What is the crisis? Defining and prioritizing the world's most pressing problems

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As consensus grows regarding the unprecedented global environmental challenges we currently face, so too does the notion that publicly funded science has a duty to dedicate resources toward overcoming these challenges. In order for scientists to shift attention and resources to the most pressing global problems, we must first enumerate these issues and establish consensus across academia as to the importance and feasibility of solving them. To this end, we have applied concept mapping to a large and diverse pool of disciplinary experts – the entire faculty of Cornell University – to empirically assess their opinions on what our most pressing global crises are, how they relate to one another, and how feasible it would be to solve them. We (1) define what Cornell University faculty see as the most pressing problems of our day, (2) sort them into relevant, modern "disciplines", and (3) rate them according to both their importance and the feasibility of solving them. This study reveals broad consensus across disciplines, groups global crises into seven thematic clusters that cross disciplinary boundaries, and rates issues relevant to all disciplines on a scale of importance and solvability. We believe that this provides a structured framework for both the scientific community and the global community to address global crises.

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A growing awareness of the global crises confronting humanity is accompanied by the realization that the scientific community should focus more attention on solving these problems. In her 1997 presidential address to the American Association for the Advancement of Science, Jane Lubchenco proposed that scientists should formulate a new social contract that compels them to "devote their energies and talents to the most pressing problems of their day, in proportion to their importance" (Lubchenco 1998). In the same address, Lubchenco listed some of the most serious environmental crises, including biodiversity loss, natural resource depletion, climate change, atmospheric pollution, and massive collapse of marine fisheries, to name a few. In addition, Lubchenco recommended broadening the definition of "environmental issues" to include those that relate to human health, the economy, social justice, and national security (see also Hadorn *et al.* 2006). Lubchenco is not alone in calling science to action (eg Bazzaz *et al.* 1998). Many others have noted that complex socioeconomic problems cannot be adequately addressed without a multi-disciplinary, broad-based approach to research and solutions (Bradshaw and Bekoff 2001). If the scientific community is to shift attention and resources to the most pressing problems of the day, we must first enumerate those problems and establish consensus across academia as to their importance and the feasibility of solving them.

One obvious way to define and prioritize important global problems is to solicit the opinions of experts. Because the issues to be considered are numerous and span many disciplines, so, too, should the pool of experts consulted represent a variety of fields. To this end, we have applied a survey technique known as "structured concept mapping" to a large and diverse pool of disciplinary experts – the entire faculty at a major research institution, Cornell University, in Ithaca, New York – to empirically assess their opinions on what the most pressing global crises are, how they relate to one another, and how feasible it would be to solve them.

Concept mapping is a widely employed empirical survey method that can quantify and give thematic structure to the opinions of a given group on a particular topic. Concept mapping, as a participatory process, facilitates the involvement of a much broader group than do methods like expert panels, working groups, and position papers, while allowing much more flexibility in group input than researcher-managed processes, such as surveys (eg Trochim 1989). The concept mapping method used in this study is different from the popular concept mapping methods proposed by Novak (1990 a, b; Novak and Gowan 1984). Novak's concept mapping has become popular as an educational tool, is based on hierarchical structure, and stresses diagramming the relationships between concepts using relational phrases (eg "is in", "contributes to"). In contrast, structured conceptualization (Trochim 1989) is a software-based social-science methodology that uses brainstorming, multidimensional scaling, sorting, and rating to summarize how a group conceptualizes a topic.

The general procedure has been described in detail by Trochim (1989; 2006) and has a long history of use in fields such as public health (Trochim *et al.* 2006; Trochim and Kane 2005), program planning and evaluation (Caracelli 1989), psychology (Daughtry and Kunkel

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1993), and medicine (Donnelly *et al.* 2005). It is particularly useful as a starting point for investigating complex and interconnected ideas, because it provides a framework for organizing those ideas and because the results often lead to more specific and informed questions for further inquiry. This technique is particularly appropriate for the topics considered here, as it avoids the potential bias of conventional, pre-defined survey questions by allowing participants to develop the statements that will later be ranked and categorized. The shortcomings of this method are based on the fact that it is demanding of the respondent's time and can therefore decrease participation rates, and that the outcome is dependent on who is invited to participate (Trochim 1989). Here, we polled all academics at a major research institution, in an attempt to mitigate potential issues regarding sample size and universal representation within the academic community.

Using a structured concept mapping survey, we (1) define the most pressing problems of our day, (2) sort these problems into relevant, modern "disciplines", and (3) rate these problems according to both their importance and the feasibility of solving them. We describe the global crisis humanity currently faces, and sort and rate the components of this crisis to create a manageable, interdisciplinary research agenda. Within our analysis of these data, we look both at the global agenda and at issues that are historically relevant applications of ecology.

Methods

Our concept-mapping survey consisted of three phases: "brainstorming", "sorting", and "rating". Separate invitations to participate in each phase were sent to the 4169 individuals on the "all-academics" e-mail list of Cornell University as of June 13, 2006. This list includes all professors, post-doctoral fellows, and research staff employed by Cornell University. All phases of the survey were conducted on the internet, using software designed by Concept Systems Inc (Ithaca, NY; www.conceptsystems.com) specifically for use in concept-mapping projects. This survey was approved by Cornell University's Committee on Human Subjects.

Brainstorming

In the brainstorming phase, participants were asked to complete the following focus prompt in 50 words or less: "One significant crisis humanity currently faces is…". Because the purpose of the brainstorming phase was simply to generate as many unique statements as possible, no relative language was used in the focus prompt (eg "*most* important crisis"), and no registration or personal information was required of participants at this time. Participants were able to view all previously added responses, which appeared in a list below the focus prompt. The brainstorming phase was open for 2 weeks (June 13 to June 27, 2006), during which time 350 crisis statements were submitted. These were edited for concision and redundancy by a discussion group consisting of the authors and several volunteers, and compiled to a final set of 116 unique crisis statements for use in all subsequent phases of the survey.

Sorting

In the sorting phase of the survey, participants were asked to sort all of the 116 unique crisis statements into groups based on thematic similarity. Participants were permitted to create as many or as few groups as they wished and to sort the responses based on any criteria they desired. The sorting phase was open for 8 weeks (August 19 to October 14, 2006), during which time a total of 70 responses were submitted. These responses were analyzed via multidimensional scaling (Kruskal and Wish 1978; Davison 1983) to produce two-dimensional plots of all 116 statements, based on their similarity to one another, as determined by respondents' groupings. The plotted statements were then parsed into statistically significant clusters via hierarchical cluster analysis (Anderberg 1973; Everitt 1980) to produce a series of "concept maps". There are many possible concept maps for any similarity plot, depending on the total number of clusters into which the responses are sorted. The objective is to select a single map that most accurately groups responses with similar themes. To achieve this, we followed a subjective review process described by Trochim (1989). A discussion group, consisting of the authors and several volunteers, reviewed a number of maps, beginning with those that had a high number of clusters (20) and moving down. For each successive map, two clusters from the previous map coalesced, and the group discussed the result. The final concept map was chosen by group consensus as the map with the fewest possible clusters that maintained thematic consistency within each cluster.

Rating

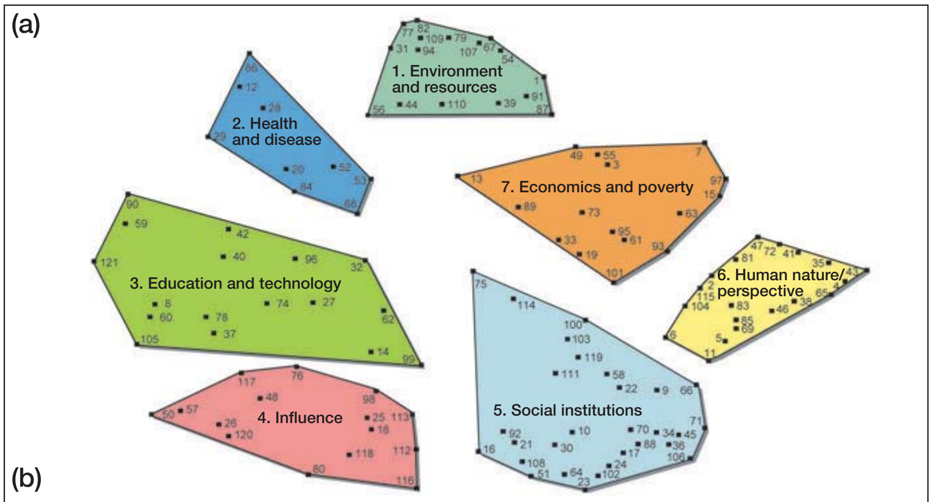
In the rating phase, participants were instructed to rate each of the 116 crisis statements from the brainstorming phase on two criteria: importance and feasibility. At this point in the survey, participants were asked to provide non-identifying demographic information on their gender, age, field of professional expertise (arts/humanities, natural/life sciences, physical sciences, social sciences, professional field), and academic position (adjunct professor, assistant professor, associate professor, full professor, post-doctoral associate, research associate, staff, or other). Ratings were based on a 1–5 Likert scale, ranging from "not at all important" and "not at all feasible" to "extremely important" and "extremely feasible". The rating phase was open for 2 weeks (June 29 to July 13, 2006), during which time a total of 122 responses were submitted. To assess overall agreement among demographic groups, pairwise correlation analyses were performed between each group, for both importance and feasibility ratings. To identify specific responses which were rated differently by different academic disciplines, Tukey-Kramer tests were performed for each statement, with importance or feasibility as the independent variable, and the academic discipline of the respondent as the dependent variable.

Results

Sorting

We received 350 statements completing the brainstorming focus prompt; these were compiled to 116 non-redundant crisis statements (complete list available in WebPanel 1). A total of 70 participants completed the sorting phase of the survey, and a seven-cluster concept map was selected as the one that minimized the number of clusters while maintaining thematic consistency within each cluster (Figure 1a). The stress value is a goodness-of-fit statistic in multidimensional scaling, with lower values indicating a better fit than higher values. Trochim (1993) reports average stress values in concept mapping of 0.285, with a permissible range from 0.155 to 0.352. The stress value of the seven-cluster multidimensional scaling solution presented here is 0.334, which is within the acceptable range. Because a comprehensive list of clustered statements was prohibitively large for inclusion here, several representative statements from each cluster were selected and thematic names were assigned to each of the clusters by a discussion group consisting of the authors and several volunteers (Figure 1b; the entire list of responses, sorted by cluster, is available in WebPanel 1).

(a)



(b)

Cluster 1: Environment and resources
- 44 The shortage of potable and clean water
- 79 The lack of sustainable energy sources
- 82 The loss of biodiversity and species extinction
- 109 Climate change and its effects on ecosystems
- 110 Overpopulation

Cluster 2: Health and disease
- 12 Emerging infectious diseases
- 28 Preventable illnesses in the Third World
- 52 The global HIV pandemic

Cluster 3: Education and technology
- 27 Anti-intellectualism and lack of respect for knowledge and rational thought
- 40 Inability of ethics to keep pace with technology
- 42 Excessive reliance on technology
- 62 The lack of adequate education, both nationally and globally
- 121 Science and technology are too complex for decision makers to understand adequately and translate into appropriate action

Cluster 4: Influence
- 25 The media fails to provide the public with balanced information
- 26 The rise of fundamentalist religion
- 80 The misuse of religion by politicians to manipulate the public
- 116 Too much corporate influence in government
- 120 Dominant religious beliefs are inherently non-rational

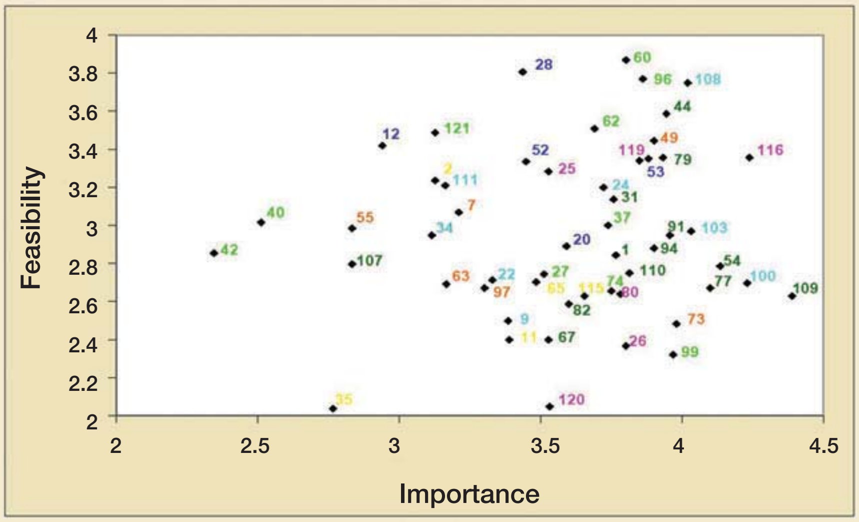
Cluster 5: Social institutions
- 9 The threat of war, violence, and terrorism
- 22 Property rights, nation states, and civil society appear inadequate to address our global crises
- 24 The use of force rather than diplomacy
- 34 The imperfect translation of the will of the public into political action
- 100 Lack of long-term perspective in political, environmental, and social actions
- 103 Lack of global responsibility on the part of corporations, governments, and individuals
- 111 Lack of incentives and venues for collective action to solve problems

Cluster 6: Human nature/perspective
- 2 People lack sense of community
- 11 Xenophobia and tribal loyalties in a global world
- 35 The natural human tendency toward selfishness, self-centeredness, and greed
- 65 The inability to take another's perspective
- 115 Failure to respect all human life equally

Cluster 7: Economics and poverty
- 49 Insufficient emphasis on sustainability in planning at all levels
- 55 Wealthy nations use a disproportionate share of resources to support trivial things
- 63 Mass migration caused by the poor standard of living among the world's poorest people
- 73 Global poverty and its effects
- 97 Market based economies lead to over-exploitation and unsustainability

Figure 1. *(a) Cluster map resulting from the multi-dimensional scaling and hierarchical cluster analysis (stress value of seven-cluster solution = 0.334). Numbered points correspond to the 116 unique crisis statements listed in WebPanel 1. Cluster names were assigned subjectively post-hoc by a committee of the authors and several volunteers. (b) Selected crisis statements from each cluster that were representative of that cluster's theme.*

The distance between clusters on the concept map (Figure 1a) is a metric of how frequently points within each of those clusters were grouped together by respondents during the sorting phase, and can be interpreted as a proxy for thematic similarity or relatedness. Responses pertaining to crises such as biodiversity loss, overpopulation, climate change, and water scarcity aggregated near the top of our concept map, in a cluster we named *Environment and resources*. These are issues that have traditionally fallen into the sphere of applied ecology. The nearest neighbors to the *Environment and resources* cluster are the *Economics and poverty* cluster, which contains issues such as rural–urban migration and globalization, and *Health and disease*, which includes problems such as preventable illness in developing nations and the HIV pandemic. Note that these two clusters include issues within Lubchenco's expanded definition of "environmental issues" (Lubchenco 1998). Our map provides options for expanding crisis definitions further, depending on the perspective of the user and the relatedness of the clusters.



The 10 most important statements	
109	Climate change and its effects on ecosystems (4.39, 2.63)
116	Corporations have too much influence in governing (4.24, 3.35)
100	Lack of long-term perspective in political, environmental, and social actions (4.23, 2.69)
54	Humans are unsustainably exploiting the environment (4.13, 2.79)
77	Maintaining the health of the planet (4.1, 2.67)
103	Lack of global responsibility on the part of corporations, governments, and individuals (4.03, 2.97)
73	Global poverty and its effects (3.98, 2.48)
99	Inequitable distribution of wealth among people (3.97, 2.32)
91	Unsuitable growth in energy use (3.96, 2.95)
44	Shortage of potable and clean water (3.94, 3.59)

The 10 most solvable statements	
108	Loss of civil liberties in the US under the guise of fighting terrorism (4.02, 3.75)
53	Death of children due to preventable causes (3.38, 3.35)
96	Inequitable access to healthcare (3.86, 3.77)
117	Women's reproductive health, education, control, and options are dictated by others (3.85, 3.34)
60	Lack of sufficient education in science, critical thinking, and environmental issues (3.8, 3.87)
28	The epidemic of preventable illnesses in the Third World (3.44, 3.81)
74	Children's activities are too structured and do not engage them in community (3.78, 2.64)
37	People and governments are paying less attention to basic science research (3.74, 3)
44	Shortage of potable and clean water (3.59, 3.94)
20	Growing obesity that impacts health by increasing the risk of chronic diseases (3.59, 2.89)

Figure 2. *Ratings for the top ten statements in terms of importance and solvability. Numbers in parentheses are the x,y coordinates (importance and feasibility of each numbered item). Clusters colored as in Figure 1: dark green* = Environment and resources *(Cluster 1), dark blue* = Health and disease *(Cluster 2), light green* = Education and technology *(Cluster 3), pink* = Influence *(Cluster 4), light blue* = Social institutions *(Cluster 5), yellow* = Human nature/perspective *(Cluster 6), and orange* = Economics and poverty *(Cluster 7).*

Occupying the lower half of the concept map, the *Influence and ideology* cluster contains problems that arise as a result of misuse of power by religious groups, corporations, and the media. This cluster's two nearest neighbors are *Education and technology*, which deals with inadequate education and the rapid pace of advancing technology, and *Social institutions*, which contains statements that deal with armed conflict, shortsightedness in political decision making, and lack of adequate incentive structures to solve global problems. The final cluster, *Human nature/perspective*, deals with problems such as selfishness, lack of empathy, lack of sense of community, and xenophobia.

Rating

One hundred and twenty-two participants completed the rating phase of the survey. The crisis statements with the ten highest importance ratings and ten highest feasibility ratings for all demographic groups combined are listed in (Figure 2). These top-rated statements, along with the representative statements from each of the seven concept map clusters, are also presented on a Cartesian plot of overall importance rating versus overall feasibility rating (Figure 2). This is a particularly illustrative way to view crisis statements in light of their composite rating.

Demographic consensus

All participants in the rating phase were categorized by gender, age, area of expertise, and professional title. The demographic and disciplinary composition of survey participants (Figure 3) was representative of the Cornell University faculty as a whole, as categorized in a 2007 faculty summary report (Whalen 2007). Pairwise correlation analyses of the importance and feasibility ratings of different demographic groups (eg correlation of male versus female statement-importance ratings) demonstrated high levels of overall agreement among all groups on ratings of statement importance (r ranged from 0.83 to 0.94, average of 0.91) and less agreement between demographic groups on ratings of feasibility (r ranged from 0.75 to 0.86, average of 0.79). The variance in feasibility increased as importance decreased, which may indicate that participants were uncertain how to rate the statements regarding feasibility that they disagreed with or considered unimportant.

Tukey-Kramer tests were performed on all importance and feasibility ratings to identify specific responses for which there was significant disagreement among academic disciplines. These results again demonstrated broad consensus across disciplines, with agreement among all disciplinary groups on 94% of both importance and feasibility ratings. The statements which were rated significantly differently among disciplinary groups and the direction of disagreement are given in Table 1.

Table 1. The seven importance and feasibility ratings that were significantly different among disciplinary groups

	Life	*Physical*	*Social*	*Professional*
Importance				
15 the inability of people to understand that effects of social, economic, and environmental systems may occur long after their causes	3.48	=	=	↑
31 water scarcity	3.8	↓	=	↑
35 the natural human tendency toward selfishness, self-centeredness, and greed	2.7	↑	↓	=
49 the lack of emphasis on sustainability in planning at all levels	3.8	=	=	↑
60 the lack of sufficient, widespread education in science, critical thinking, and environmental issues	3.8	↑	↓	↑
99 the inequitable distribution of wealth among people	3.78	=	↑	↑
110 overpopulation	4.09	=	↓	=
Feasibility				
15 the inability of people to understand that effects of social, economic, and environmental systems may occur long after their causes	3.45	↓	↓	=
25 that the media shapes the news into manageable, ideological soundbytes that do not provide the public with balanced information	3.7	↓	↓	=
74 that children's activities are too structured and do not engage them in community	4.19	↓	↓	=
102 the abuse of US power	3.14	↑	↓	↑
104 materialism and overemphasis on money	2.1	=	↑	↑
108 the loss of civil liberties in the US under the guise of fighting terrorism	4.32	↓	↓	=
113 the failure of the liberal elite to recognize the benefits of globalization on the underdeveloped nations of the world	3.6	↑	↓	↓

Notes: The crisis statement in contention is given in the first column, followed by the mean rating, among life scientists, on a 1-5 Likert scale. The following three columns indicate whether the response was rated significantly higher than (↑), lower than (↓), or equal to (=) the rating by physical scientists, social scientists, and professionals, respectively.

Discussion

If the scientific community is to enter into a new social contract, adjusting its agenda to address the most pressing global crises of our day, these crises must first be identified and prioritized. Here, we demonstrate how an empirical survey technique – concept mapping – can be used to quantify the opinions of experts regarding global crises. The concept map produced by our survey reveals seven statistically significant clusters into which the participants sorted global crises. The content and arrangement of these clusters provide an information-rich visual map of broad thematic categories that can be used as a framework to guide theoretical, analytical, and experimental efforts.

In addition to defining global crises and organizing them thematically, our survey also allowed participants to rate both the importance of each crisis and the feasibility of solving it. These two metrics are simple and easy to collect, yet they provide extremely useful information for determining where science and society should focus attention, funding, and action. Interestingly, there was a high level of agreement on both the importance and feasibility ratings of crises across all demographic groups. For the few ratings that were significantly different among groups, there were no apparent thematic patterns in the contentious crisis statements or the demographic groups in disagreement.

A plot of importance rating versus feasibility rating, divided into quartiles (Figure 2), offers an informative and intuitive view of the composite rating of crisis statements. It is evident, from the color-coded response numbers on the plot, that no single cluster dominated any one quadrant. All of the seven broad thematic categories contain both important/unimportant and solvable/insolvable issues.

Of particular practical interest are the quadrants on the right half of the graph. The upper right quadrant contains statements that were rated as both highly important and highly feasible to solve and, as such, are obvious candidates for immediate action. The shortage of clean water, inadequate education, and the HIV pandemic all appear in this quadrant. The lower right quadrant contains those statements that were rated as very important, but not highly feasible. This quadrant includes, perhaps not sur-

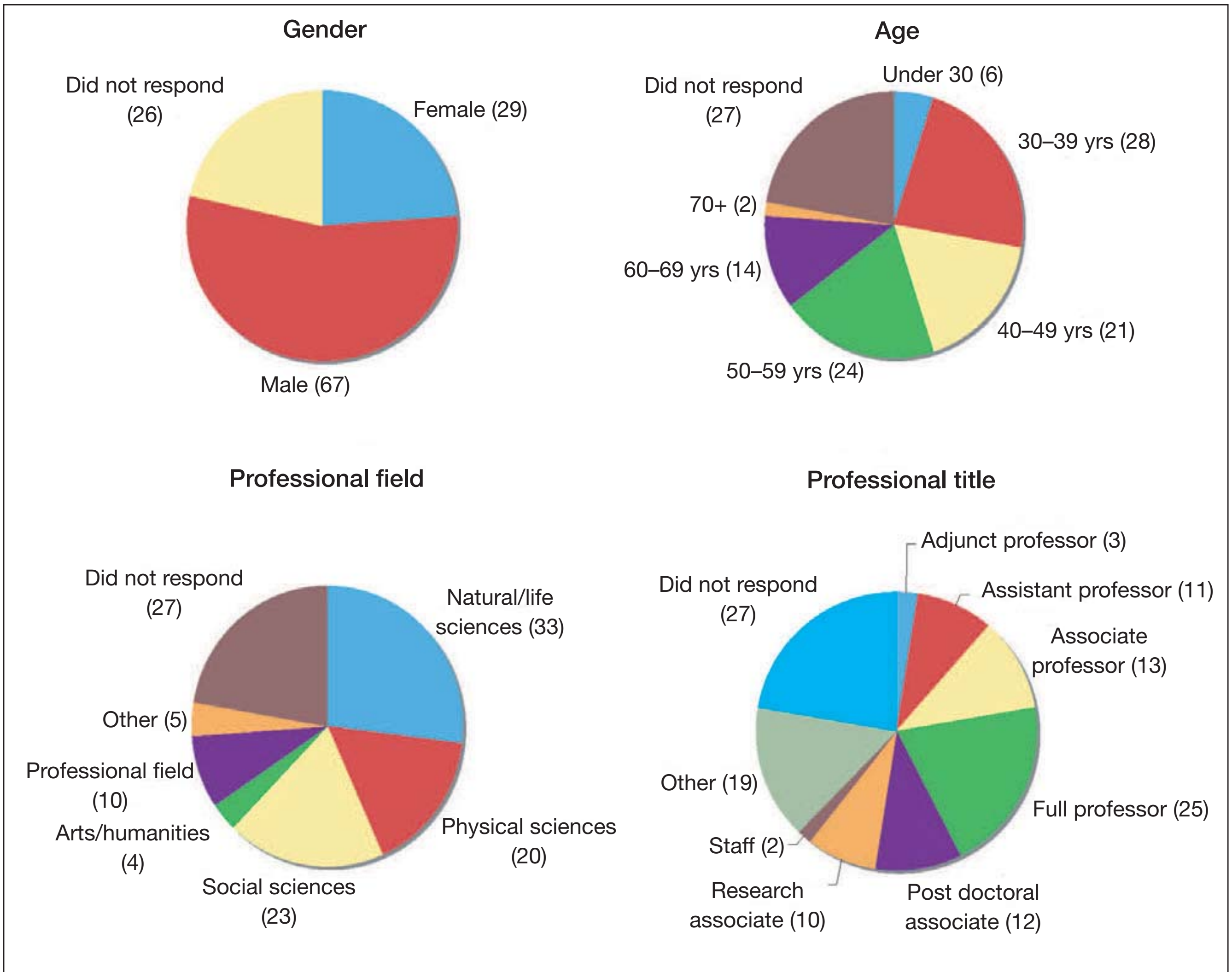


Figure 3. *Demographic and disciplinary classifications of the 122 respondents to the rating phase of the survey.*

prisingly, statements that deal with human nature and ideological conflict. However, it is interesting to note that politically hot topics such as climate change, dwindling energy reserves, sustainability, biodiversity loss, and overpopulation also occupy this important/infeasible quadrant.

The results presented here help define, organize, and prioritize the most pressing global crises of our day. As such, they should provide useful practical information for setting research and policy agendas and implementing the new social contract for science laid out by Lubchenco a decade ago. Of course, academic faculty represent only a fraction of those whose opinions will need to be considered on these important issues, and the conclusions presented here are far from definitive. Nonetheless, we feel that our results provide a starting point for focused dialogue and future inquiries, and that concept mapping offers a powerful and convenient tool to conduct such inquiries.

Concept mapping is a useful method whenever one wants to better understand what a group of people thinks collectively about an idea or topic. Particularly in this study, concept mapping reveals what a group of experts from many disciplines thinks about the various crises humanity faces. Furthermore, our findings highlight the crises which this group believes to be important and solvable. As a method, concept mapping often generates more questions than it answers, but it generates those questions in a structured way. These structures – the statements, clusters, and ratings – offer a rich visual map that can be used as a framework to guide deep theoretical, analytical, and experimental efforts. Where this study is concerned, the authors view the findings as a starting point in the process of considering the importance and solvability of the various crises we face, but also as a framework that can be used for scientific research, policy, and educational agendas. Finally, this study shows that problem solving is inherently interdisciplinary, and that understanding how a group of scientists thinks about these issues is a major step toward solving them. Potential avenues for future investigation include conducting more detailed concept-mapping surveys on one or more of the thematic clusters from this survey, or applying a survey similar to the one presented here to different demographic groups, such as politicians, business people, children, or the public at large.

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