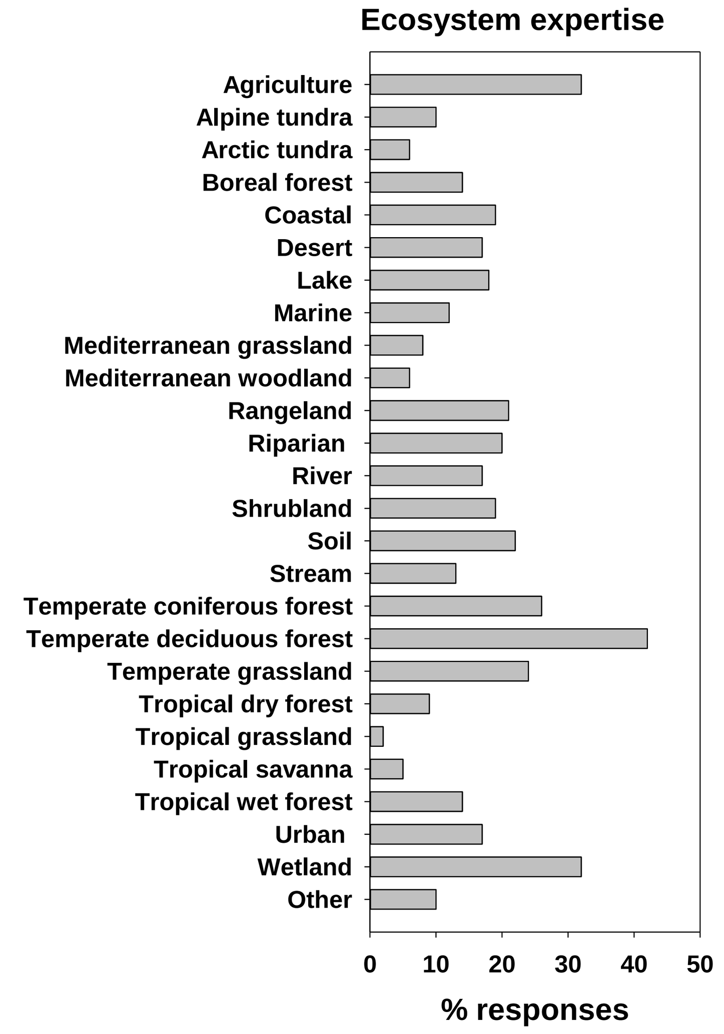
Researchers: n=180, 85% ESA members

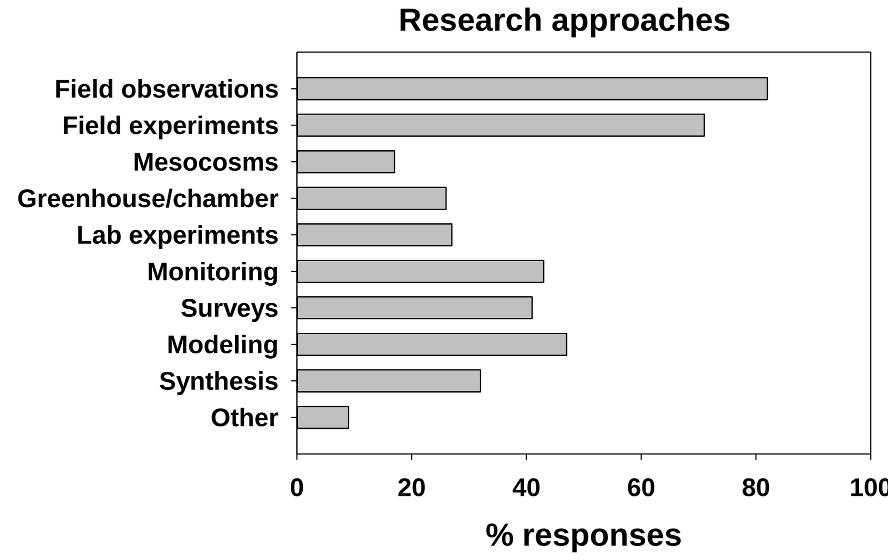
- Respondents were predominantly academic researchers from across the US, along with some international participants
- Research expertise was dominated by community and ecosystem ecologists who focused on field experiments and field observations at local, watershed and regional scales, across a wide range of ecosystem types.





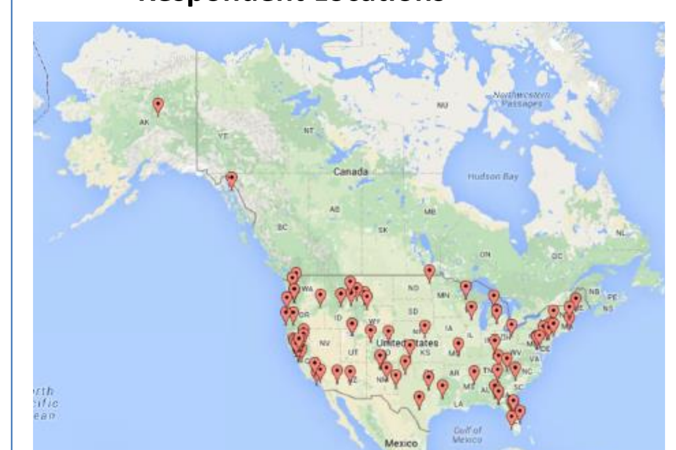


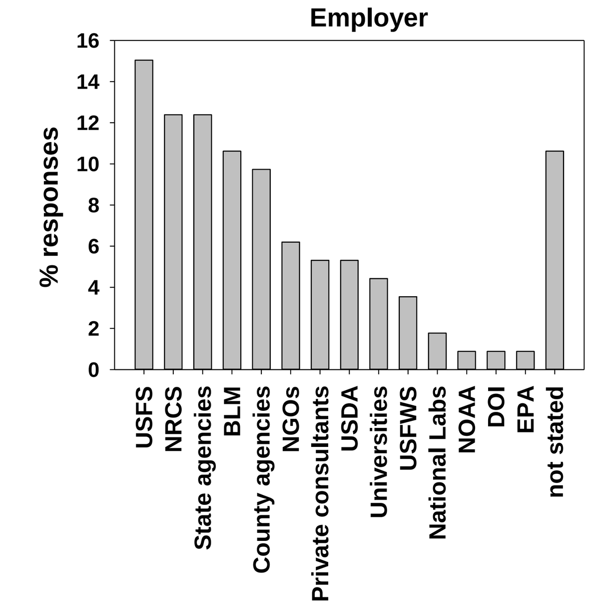


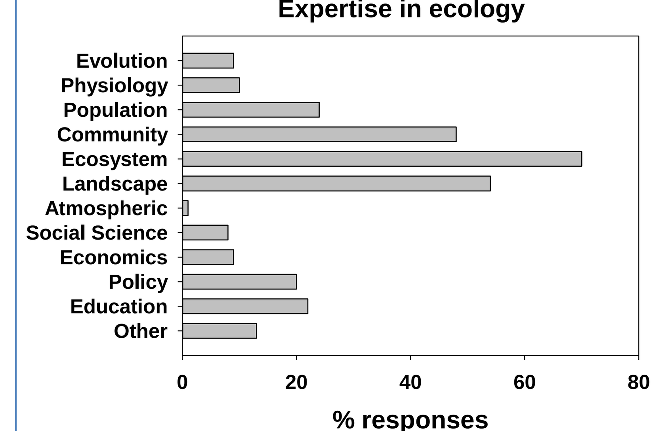


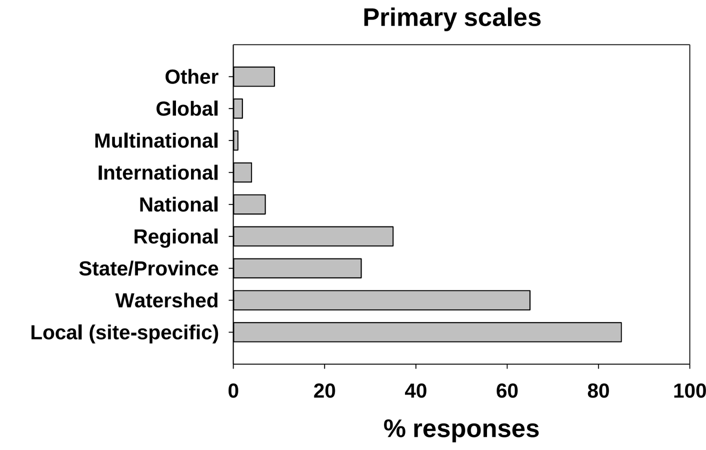
Managers: n=113, 22% ESA members

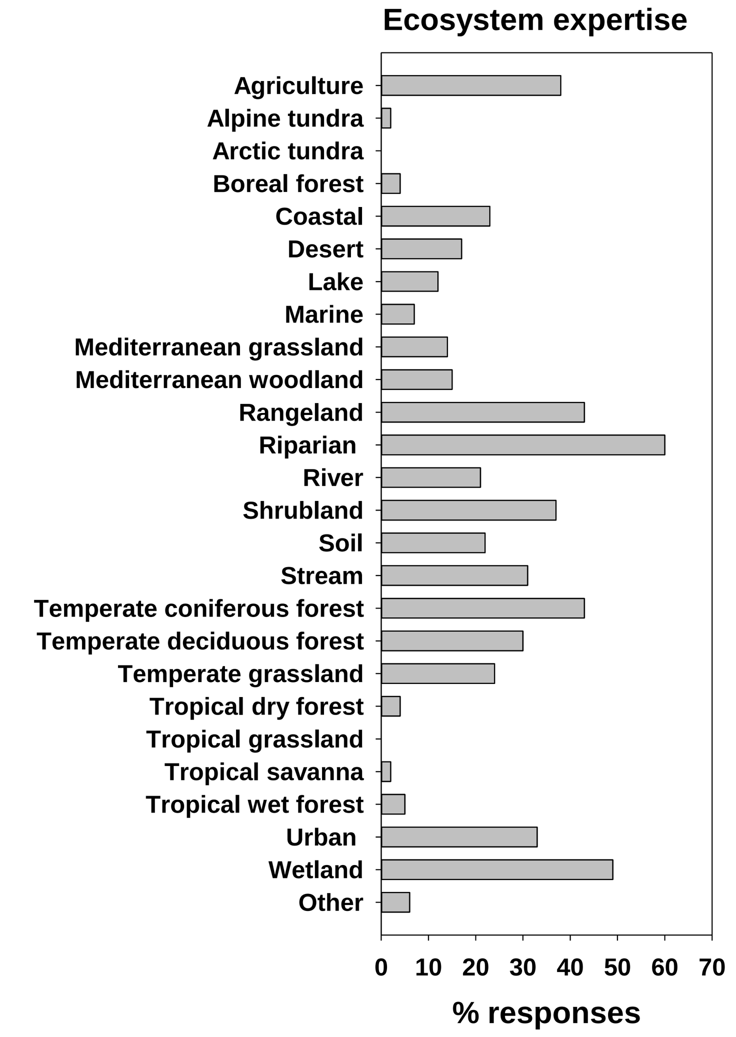
- Respondents were mostly from federal, state and county agencies across the US (with one response from Australia).
- Participants had a wide-range of management expertise, with an ecological focus on community, ecosystem, and landscape ecology at local and watershed scales, and to a lesser extent, at state and regional scales. Focal ecosystem types were varied, but many managers indicated expertise in the following systems: riparian, wetland, rangeland, temperate coniferous forest, agriculture, and shrubland.

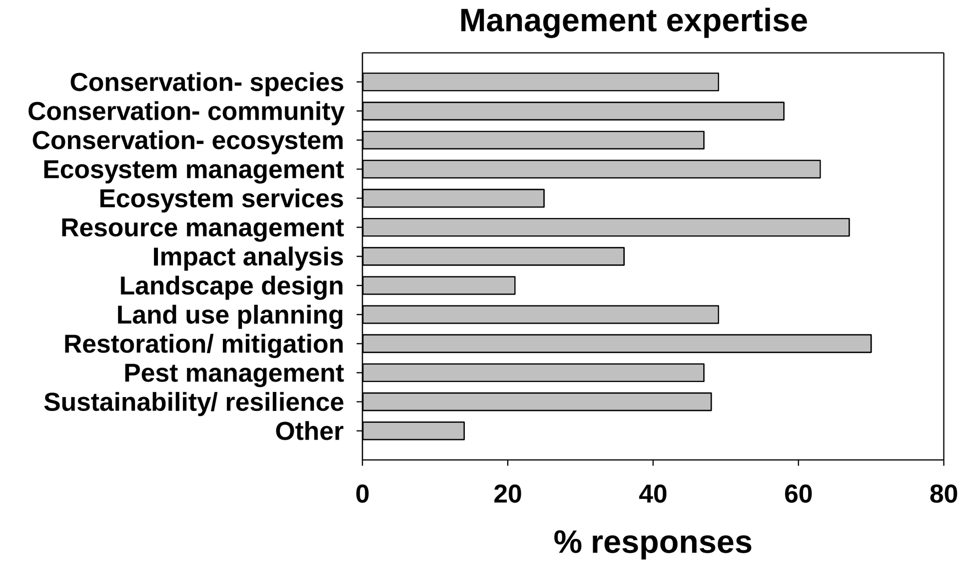






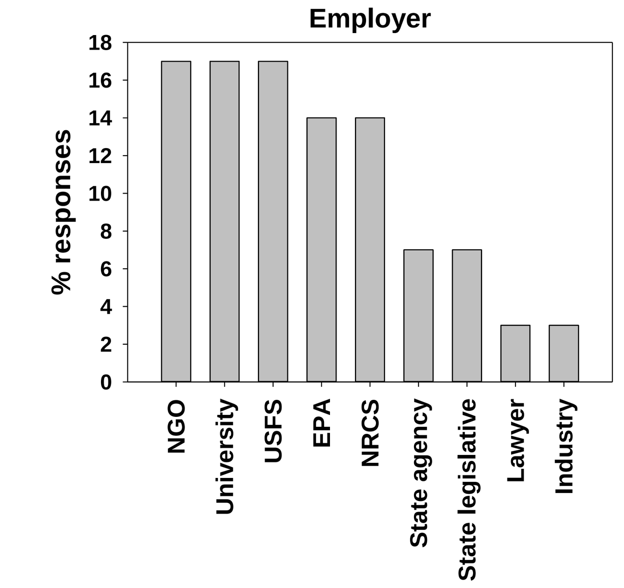


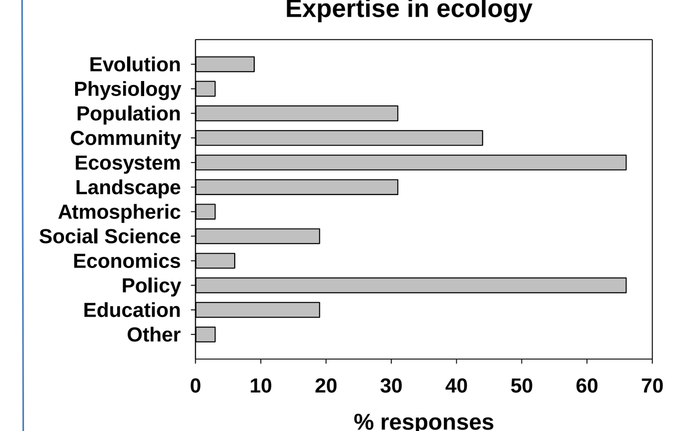


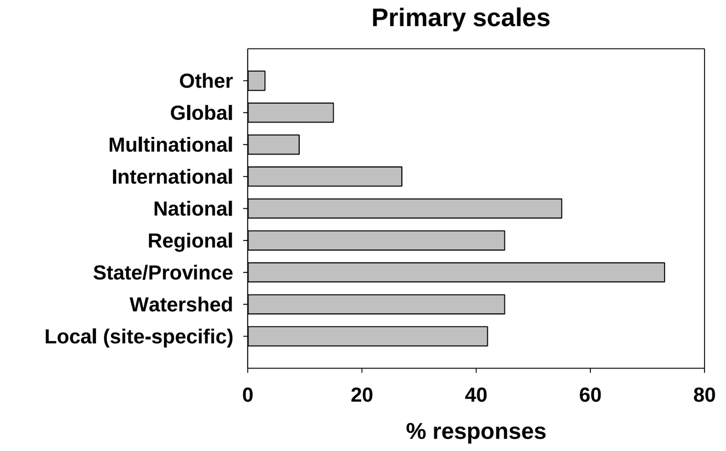


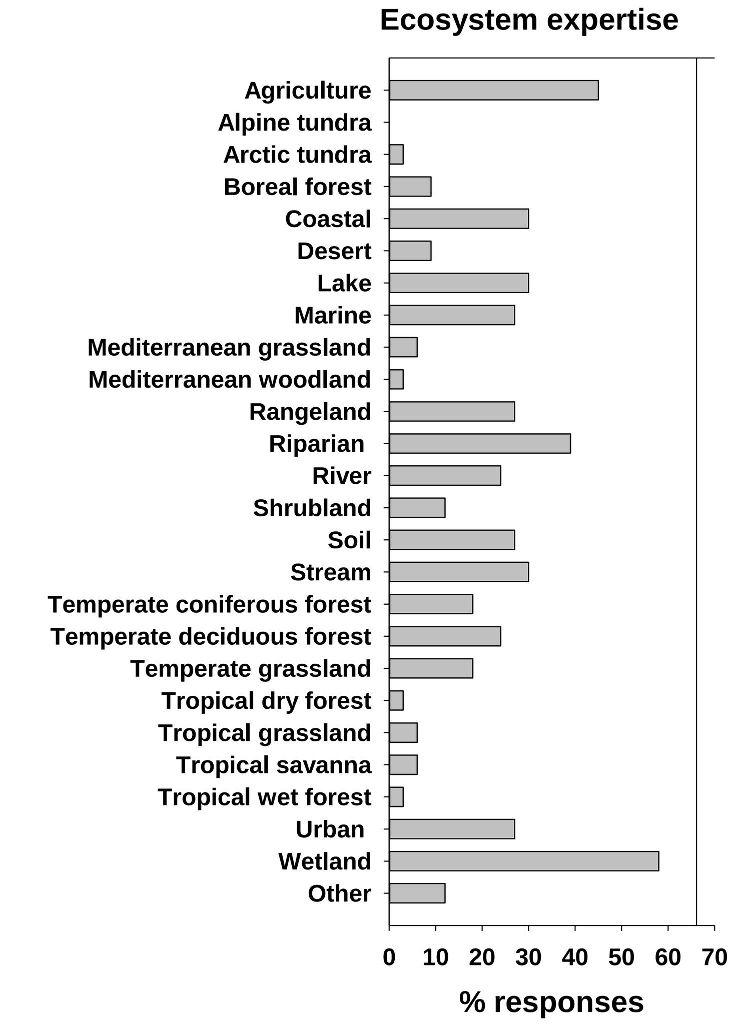
Policy: n=38, 61% ESA members

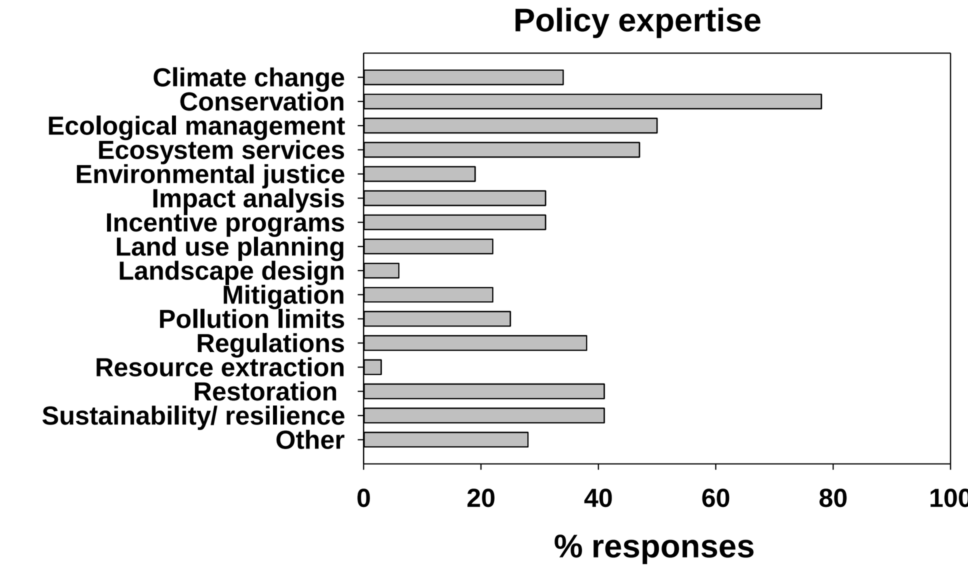
- Participation in the policy survey was low. Most respondents were employed by NGOs , federal agencies, and universities across the US.
- Policy expertise in conservation was most common, but most individual respondents had expertise in multiple environmental policy fields. 70% of respondents engage in state policy, and collectively, respondents engage in policy from local to national levels. Ecological expertise was largely in population, community, and ecosystem ecology across a range of ecosystem types (particularly wetlands and agriculture).











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Centennial Survey: Current & Future Environmental Challenges

Introduction:

All three surveys asked participants to identify the 3-5 most pressing current and future environmental challenges.
Researchers were asked about environmental challenges in general.
Managers were asked about challenges in environmental management.
Policy makers were asked about challenges in environmental policy.

When comparing the responses, it is important to consider the different nature of these questions- different responses are likely to reflect the different foci of the three professional communities (which was a key goal of this survey).

Summary:

All three communities identified diverse challenges, highlighting the need for interdisciplinary collaboration to address multiple goals (which was the top-rated current challenge for all communities).

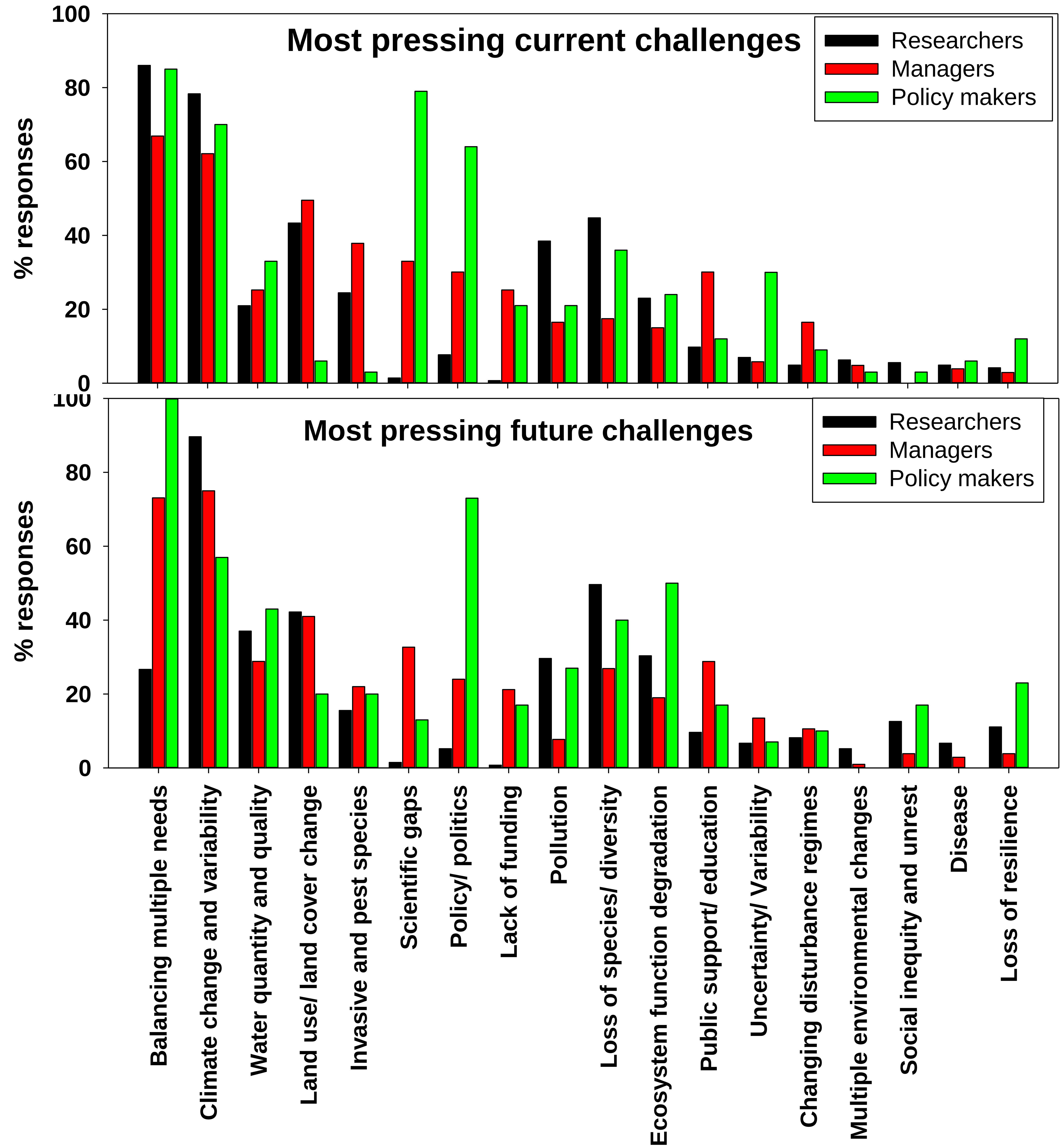
SUMMARY OF CURRENT CHALLENGES:
Shared areas of focus provide immediate opportunities for collaboration. The common pressing challenges across all three communities are:
(1) Balancing multiple needs (e.g. human resource use with conservation of species and ecosystem services).
(2) Climate change and variability (predicting, adapting to, and mitigating the impacts of climate change)
(3) Water quantity and quality- while receiving fewer responses, it was a common pressing challenge across groups.

Differences across groups provide opportunities to understand different priorities, or areas where better communication and collaboration are needed to address the challenges. The main differences across groups are highlighted here:

- Highly ranked challenges for research & management (not policy): policy makers do rank these topics more highly as future challenges
  - Land use/land cover change (habitat loss, degradation and fragmentation)
  - Invasive and pest species expansion and impacts
- Highly ranked challenges for management & policy (not research): some of these challenges can be addressed with more focus from the research community, but others are societal issues that must be addressed by all three groups.
  - Scientific gaps, in particular:
    1- Research approaches that improve understanding and management of complexity and variability in ecosystems
    2- Research addressing the scales of management and policy, particularly focusing on larger spatial scales and longer temporal scales
    3- Faster synthesis and systems-level integration needed for decision-support
  - Policy and politics, including:
    1- Political climate is contentious on environmental issues
    2- Inflexible policies limit adaptive management options
    3- The challenge of developing effective approaches in policy and management that can:
    - balance multiple goals
    - be effective and flexible across different scales, land use types, and ecosystem types
    (this is largely perceived as limited by the scientific gaps)
  - Funding-
    1- Lack of funding for management, monitoring, and management-focused research; limited staffing and funds to support manager engagement in conferences and research
    2- Funding agency priorities limit the scope of research topics and approaches that are funded
    3- Short-term funding limits the scope of projects and the ability to develop long-term management efforts, particularly in restoration and conservation.
- Highly ranked for research & policy (not management): mangers rank this more highly as a future challenge
  - Loss of species/diversity (based on other survey questions, managers recognize this as a critical issue, but it may not be one of the 3-5 most pressing challenges they currently face, particularly since most are focused on specific sites rather than on the regional scale)
- Topics specifically emphasized by each of the groups (but not the others):
  - Research- Pollution (nutrients, heavy metals, etc.)
  - Management-Public misinformation and lack of support interferes with management options and implementation (need for enhanced scientific literacy in both the environmentalist and anti-environment communities)
  - Policy- Uncertainty and variability make it easy to question/discredit environmental policy. There's a need for stronger scientific consensus and decision support tools that can aid in planning and risk assessment.

Comparison of current and future challenges: There was high similarity in current vs. future challenges. When comparing future challenges to the current challenges, differences were largely within groups:.

- Research: Less focus on balancing multiple resources
  More focus on water quality
- Management: More focus on loss of species and diversity
  Less focus on invasive species
- Policy: More focus on land use/ land cover change, degradation of ecosystems, and invasive species
  Less focus on scientific gaps



Centennial Survey : Research Advances and Frontiers

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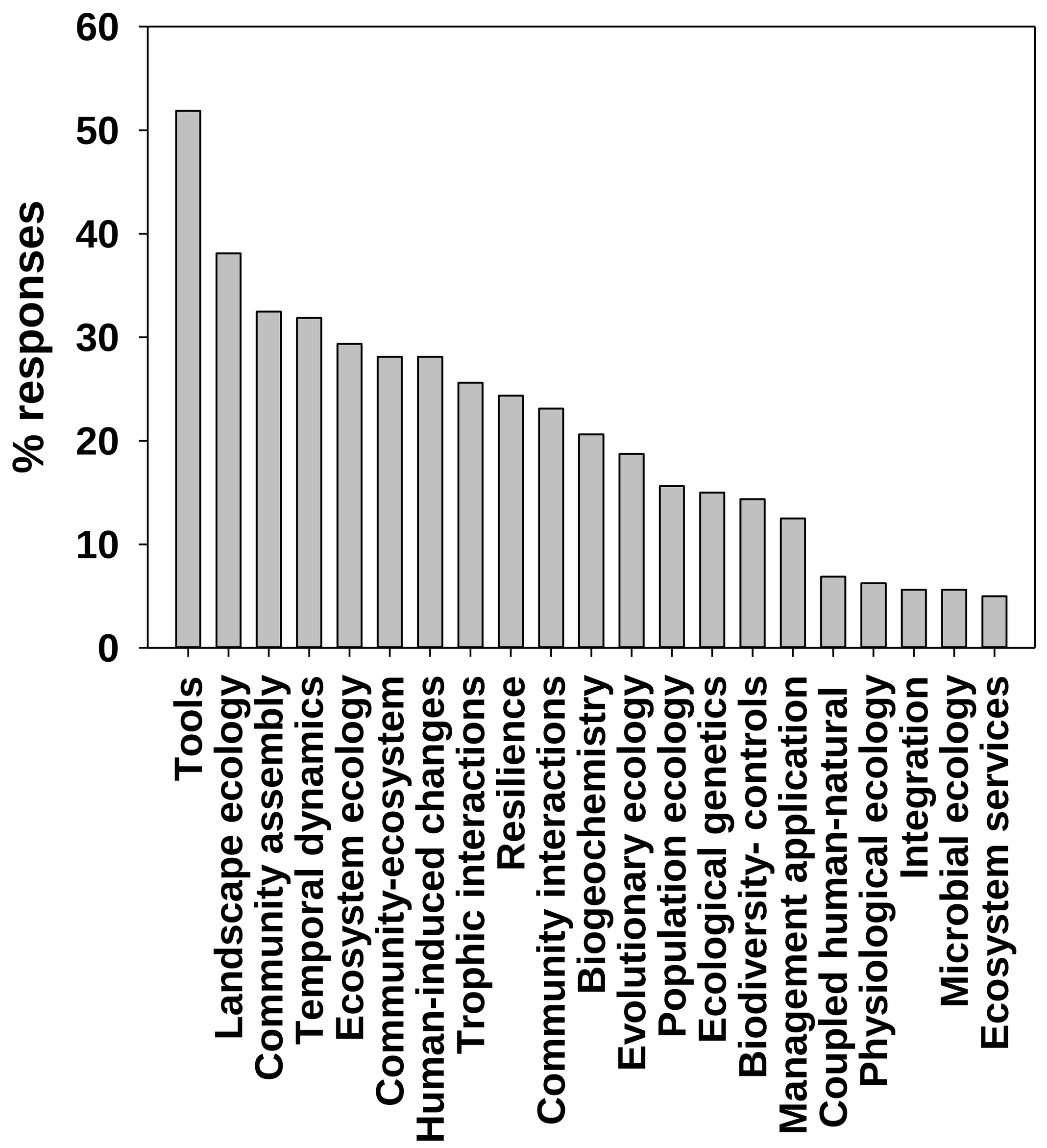
INTRODUCTION: Researchers were asked to identify the most important scientific ideas in ecology, the most pressing unresolved ecological questions, and the key ecological insights that can address environmental challenges (for list of environmental challenges, see poster #2). Answers varied widely in their specificity vs. generality, which accounts for the summary "bins" varying in scale and specificity (with some being a subset of others, which occurred when both the general principle and specific examples were popular answers). Tables below each graph summarize the scope of each category.

SUMMARY: While answers were diverse, common threads did exist across the multiple fields of ecology, and are fundamental to both the past advances and future frontiers of ecological research. These include: (1) Addressing ecological patterns and underlying mechanisms across spatial and temporal scales; (2) A focus on complexity and interactions; (3) The importance of advances in measurement and statistical tools to address complexity across scales; and (4) More focus on integration across ecological fields, and with fields outside of ecology (e.g. social science, earth science).

Advances

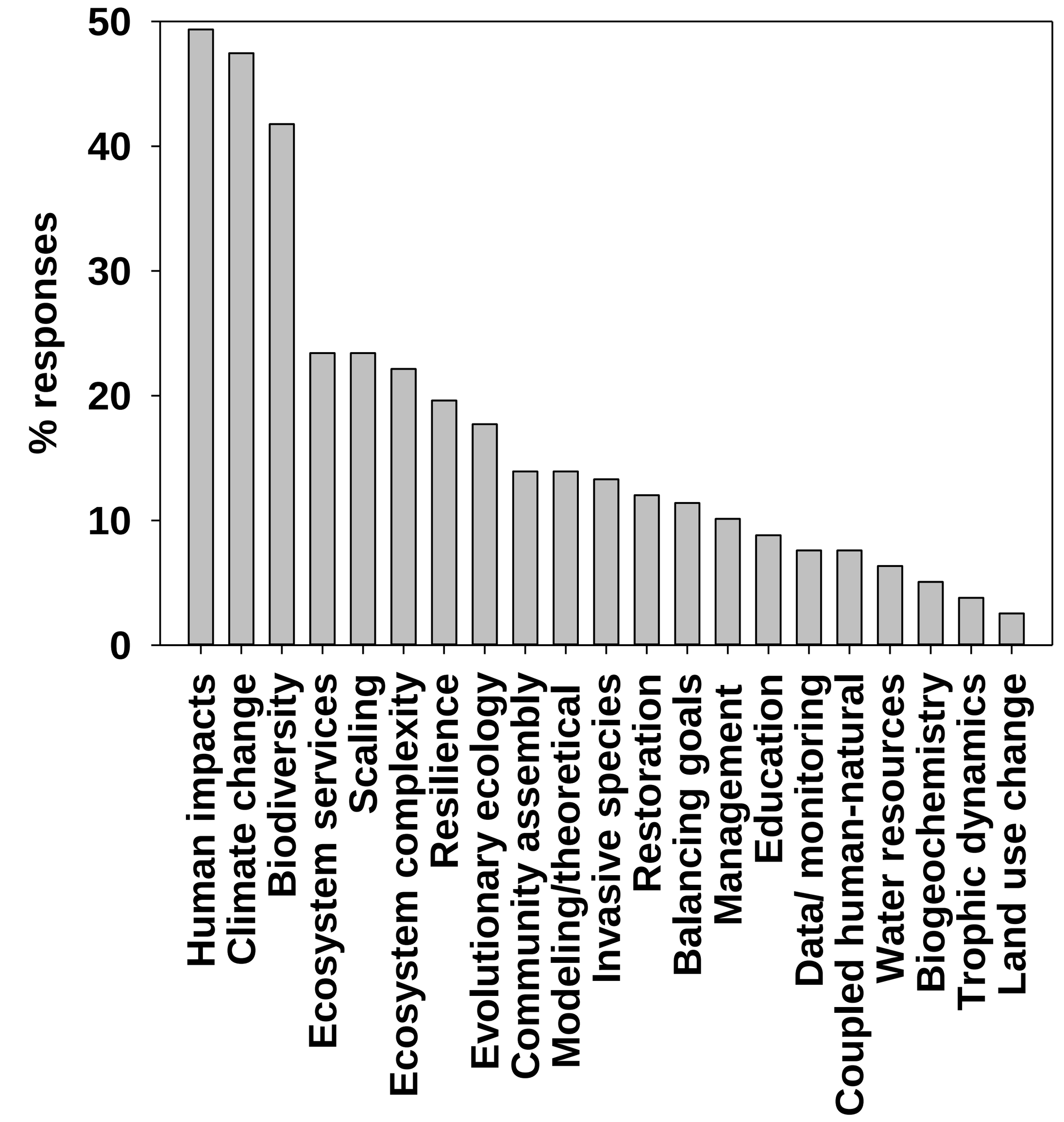
What are 3-5 of the most important scientific ideas/ advances in ecology over the last 100 years?



Category	Most popular responses	Other responses in category
Tools	GIS, Remote sensing, Advanced Statistics, Data availability and collection	Modeling, Stable isotopes, Genomics, Eddy flux, Wildlife tracking, Molecular methods
Landscape ecology	Scaling, Patch dynamics/ mosaic, Watershed-scale, Global-scale	Spatial ecology, Hierarchy, Context-dependence, Pattern and process, Gradient analysis, Mapping, Distribution, Species area curves
Community assembly	Niche, Invasion, Individual species determine community response	Filters, Distribution controls, Neutral theory, Functional traits
Temporal dynamics	Succession, Disturbance ecology	Dynamic equilibria, Long-term data, Paleoecology, Legacy/history, Stochastic processes
Ecosystem ecology	Systems-level thinking	Interactions, Direct/ indirect effects, Mass balance, Feedbacks
Community-ecosystem interactions, functions	Diversity-ecosystem function, Terrestrial-atmospheric links	Stoichiometry, Plant-soil feedbacks, Disease ecology, Keystone species, Functional traits, Species effects
Human-induced environmental changes	Climate change	Pollutant loads, Anthropocene, Extinctions, Bioaccumulation, Land use/ land cover change, Reversing human impacts
Trophic interactions	Trophic cascades	Bioaccumulation, Predator-prey, Optimal foraging, Food web theory, Lotka-Volterra, Importance of top predators
Resilience/ alternate states	Alternative stable states, Biodiversity effects on resilience	Sustainability, Thresholds and tipping points, Regime shifts
Community interactions	Competition, Plant-microbial interactions, Positive interactions	Mechanisms other than competition, Apparent competition, Consumer-resource interactions, Communication across species, Interspecific interactions, Networks, Meta-community
Biogeochemistry	Global scale, Coupling of biogeochemical cycles, Energetics, Nutrient deposition	Carbon and energy flow, Pools and fluxes, Mass balance, Collaboration with hydrology/ geology
Evolutionary ecology	Adaptation to environmental change	Time scales of adaptation, Interaction/integration of ecology and evolution as mechanistic drivers
Population ecology	Meta-population, Modelling	Density-dependence, Demography, Carrying capacity, Population growth, Population crashes
Ecological genetics	Landscape genetics	Conservation genetics, Phylogeny, Population genetics
Biodiversity- controls	Island biogeography	Beta-diversity, Extinctions, Community interactions
Management application	Restoration, Conservation	Ecological engineering, Adaptive management, Agroecology
Coupled natural-human	Humans as part of ecosystems, Focus on human-impacted systems	Behavior/psychology impacts, Economics
Physiological ecology	Allometry/ body size	Trait-driven interspecific interactions, Plasticity, Metabolic theory
Integration of disciplines	Integration across ecological disciplines	Integration with: Socio-economics, Hydrology/geology, Earth science
Microbial ecology	Role of microbes	Biofilms, Microbial loops, Microbiomes
Ecosystem services	Understanding that ecosystem functions deliver bundles of services for humans	Carbon sequestration, Water, Climate controls, Pest regulation

Unresolved Questions

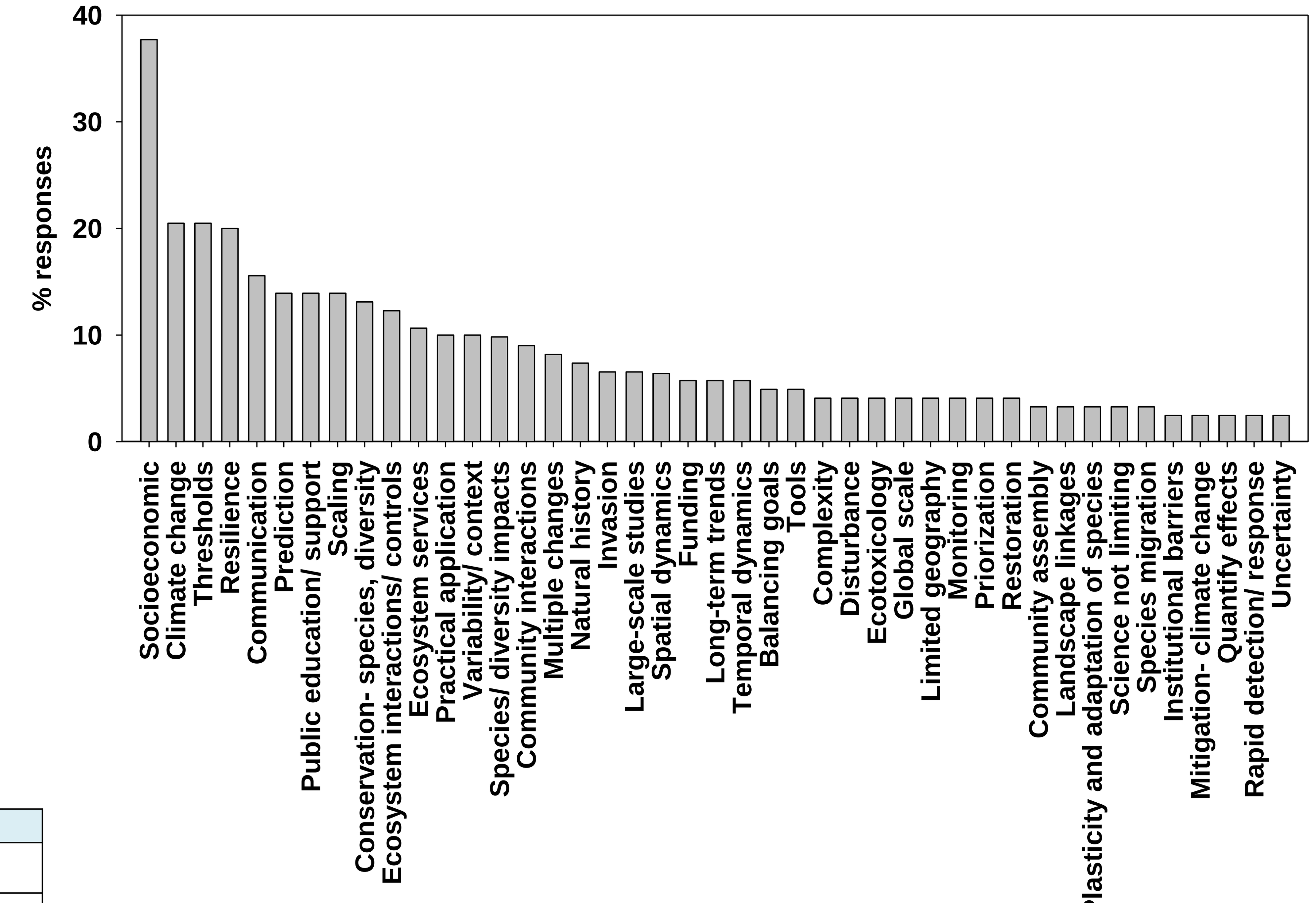
What are 3-5 of the most scientifically pressing unresolved questions in ecology?



Category	Most popular responses	Other responses in category
Human impacts	Multiple environmental changes	Pollutant loads, Anthropocene, Extinctions, Which changes have strongest impacts?, Scale of impact
Climate change	Impacts, Predictions	Distribution changes, Creation of novel systems, Uncertainty, Management, Mitigation, Regional changes, Time frame of climate effects
Biodiversity	Conservation of diversity, Ecosystem impacts	Beta-diversity, Metrics to measure and scale diversity, Diversity types (taxonomic, functional, ecosystem), Distribution
Ecosystem services	Balancing human activities and services, Tradeoffs and synergies	Carbon sequestration, Water, Climate controls, Pest regulation, Impacts of diversity and species, Scaling, Valuation
Scaling	Integrating across spatial and temporal scales, Small-scale studies to regional/ global	Temporal variability and dynamics, Spatial patterns and controls over communities and ecosystem services, Key controls vary with scale
Ecosystem complexity	Understanding and managing key interactions and components	Heterogeneity in controls and interactions, Community-ecosystem feedbacks, Links across scales, Generalize despite complexity, Top-down vs. bottom-up
Resilience	How to maintain and predict resilience	Managing for resilience, Thresholds and tipping points, Regime shifts, Novel ecosystems
Evolutionary ecology	Adaptive capacity and pace	Interaction/integration of ecology and evolution as mechanistic drivers, Limits to adaptation, Scale impacts, Climate impacts
Community assembly	Changes in controls and distribution with climate	Relative importance of different controls, Impacts of contingency and chance, Co-existence mechanisms
Modelling/ Theory	Predictive understanding possible despite complexity? (Can simplify enough for models?)	Predictive models for management, Balancing prediction and uncertainty, Indirect interactions, Integration of community theories, Qualitative to quantitative understanding of system, Population dynamics and crashes
Invasive Species	Impacts, Spread	Identify risky species, Management
Restoration	Effective approaches	What is possible? What are baselines? Use to test understanding of complexity
Balancing multiple goals	Resource use and limits	Resource extraction, Fisheries, Forestry, Rangelands, Sustainability
Management application	Managing under change and uncertainty	Adaptive management, Heterogeneity and management prescriptions
Data and monitoring	Long-term data	Spatial data, Statistical methods, New methods and measurements, Developing indicators and statistics
Coupled natural-human	Understand and impact key driver of ecosystem changes	Valuation, Socio-economic impacts
Water resources	Drought impacts, Vegetation-hydrology interactions	Scaling controls, Understanding mechanisms of water supply
Education	Public awareness of climate change, loss of ecosystem services	Communication methods, Communication with policy makers and managers, Enhance public support
Biogeochemistry	Interactions of cycles, Environmental controls	Subsurface-surface interactions, Changes in flows, Microbial processes regulating C cycling, Energetics
Trophic interactions	Trophic cascades	Bioaccumulation, Predator-prey, Optimal foraging, Food web theory
Land use change/ fragmentation	Fragmentation impacts on species	Conservation and ecosystem service preservation, Urbanization

Gaps Addressing Environment

What are the gaps in our ecological understanding that limit our ability to address these environmental challenges?



Category	Category (Continued from 1st column)
Socio-economic context	Temporal dynamics- Baseline conditions, Lag phases, Time, Contingency, History
Climate change- Impacts, Predictions, Pace	Balancing goals- Human resource use and environmental goals
Thresholds/ critical loads/ tipping points- What is feasible?	Tools- Statistics and experimental approaches to address scales/complexity
Resilience- Buffering change, How to manage resilience, Decision support for alternate states, What provides adaptive capacity?	Complexity, Systems-level thinking, Consideration of direct and indirect effects
Communication- Translation of science	Disturbance- Changing regimes, Impacts of disturbance
Public education/ Building public support	Ecotoxicology
Scaling- Bridging small-scale and large-scale studies, How controls/risks/ management approaches change with scale, Global impacts of local processes, What is correct scale to study?, Hierarchy	Global- scale understanding of species, biogeochemistry
Conservation- Species/diversity, What are the key controls and management methods?	Limited geography- Our studies/understanding are limited to certain systems and locations (North America/ Europe)
Ecosystem interactions/ controls- Fundamental controls over systems, System-specific understanding, Complexity	Monitoring- Need for more monitoring, Long-term trends, Monitoring across scales and gradients, Determination of indicators
Ecosystem services- Controls, Scales, Management	Prioritization of species, processes, sites (and how that changes with scale)
Practical applications- Tests of management and policy options, Linking theory to decision tools	Restoration- Methods, Potential, Test of theory
Variability/ Context-dependence	Community assembly- Controls and how they change with context and scale
Impacts of changes in species and diversity on ecosystems, Structure/ function relationships	Landscape linkages determine populations, species migrations, ecological change, biogeochemical fluxes
Community interactions- As drivers of change, stability, conservation	Plasticity and adaptation of species- Magnitude and pace
Multiple environmental changes- How they interact in their impacts, Temporal dynamics of multiple changes	Science not limiting- Politics interferes with application of science to solve environmental challenges
Natural history- Need for integration into theory and application, Loss of natural history knowledge and skills	Species migration- Pace, Spatial distribution
Invasion- Spread, Impacts, Identification of potential invasions, Management	Institutional barriers- "Too busy" to go beyond what immediately rewarded for
Large-scale- Studies at the management/policy scales	Mitigation of climate change
Spatial dynamics- Distribution, Controls	Quantify human effects on environment
Funding- Levels, Priorities, Short-term	Rapid detection/ response, Early warning signs
Long-term trends- The importance of long-term data in establishing changes, Determining temporal dynamics	Uncertainty limiting theory, prediction, management

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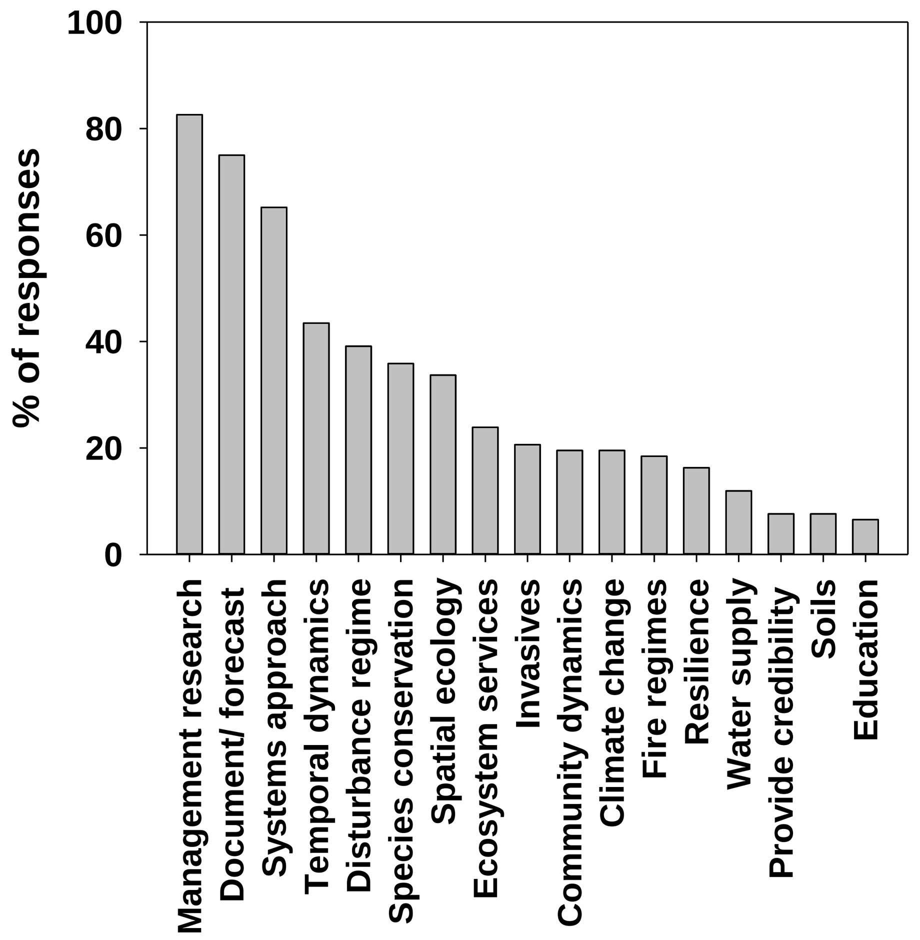
Centennial Survey: Integration of Management and Research

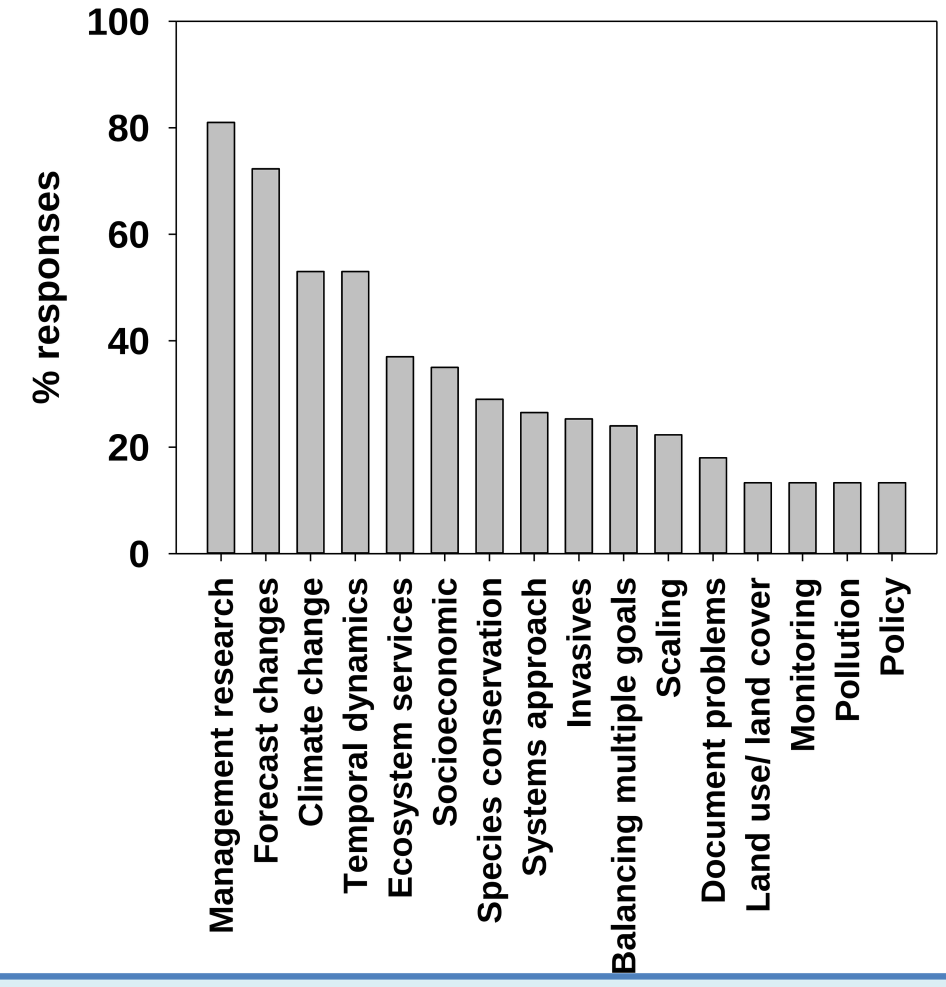
Contributions of science to management

What are the 3-5 most important contributions of ecological science to environmental management?



Key information gaps

What are 3-5 key information gaps in environmental management that can be addressed through ecological research?



<u>Summary:</u> Managers identified the most important contributions of ecological science to environmental management. Many of these contributions are closely aligned with the key knowledge gaps that limit effective management, highlighting the need for further research progress on these topics.

<u>1. Management research:</u> Managers stressed the critical contributions (and frontiers) in both basic and applied ecological research:
- Understanding the controls over ecological processes provides:
  - frameworks to guide management decisions (e.g. ecosystem-based management and planning)
  - ideas for new management approaches and tools, and how to adapt management approaches under changing conditions
  - criteria for prioritization of goals based on feasibility and level of threat
- Research on the effectiveness of management tools
- Guidance and collaboration for developing and synthesizing adaptive management
- Focus on management-scale (e.g. watershed-level studies)
- The fields of conservation and restoration ecology were most frequently highlighted as key contributions to management

<u>2. Documenting & forecasting changes:</u> are key contributions to management (e.g. population decline and recovery, system changes in response to pollution). Looking forward, managers are more concerned with forecasting than documenting changes (particularly in response to climate change). Key needs include:
- Early detection of potential problems and determination of thresholds, so that problems can be resolved before recovery is unfeasible
- Decision support tools that evaluate alternate scenarios of future conditions, particularly focused on the projected long-term effects of various management actions (or inaction). In particular, there is a need to assess potential climate change adaptation and mitigation approaches
- Downscale climate predictions (and climate change impacts) to a local level

<u>3. Systems approach:</u> Many respondents highlighted the limited application of reductionist research, and the great contribution of the systems approach. Ecological management occurs in the context of complex systems, with many uncontrolled (and sometimes unknown) driving variables. The systems approach has :
- Elucidated the fundamental processes driving systems (e.g. links between structure and function)
- Integrated across fields of ecology to address multiple drivers and multiple goals
- Provided a framework to understand and manage complex systems, focusing on the importance of various ecosystem components and their interactions (e.g. cascading effects, direct vs. indirect effects)

<u>4. Temporal dynamics:</u> Long-term data have documented the trajectory of environmental changes, as well as the range of natural variability within systems. A key contribution has been the recognition of the importance of disturbance regimes in determining ecosystem structure and function, facilitating the use of disturbances as management tools. Other temporal contributions include:
- The recognition that past events can shape future dynamics
- The conditions under which regimes shifts occur

A key gap is the need for long-term data on the impacts of management practices

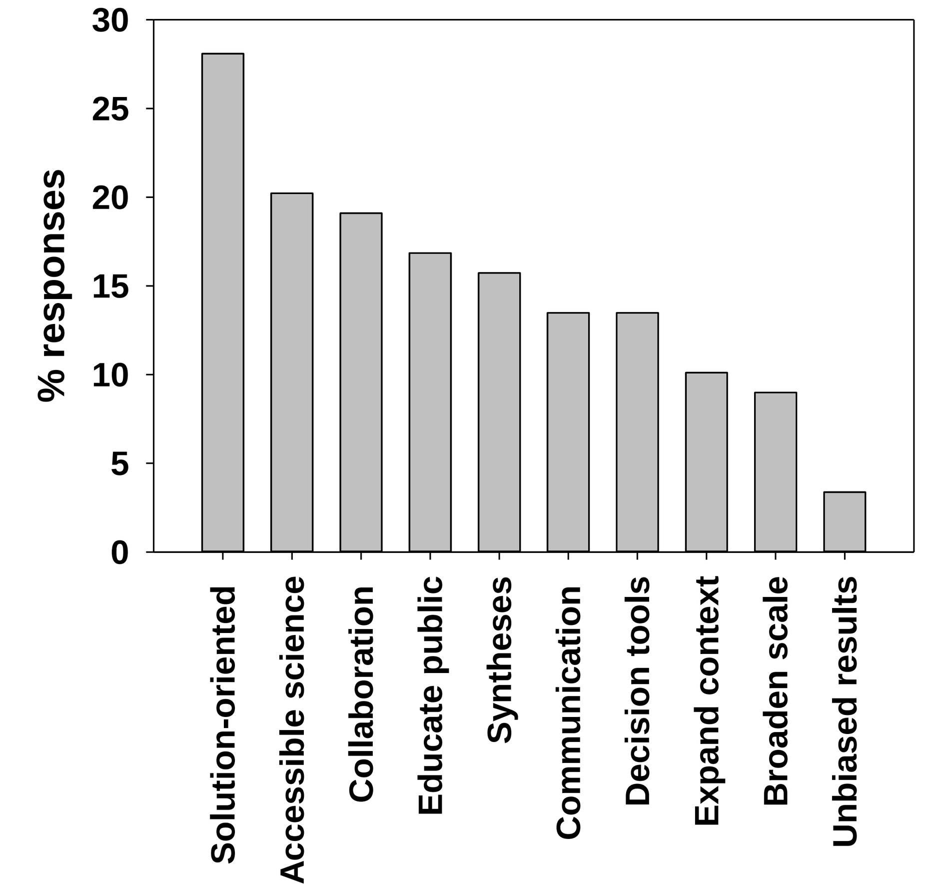
<u>5. Species ecology & conservation</u> have provided the foundation for management of species and diversity by:
- Identifying and prioritizing at-risk species
- Guiding management approaches to conserve and create core habitat, particularly under changing conditions

<u>6. Spatial ecology/ scaling</u> has contributed to management through:
- Understanding the key variables that drive heterogeneity in ecological structure and function, allowing for the development of "threat maps" and site-specific best management practices
- Elucidating the ecological impacts of changes in land use and land cover (particularly fragmentation and connectivity) and application to preserve design
- Providing spatial and conceptual tools to aid management decisions (e.g. GIS, Ecological Site Descriptions)
- Understanding ecological processes at the actual scale of management (e.g. watershed, region) rather than just in local, small-scale plots

The key gaps are largely focused on scaling, including:
- Consideration of multiple scales and how ecological controls and best management practices vary by scale
- Determining the best scale to manage key problems (e.g. fire control, invasive species, water supply)
- How to translate general ecological knowledge to the local scales where management decisions are made

Enhance contributions of research to management

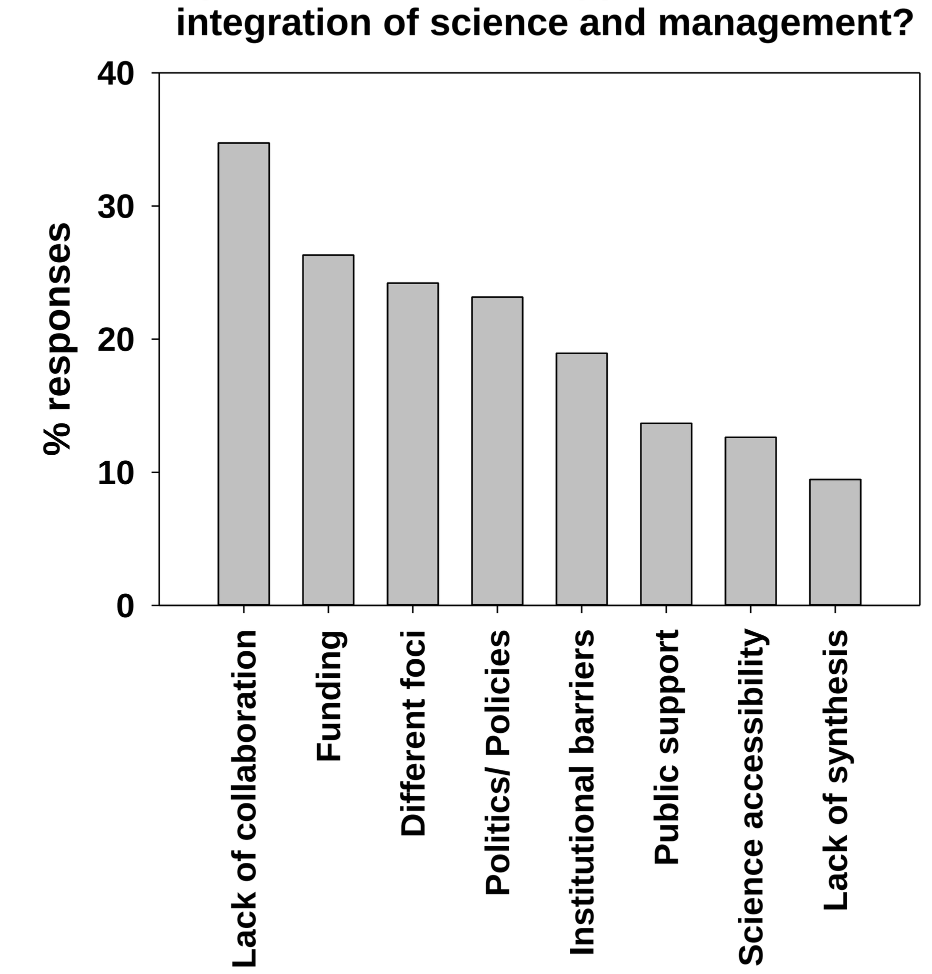
How can ecological research enhance its contributions to environmental management?



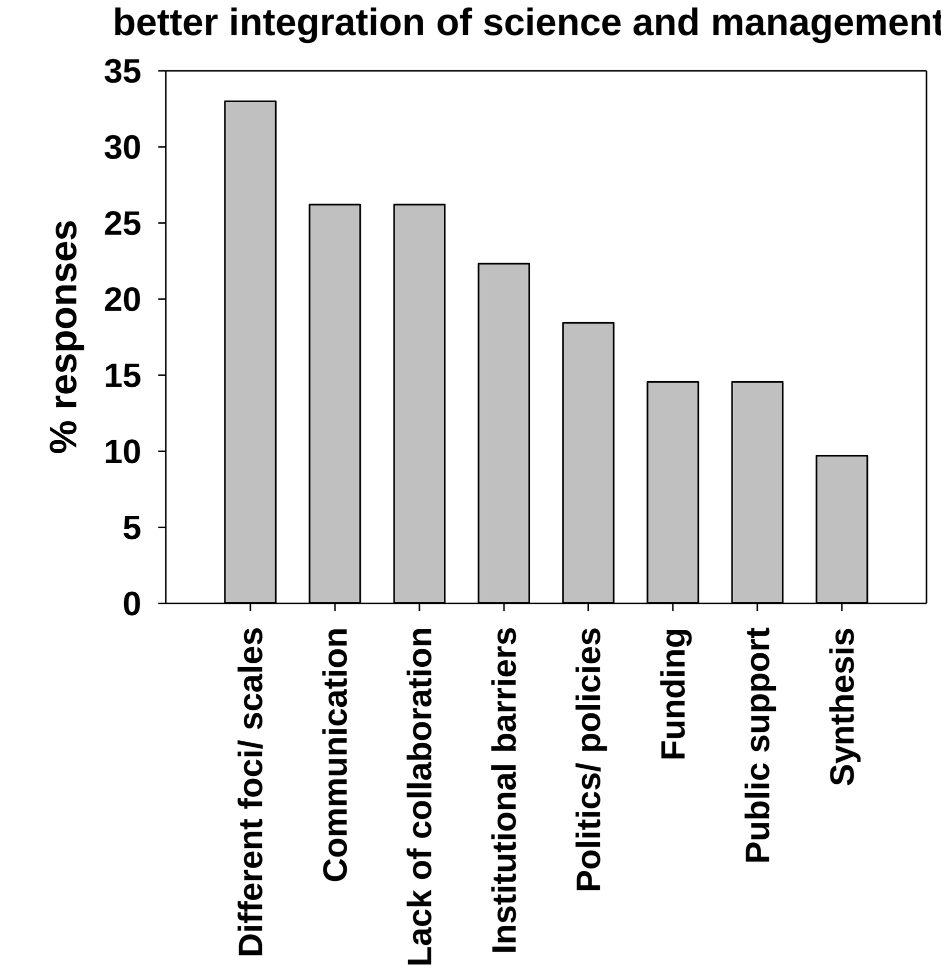
<u>Summary:</u> Managers identified key ways that ecological research can enhance its contributions to management:
1. <u>Solutions-oriented research</u>: Develop and test a diverse toolbox of management options for conservation, mitigation and restoration. Develop management frameworks that integrate ecological complexity.
2. <u>Improve accessibility of research:</u>
   - Make research results publically available - many managers don't have access to journals and literature databases (e.g. Web of Science)
   - Avoid jargon and clearly describe implications for management
   - Increase speed of information dissemination
   - Submit research summaries to management newsletters
3. <u>Collaborate with managers</u> throughout the research process, including project development, implementation, synthesis, and outreach. Participate in adaptive management projects. How can we incorporate the wisdom of the "gut feeling" of long-term managers with more traditional (but often less integrative) data-driven approaches?
4. <u>Educate the public and policy makers</u> to enhance public and policy support of ecological management. Strongly voice scientific consensus and don't "hide in the lab when politics get messy"
5. <u>Provide syntheses/ assessments</u> of scientific understanding, and keep syntheses up-to-date
6. <u>Communication</u> : Scientists and managers need to communicate regularly over the long-term. Two-way conversations are needed to prioritize research goals and approaches (giving a research summary talk at a management conference is not adequate communication) Create science liaison positions to facilitate translation of science into action.
7. <u>Develop decision support tools</u> : Particularly when actionable data are not yet available, develop frameworks and scenario models , based on an integration of available knowledge
8. <u>Expand the context of research</u> to include social science, economics and policy, which often have strong impacts on management implementation
9. <u>Broaden the scale of research</u> to larger spatial and longer temporal scales
10. <u>Maintain unbiased , basic research</u>, which is critical to providing credibility to science-based management approaches

Hurdles to integration

Managers- What are the biggest hurdles to better integration of science and management?



Researchers- What are the biggest hurdles to better integration of science and management?



<u>Summary:</u> Managers and researchers identify many similar hurdles in integrating science and management, some of which can be addressed through increased collaboration and communication by dedicated participants.

- The effectiveness of <u>collaboration and communication</u> requires investment of time to develop shared visions. Effective collaboration would be facilitated by training both managers and researchers to better understand the foundational knowledge, skillsets, and goals guiding each community.
- Collaborative efforts can develop more <u>effective tools to impart scientific findings</u> to managers (e.g. decision support tools)
- <u>Different focal research topics, scales, priorities and approaches</u>- While both communities highlight this as a hurdle, this survey suggests that mutual scientific frontiers include:
  - Understanding of how ecological dynamics and their controls vary over spatial and temporal scales
  - Understanding how multiple environmental changes and interactions across ecosystem components contribute to complex system dynamics

  These questions are difficult to address through traditional research approaches, and likely will benefit from collaborative research with managers across a diverse array of sites .

Centennial Survey: Integration of Policy and Research

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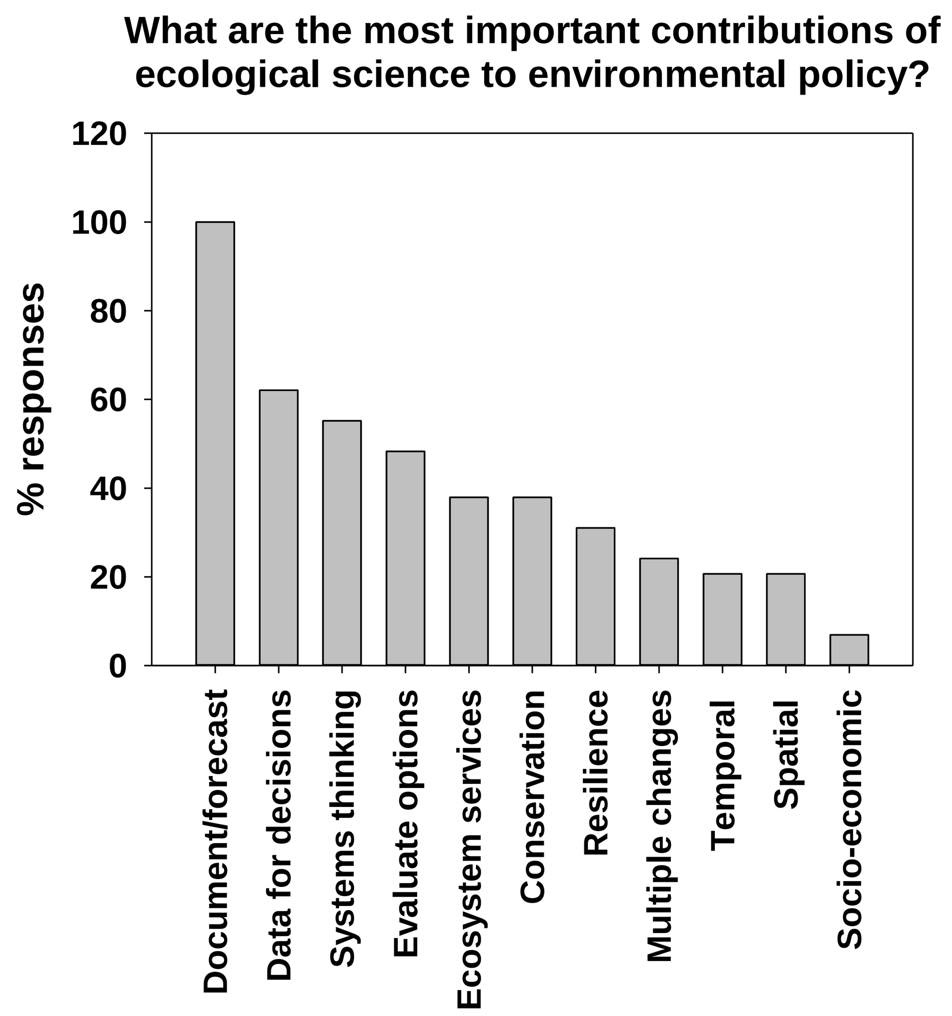
Contributions of science to policy



When policy makers were asked about the most important contributions of ecological science to environmental policy, their answers largely fell into two categories:

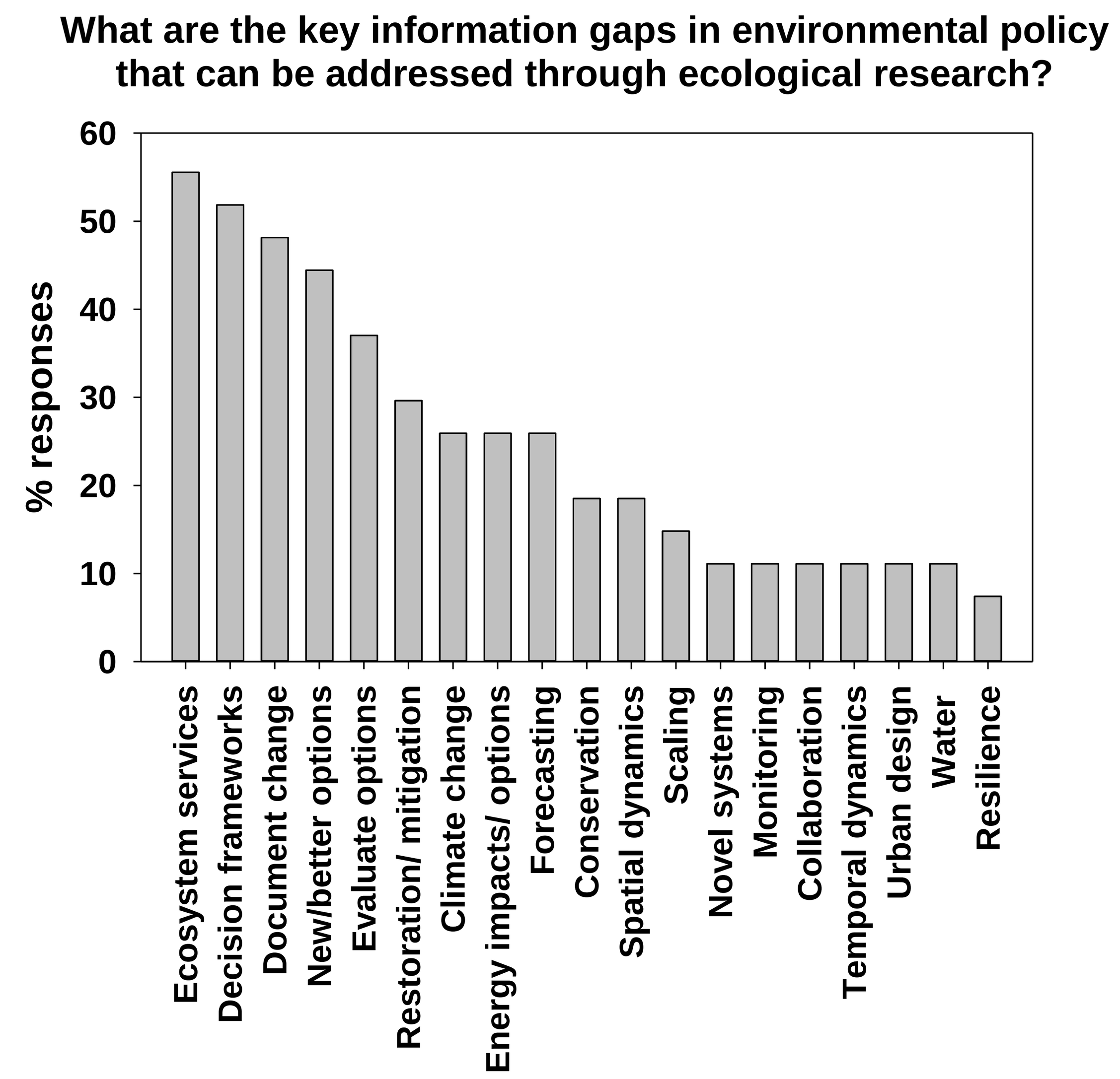
1. Rigorous data to:
- document environmental changes
- establish thresholds
- compare management/ policy options
- provide unbiased, legally-defensible data to support decisions.

These data are largely derived from rigorous long-term monitoring efforts

2. Conceptual frameworks that can be used to guide decisions. These approaches:
- Incorporate complex ecosystem interactions (systems theory) across spatial and temporal scales
- Evaluate tradeoffs and synergies across multiple goals (e.g. human resource extraction and conservation)
- Provide predictive models
  - To forecast potential environmental issues before they are a problem
  - To project the outcomes of different policy and management options
  - To forecast potential changes under future conditions
- Are the basis for effective management approaches such as conservation and restoration

These conceptual approaches should focus on large spatial scales, provide long-term outlooks, and provide the ability to scale across space and time

Key information gaps



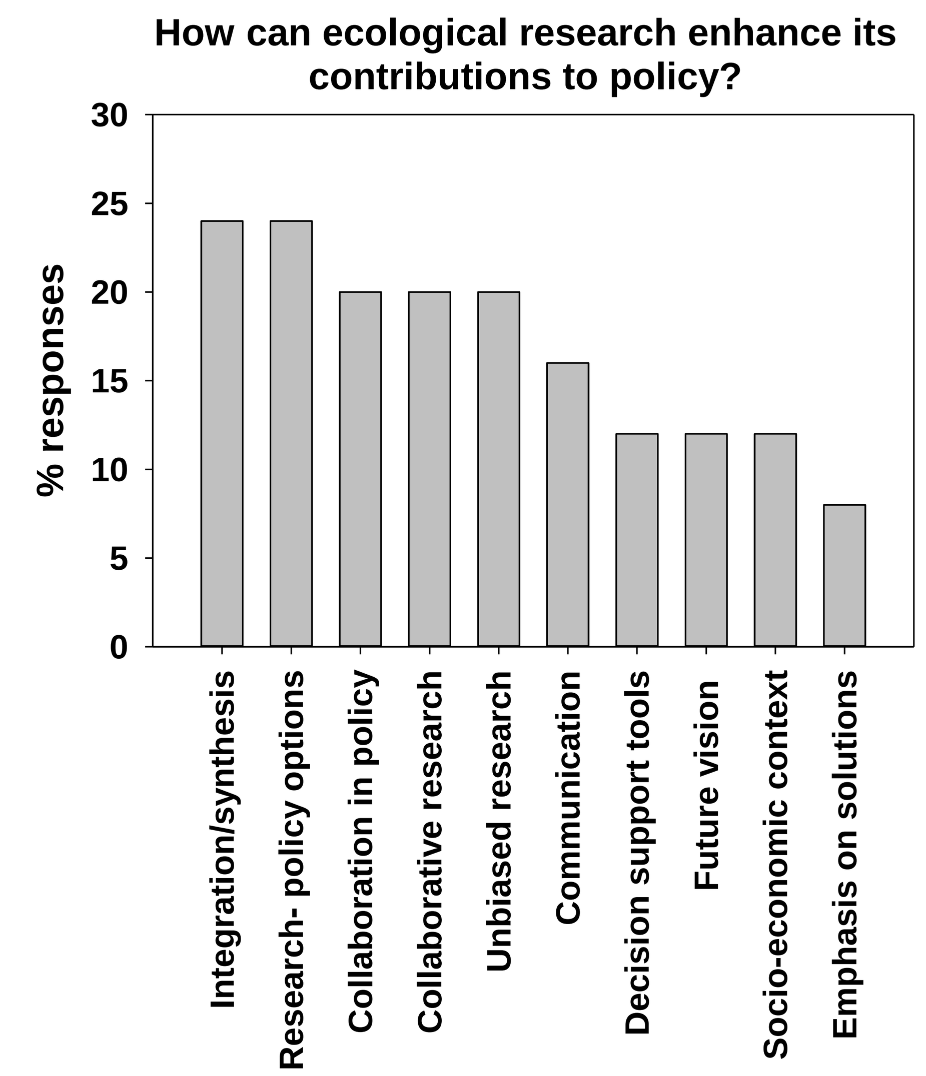
Policy makers identified information gaps for effective environmental policy. Research to address these information gaps would build upon the same data and conceptual frameworks that were identified as "significant contributions of ecology to policy" (see previous section). A few strong needs emerged:

1. Expand long-term monitoring efforts in order to document environmental changes and evaluate the impacts of different management options.

2. Integrate data and conceptual models to develop:
- Decision frameworks to select best policy options
- Novel and improved options for mitigation, adaptation and restoration in response to rapidly changing environmental conditions
- Improved forecasts of the consequences of changing environmental conditions

3. Application of data and decision frameworks to address pressing policy issues:
- Operationalize ecosystem services. How will environmental changes impact key ecosystem services (e.g. carbon sequestration, water supply, pollination), and how can management enhance suites of services?
- Development of policy and management for adaptation and mitigation of climate change
- What are the environmental consequences of different energy sources, and energy policies?
- What are the most effective restoration, mitigation, and conservation approaches, and how do these vary by scale, region, and ecosystem type?
- Operationalize resilience. How can we promote resilience, and how do these approaches vary by scale, region, and ecosystem type?
- Establish guidelines for designing and managing novel ecosystems, urban systems, and agroecosystems

Enhance contributions of research to policy



Summary: Policy makers identified key ways that ecological research can enhance its contributions to environmental policy:

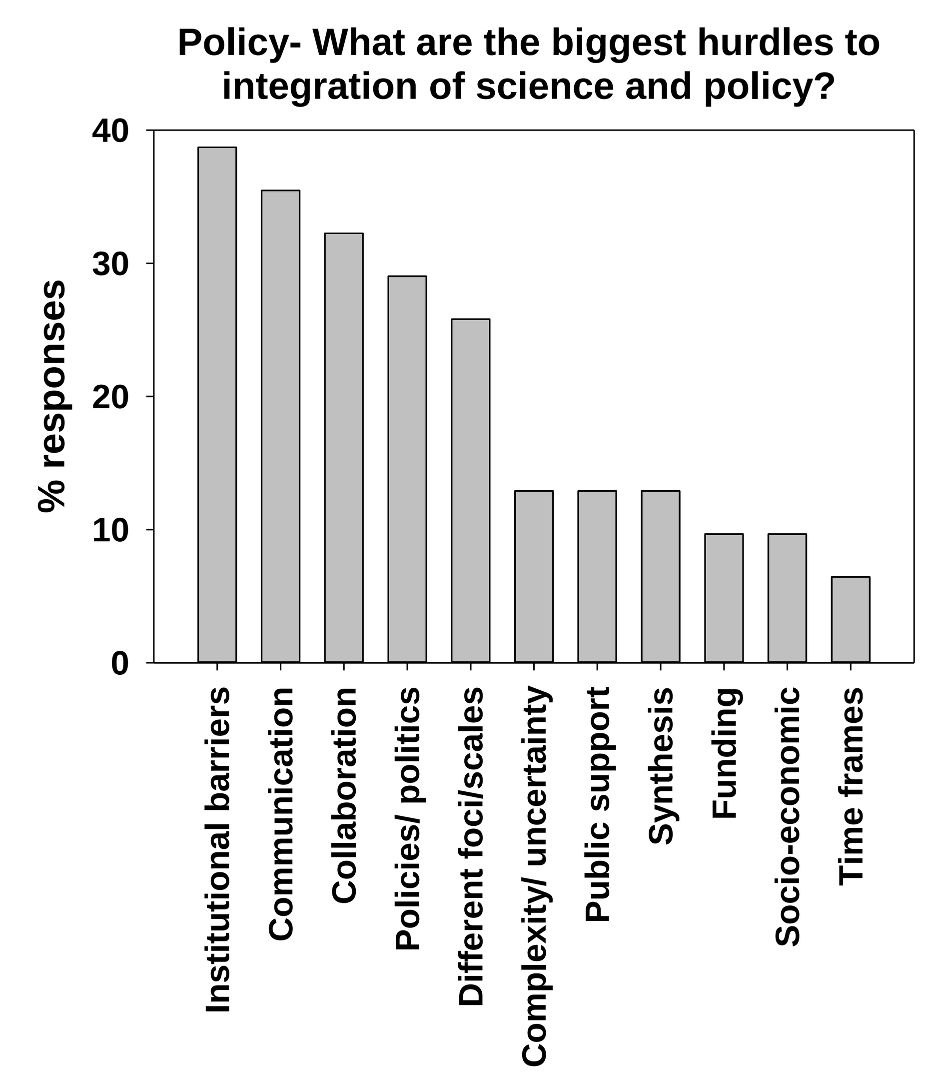
1. Integration and synthesis:
- Syntheses need to be updated often, and occur more rapidly
- Syntheses shouldn't just be a review of piecemeal results, they need to integrate across studies to provide a big-picture vision
- Syntheses should be communicated through decision support tools that can be directly used by practitioners
- Scientists need to be bolder in voicing consensus, when it exists

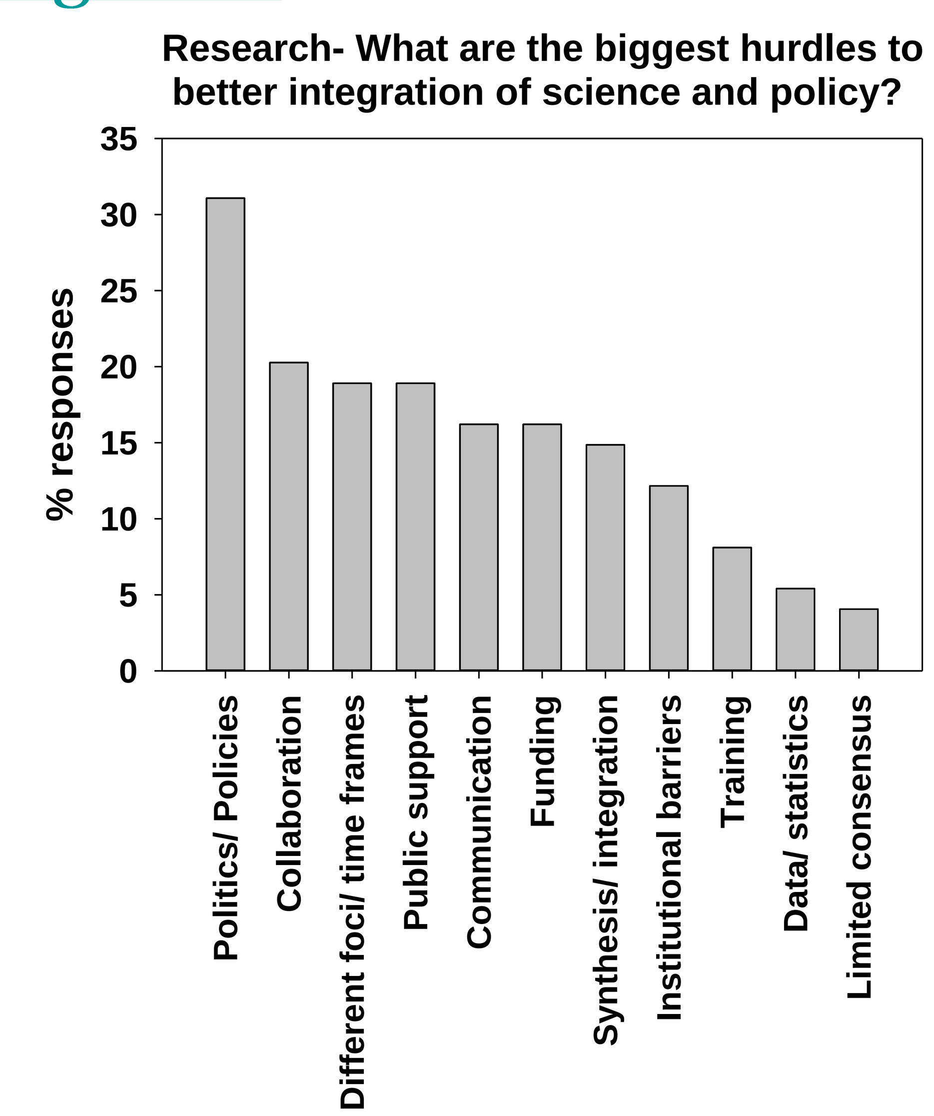
2. Research should:
- Collaborate with policy makers from the start, to define research priorities and approaches (it's not enough just to inform policy makers of your results after a study is complete)
- Balance :
  - targeted research focused on practical policy needs (e.g. monitoring environmental change, testing tools for practitioners)
  - basic research that "thinks outside the box" and identifies emerging issues , novel solutions, and vision
- Partner with social, economic and political sciences to provide realistic solutions
- Maintain rigor, independence, peer-review, objectivity, credibility (not driven by agendas)

3. Collaboration in policy:
- Develop long-term relationships with policy makers, meet with them regularly (this is an invitation!!), gain trust. Policy development is a long-term process, and has to get updated with new information
- Engage in "peer review policy" (e.g. public comments on proposed policies)
- Work with policy makers to design policy options based on scientific evidence (realizing that policy must also address socioeconomic contexts)

4. Communication:
- Get training! Collaborate with policy makers and bridge organizations to craft your research synthesis. Know the line between informing policy and advocating your values
- Provide a strong, direct voice in supporting policy options when research supports them as the best option (One policy maker's take on the climate change debate- "Where are the ecologists?!")
- Promote the power of science to provide practical solutions (rather than just delivering the message that "the sky is falling")
- Engage in communication of science directly to policy makers and the public (e.g. op-eds)

Hurdles to integration





Summary: Policy makers and researchers identify many similar hurdles in integrating science and policy, some of which can be addressed through increased collaboration and communication by dedicated participants.

- The effectiveness of collaboration and communication requires investment of time to develop shared visions. This is particularly important because research will not always be able to keep pace with the immediate information needs in policy. Collaborative efforts can develop more effective tools to impart scientific findings to policy makers (e.g. decision support tools), which can be particularly effective in guiding immediate policy needs when data are lacking
- Effective collaboration can be facilitated by liaisons (e.g. bridge organizations) that can train both communities in partnering with each other
- Increased engagement of researchers in policy development can help develop a more ambitious vision of what policy can accomplish
- Increased communications can provide researchers with a better understanding of the types and scales of questions that need to be addressed for effective policy

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Centennial Survey Synthesis: Opportunities and Challenges in Linking Science, Management, and Policy

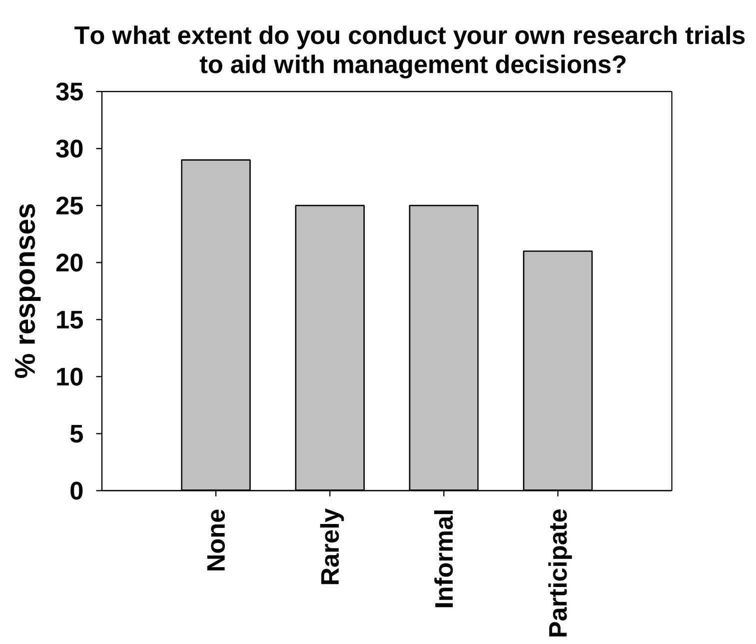
Opportunities in Research:

Most survey respondents from all three communities strongly emphasized the importance of enhanced collaborations and integration between science, management, and policy. This survey indicates that there is substantial common ground to simultaneously address research priorities identified by all three groups :

- All three groups identified the following as the most pressing environmental challenges:
  - balancing multiple goals
  - climate change and variability
  - water supply
- On the surface, priority conceptual research frontiers may appear different from applied research frontiers (in terms of focal goals, experimental manipulations, and scales addressed). However, all groups identified research priorities that address the same underlying frontiers in ecological science:
  (1) Addressing ecological patterns and underlying mechanisms across spatial and temporal scales
  (2) Understanding ecological complexity and interactions, and how these vary in response to multiple environmental changes.
  (3) A focus on integration across ecological fields, and with fields outside of ecology (e.g. social science, earth science) to develop a "big picture" synthesis of how ecological systems function
  (4) The importance of long-term data in understanding natural variability within ecosystems, and to detect environmental changes over time

These common foundations provide the opportunity for collaborative research that can simultaneously address specific short-term practical needs (e.g. comparison of management trials) and conceptual advancements. Our conventional research approaches are limited in their ability to address complexity across scales. This can be addressed by partnering with managers to assess the impacts of replicated large-scale management trials distributed across space and time (which is not feasible for researchers to do on their own).

Both the policy and management communities stress that the time frames and focal subjects of current funding opportunities do not address their needs. This limits the ability of managers to participate in research that could guide their management.



20% of managers participate in research, 25% engage in informal, small-scale management trials, and over 50% have little to no participation in research (this was usually attributed to lack of time , personnel, and funding).

While there is a need for ecological research to address specific management and policy options, both the management and policy communities stressed the importance of basic research, which is critical for:

- Developing new ecological insights and foci, providing the vision to identify emerging issues , novel solutions, and conceptual frameworks to guide decision making
- Maintaining credibility of science through rigorous, unbiased research

Multiple Collaboration Approaches:

The most effective collaborations are based on long-term relationships, with regular two-way communication, and willingness of all parties to understand the different goals and responsibilities associated with each community.

Core collaborative goals should include:

1. Training in the conceptual frameworks, communication approaches and skillsets that are important in management and policy, in order to enhance our ability to collaborate and communicate with these communities
2. Collaborative development of research priorities and approaches that address key practical needs (appropriate topics and scales for management and policy), cutting-edge theoretical questions, and the socio-economic context that influences the implementation of policy and management
3. Collaboration in the development of integrated research syntheses. These syntheses need to go beyond collections of individual study results- they need to integrate these studies into a big-picture understanding of the system. Ideal synthesis products include models and decision support tools, which allow managers and policy makers to make decisions based on updated conceptual frameworks. These decision support tools should:
   - Predict the long-term impacts of different approaches in management or policy
   - Predict how management or policy approaches should change under changing environmental conditions
   - Provide site- and time-specific recommendations
4. Collaboration in developing new policies, and in updating existing policies to reflect changes in ecological theory and evidence
5. Collaboration in adaptive management to help design management trials and monitoring methods, and to provide synthesis

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For more information, or if you are interested in collaborating with ESA's Science Committee on efforts to enhance integration of science into policy and management, contact: veviner@ucdavis.edu