



ALL THINGS TO ALL PEOPLE

An assessment of DCDC as a boundary organization

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## Introduction

In 2004 Arizona State University received funding from the National Science Foundation to create the Decision Center for a Desert City (DCDC). Funded through NSF's program on Decision Making Under Uncertainty, DCDC was designed to study water policy decision making under climatic uncertainty in a rapidly growing metropolitan urban ecosystem. DCDC's focal research areas include vulnerability, modelling and evaluation, education and outreach, climate change and urban heat islands, water demand and decision making, and science-policy interactions. In addition to traditional academic research, DCDC also attempts to act as a 'boundary organization' spanning the research and resource management communities. Originally conceived of by David Guston (1999), boundary organizations are institutions designed to exist at the science-policy interface, facilitating information flow across this boundary. This report is an assessment of DCDC's activities as a boundary organization. It examines its successes, the tensions and challenges it faces working in this capacity, and the broader social and organizational processes in which its work is embedded.

Understanding these issues is important for both practical and theoretical reasons. Practically, this assessment will allow the center to reflect on its activities, consider what has worked and where more work is needed, and to understand some of the challenges and tensions that accompany its boundary work. Theoretically, this study enhances understanding of boundary organization activities in an as yet unexplored context. Existing research has focused on boundary organizations in non-academic settings (e.g. technology transfer offices at the National Institute of Health and extension agencies), with scant attention paid to academically-based boundary organizations. Further, the academic environment in which DCDC works is far from traditional. Arizona State University is attempting to transform itself into The New American University, an institution which embraces its relations and commitments to the non-academic community, emphasizes interdisciplinarity, and focuses on use-inspired research. This study will allow greater understanding of how boundary organizations function under these conditions, and more broadly, some of the organizational and cultural issues accompanying ASU's transition.

### *Data and Methods*

This study is informed by both qualitative and quantitative data. Qualitative data come from in-depth interviews with researchers and policy makers and analyses of organizational documents and reviews. In most cases we travelled to meet interview subjects, interviewing them at their home institutions. A total of thirty-three interviews were conducted, including seventeen DCDC researchers and staff and sixteen members of the water policy and management communities. Interviews each lasted approximately 45-60 minutes. Interview questions were designed to capture respondent's perceptions and opinions about DCDC boundary work to date, their opinions about co-production of knowledge and boundary work generally, and suggestions as to how DCDC might

improve its ability to provide information to policy makers which is salient, credible and legitimate.

Quantitative data were collected through a web-based survey and the DCDC publication database. The web-based survey was administered to DCDC researchers and members of the water policy and management communities in January, 2008. A total of 176 surveys (109 to DCDC staff and researchers, 68 to the policy community) were administered. We received responses from 69% of DCDC members and 47% of decision makers. The survey was designed to measure interactions between and among DCDC researchers and decision makers, their opinions about factors relating to the knowledge transfer process, their views on the success with which DCDC has accomplished its boundary work, and the extent to which policy makers have received and used DCDC science. The DCDC publication database was used to create co-authorship networks and examine patterns of interdisciplinary collaboration. All data collection was approved by Arizona State University's institutional review board.

This report presents and briefly discusses our study results and is divided into five main sections. **Section I** examines interactions between decision makers and DCDC members, and patterns of communication and collaboration among DCDC researchers and staff. **Section II** details DCDC's impacts on the water policy community, and reports on DCDC and policy community members' attitudes and their satisfactions with DCDC boundary work. **Section III** describes the tensions and challenges related to DCDC boundary work in three areas: 1) saliency, 2) credibility, and 3) legitimacy. It also describes the perceptions that DCDC members and the policy community have of one another and catalogues tensions and discrepancies in the outcomes desired by these groups. **Section IV** makes suggestions as to how DCDC might improve its functioning as a boundary organization in light of data presented here.. We end with a coda considering the larger organizational and social environment in which DCDC functions.

## Section I. Interaction and Communication

Boundary organizations exist at the interface of the science and policy community, serving as a connective node and linking diverse sets of actors and organizations. This section examines the patterns of interaction and communication catalyzed by DCDC. We first consider interactions between DCDC members and the policy community. We then analyze patterns of communication and collaboration among DCDC members to determine the extent of interdisciplinary interaction within the center.

### *Science-Policy Interaction*

Figure 1 is a network diagram depicting patterns of communication between DCDC affiliates and the policy community. This network is based on survey respondents' answer to the following request: "*Please list the five DCDC members/members of the policy community you interact with the most.*" Data are based on responses from 32 policy makers and 74 DCDC members. The resulting network contains a total of 134 actors.<sup>1</sup> Forty-four percent (47) of respondents reported no interaction. They are not included in the graph. On average, policy makers claimed to interact with 2.1 DCDC members, while DCDC members reported slightly greater average numbers of contacts in the policy community (2.6).

The main features of the science-policy communication network can be described in terms of the overall network structure, as well as structural position of individual actors. We will discuss them in that order. The communication network is composed of one main group of interactions and nine smaller groups. These smaller groups are comprised of DCDC members who have reported contacts in the policy community not named by any other respondent. These DCDC members were not listed as a contact by the policy makers who took the survey and hence appear as unconnected clusters in Figure 1. Interestingly, while these DCDC members are disconnected to the main group of interactions, some are nonetheless well connected within DCDC communication networks ( See Figures 9 and 10). The unique contacts held by these DCDC members can make them important connections between DCDC and otherwise disconnected members of the policy community.

An important consideration in analyzing the structure of communication networks is the centrality of the actors. Some actors in the network are more central than others. Two important measures of centrality are degree centrality and betweenness centrality. ***Degree centrality*** is the total number actors to which a given actor is connected. ***Betweenness centrality*** measures the extent to which an actor indirectly connects other actors in the network, and indicates the potential of the actor to act as a channel for

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<sup>1</sup> The reason the network contains more people than the total number of survey respondents is that respondents often named as their contacts people who did not take the survey.

Table 1. List of actors with the highest degree and betweenness centralities in the science-policy communication network.

Degree		Betweenness	
	Position and/or Discipline		Position and/or Discipline
DCDC	<b>Senior Staff/Faculty - Geography</b>	DCDC	<b>Senior Staff/Faculty - Geography</b>
DCDC	<b>Staff/Liaison - Sustainability</b>	DCDC	<b>Staff/Liaison - Sustainability</b>
DCDC	Staff/Faculty - Sustainability	DCDC	Faculty - History
DCDC	Staff	Policy	<b>Development/Water</b>
Policy	<b>Development/Water</b>	Policy	Water
DCDC	Staff		
Policy	Water		
DCDC	Senior Staff/Faculty - Sustainability		
DCDC/DT	Grad student – School Earth and Space Expl		
Policy	Water		

Actors in bold indicate that the same actors appears in both lists (degree and betweenness).

information flow. The actors with the highest degree and betweenness centralities are listed in Table 1<sup>2</sup>. Of the ten actors with the highest degree centrality, the majority are DCDC members and the most central are DCDC PIs and staff. Of the three policy makers, two have close connections to ASU and have played key roles in DCDC. The same finding hold true for betweenness centrality, indicating the potential of these actors as information hubs.

Policy makers were also asked if any of their interactions with DCDC members had led to new information being used to either *support* or *change* existing policy or management practices. A total of eleven DCDC members were noted as having provided information used to support existing policy, and six were noted as having provided information used to change existing policy. These are listed in Table 2. Of the thirty-two members of the water policy community who completed the survey, 62.5% had sought information from DCDC. Respondents were also asked about the type of information they sought in each of these cases. These answers have been aggregated and are presented in Figure 2. They indicate that 76% of DCDC information sought by respondents was related to the areas of model visualization, climate change and water demand, and information related to water/climate briefings. Educational materials (4.8%) were less requested by respondents and a sizeable portion of information requests were on a variety of other topics (19%).

<sup>2</sup> For both centrality measures the topmost central actors were chosen by plotting the scores for all actors and choosing the cut-point at which centrality dropped off significantly.

Table 2. DCDC members who were cited, by policy members, as contacts with whom interaction led to new information being used to support or change existing policy/management practices.

Info used to <i>support</i> policy/management practices		Info used to <i>change</i> policy/management practices	
Position and Discipline	# citations	Position and Discipline	# citations
DCDC intern	1	DCDC intern	1
Faculty –Math & Computation	2	Grad student – School Earth and Space Exploration	1
Faculty - Geography	1	Senior DCDC Staff/Faculty - Geography	1
Staff - Sustainability	1	Staff/Liaison - Sustainability	2
Grad student – School Earth and Space Exploration	2	Faculty - Geography	1
Staff/Liaison - Sustainability	1	Faculty - Geography	1
Faculty - Geography	1		
Staff - DCDC	1		
Senior DCDC Staff/Faculty - Geography	1		
Faculty - Sustainability	1		
DCDC Staff/Faculty - Sustainability	1		

In summary, we can see that the network of communication between DCDC affiliates and policy makers is made up of one main group and nine individual subgroups representing unconnected DCDC members and their reported contacts. Although not connected in the science-policy network several of these individuals are nonetheless well connected in the internal communication networks of DCDC and can as such potentially provide important connections between DCDC and otherwise disconnected members of the policy community. Furthermore, a small set of highly connected actors emerge. These actors have the potential to play an important role as information hubs in the organization and between the organization and policy makers.

### *1.2 Interdisciplinary Interactions in Collaboration and Communication.*

One of the stated goals of DCDC is to integrate information and theory from across disciplines in bringing scientific information to bear on water policy issues. Integration of expertise across disciplines is also one of the mandates of the New American University, and an important aspect of the transformation which ASU is currently attempting. We conducted several different types of analyses to gauge the extent of interdisciplinary collaboration and communication among DCDC members. We assessed the degree of interdisciplinarity within DCDC in three ways: 1) examining the extent of co-authorship among members of different disciplines on DCDC publications, 2) examining information flows among DCDC members regarding scientific and policy issues, and 3)

interviewing DCDC researchers about their interactions with members from different disciplines and thematic areas. In this section we review these findings.

### *Co-authorship*

The stock in trade of scientific work is publications, and co-authorship the prototypical form of collaboration. As such, it offers an appropriate point at which to begin examining issues of interdisciplinarity. In order to examine interdisciplinary collaborations, we gathered information on all DCDC publications. Using these data, we produced co-authorship networks and examined information on authors' disciplinary affiliations.<sup>3</sup> Findings are presented in Figures 3-9. On average, DCDC publications are authored by members of 1.92 disciplines. This trend has changed in a slightly negative direction over time, from a high of 2.17 in 2005 to a low of 1.8 in 2008 (Figure 3). The discipline with by far the greatest representation in DCDC publications is geography. There were twenty unique authors from geography in the DCDC publication database, twice as many as the next category (Figure 4). Other disciplines with significant representation include School of Life Sciences (9), business and economics (7), and planning, policy and community development (5). All other disciplines have three or fewer unique authors who have published DCDC research<sup>4</sup>. Geographers also contribute to a greater percentage of DCDC publications than any other group, appearing as co-authors on more than 70% of DCDC publications (Figure 5). This is more than three times greater than sustainability, the discipline with the next most frequent representation on DCDC publications. Other disciplines with co-authors on more than ten percent of DCDC publications include School of Human Evolution and Social Change, School of Earth and Space Exploration, School of Life Sciences, School of Sustainability, and the Decision Center for a Desert City.

Social network analysis offers another way of examining disciplinary integration. We created a co-authorship network of all DCDC publications (Figure 6). In this graph disciplines are represented by colors, the size of the author's name indicates their centrality, and the thickness of lines the number of co-authored papers. As can be seen

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<sup>3</sup> Disciplines are notoriously difficult to define, and this is more so the case at ASU. In these analyses we operationalize disciplines using broad categories related to the departments and schools in which DCDC members are employed. DCDC members who reported communicating with others about scientific and policy matters came from 28 different departments and institutions (a fact which in itself is telling of the breadth of expertise represented in the center). To facilitate analysis, we collapsed departments and organizations with low membership into a single category, 'other,' and combined some related organizations into a single category (e.g. CSPO and the Morrison Institute as 'planning, policy, and community development'). The disciplinary categories used are as follows: School of Human Evolution and Social Change; School of Earth and Space Exploration; School of Life Sciences; School of Sustainability; Education; Planning, Policy, and Community Development; Business and Economics; Geography; History; Decision Theater; Decision Center for a Desert City; Math and Computing; City of Phoenix; Other. Disciplinary coding categories and are noted in the appendix.

<sup>4</sup> Excluding the category 'other,' as we do in the analyses below.

from the figure, the graph as a whole is weakly connected. There are many sub-graphs (circled in the figure) and the overall density is .091, indicating that less than 10% of all possible connections are present. Geographers dominate the network, having greater numbers than other disciplines and occupying more central positions (Figure 7). Of the twenty authors with betweenness centrality scores greater than zero, half are geographers. Of the remaining ten authors, two are spatial analysis specialists in the School of Earth and Space Exploration, with geographic expertise. The disciplines most disconnected to the main graph are history, business and economics, policy and community development, and education. The School of Human Evolution and Social Change is represented in the main sub-graph by only one author. Out of fifty-one publications, five are authored by members of four or more disciplines. Of these five, four incorporated some element of climatological research, including analyses of mesoscale meteorological modeling, urban heat islands, and neighborhood microclimates.

Interviews with DCDC researchers also confirm the above findings. Members reported that collaboration among members of different themes and disciplines happened at relatively low levels. Where interdisciplinary collaborations have occurred, they have been between members of broadly similar disciplines within one of the research themes (e.g. historians, sociologists and geographers working in the general realm of vulnerability), or between themes who require broadly similar sorts of expertise (e.g. vulnerability and decision science, both of which are grounded in social science methods and analyses). To date, there has been little interaction among social and physical sciences, with the major exception being the use of climatological data and models for the purposes of social analysis (e.g. the use of predictions from climate model to consider future vulnerability among groups of Arizona water uses). In all, interdisciplinary collaboration among DCDC members appears to be occurring at moderate levels, most often among members with similar research interests and expertise.

### *Patterns of Communication*

In contrast to collaboration, there is a high degree of communication among DCDC members from different disciplines. Of seventy-four survey respondents, fifty-eight (78%) reported communicating with at least one other DCDC member about scientific issues. The average number of contacts was 2.7, with .53 occurring with members of one's own discipline and 2.15 (80%) occurring outside one's discipline (Figure 8). These patterns can be explained in part by the fact that DCDC PIs and staff function as communication hubs in the network, and most respondents are not in the same disciplines as these actors. Thus most communication will occur between members of different disciplines, with the majority of this communication centering on a few key individuals. Still, there is a significant amount of interdisciplinary communication regarding scientific issues among DCDC members who are neither PIs nor staff. Consider Figure 9, depicting DCDC members' scientific communication network. While core DCDC members are by far the most connected, there is also substantial interdisciplinary communication between non-DCDC PIs and staff. Of the eighty-four actors in the network twenty-seven (31%) have betweenness centrality scores greater than zero, and of these nine disciplinary categories are represented. Geography and the School

of Sustainability have the greatest number of central actors (5), followed by the School of Life Sciences and the Decision Center for a Desert City (3). All other disciplines have two or fewer members with non-zero centrality measures<sup>5</sup>. Graduate students and postdoctoral researchers also make up a significant proportion of the most central actors in the network (.22%), with one occupying the third most central position.

With respect to policy issues, fewer DCDC members engaged in communication and did so with fewer people, but a greater proportion of their communication was with members of other disciplines (Figure 10). Of seventy-four respondents forty-six (62%) reported communicating with other DCDC members about policy issues. The average number of contacts was 1.92, with .3 occurring with members of one's own discipline and 1.6 (84%) occurring outside one's discipline (Figure 11). Again, while DCDC PIs and staff dominate the communication network, there is a significant amount of interdisciplinary communication not involving these individuals. Of the eighty-four actors in the policy communication network twenty-one (25%) have betweenness centrality scores greater than zero. Among these most central actors are representatives from ten disciplines. The discipline with the greatest representation is geography (6), followed by School of Sustainability (3), School of Human Evolution and Social Change (2), Planning, Policy and Community Development (2), and the Decision Center for a Desert City (2). All other disciplines (School of Life Sciences, Education, and History) have one member with non-zero centrality measures. Again, graduate students and postdoctoral researchers are present among the most central actors, constituting 15% of this group.

Overall, we can see that interdisciplinary collaboration among DCDC members appears to be moderate, occurring most often among members with similar research interests and expertise. Interdisciplinarity as measured through co-authorship reveals dominance by geographers, both in terms of number of authors who contribute to publications and also in terms of the percentage contribution to the overall number of DCDC related publications. Dominance of geography is also verified by social network analysis showing a co-authorship network which is weakly connected. History, business and economics, policy and community development, and education appear as the most disconnected disciplines in terms of publication collaboration. There is also little collaboration among the natural and social sciences. Communication among DCDC members about scientific issues appears to be occurring at relatively high levels and at higher levels of interdisciplinarity in general as well as between members of different disciplines. Communication among members about policy related issues happens slightly less, though occurs between members of different disciplines more often. While DCDC staff and PIs to dominate central positions in the communication network, graduate students and postdocs also play an important role in DCDC's internal communication networks.

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<sup>5</sup> In order of representation, Geography (5), School of Sustainability(5), School of Life Sciences (3), Decision Center for a Desert City (3), School of Human Evolution and Social Change (2), School of Earth and Space Exploration (2), Planning, Policy and Community Development (2), Education (1), and Business (1).

## Section II. Assessing Successes of Boundary Management

Boundary organizations exist to facilitate interaction between the scientific and policy communities, allowing for informed decision making. For an academically based boundary organization such as DCDC, a major indicator of success is the extent to which information produced by the organization impacts decision makers and decision making processes. As stated in one of the project summaries published by DCDC, it “seeks to build a new model of science and policy engagement that allows decision makers and scientists to collaborate on important research questions and experiment with new methods.” When speaking of the production of science which is simultaneously relevant for practitioners, the idea of Pasteur’s Quadrant is often invoked. Coined by Donald Stokes in his seminal work of 1997, Pasteur’s quadrant refers to work that retains high scientific integrity and rigor but which at the same time is relevant and useful in its application outside of academia. To gauge the degree to which DCDC has been successful in operating within Pasteur’s quadrant, we examine the process of spanning the science-policy boundary. We use interview and survey data to examine how and to what extent DCDC research and activities have impacted decision making in the Phoenix water policy community. We also consider policy makers’ satisfaction with accessing DCDC information, and the opinions of policy makers and DCDC researchers regarding factors influencing the use of DCDC research.

### *2.1 Qualitative Assessment of Impacts*

There is a broad consensus among DCDC academic affiliates that their research is likely to have had little impact on water policy and decision making to date. The extent to which impact has occurred is also largely unknown within DCDC. One reason for this is that few specific goals have been formulated in collaboration with the policy community, and without such goals an assessment of impact and success is more difficult. Nonetheless our data indicate that DCDC has enjoyed some successes in the following four main areas: 1) climate research, 2) modelling and visualization, 3) network facilitation, 4) educational outreach. Each is addressed in turn.

**Climate research:** The clearest cases of DCDC research being used by a water management organization are in the area of climate research. These include the development of the hydrological model for the Salt and Verde watershed and the creation of a new drought index. In the former case the Salt River Project used the information to consider future run-off given various climate change scenarios. In the latter, the Bureau of Reclamation has helped fund the drought index and considers it to be potentially useful for future decision making.

**Modeling and visualization:** WaterSim is perhaps DCDC’s best known product, and the flagship boundary object for the organization. While members of the water policy

community noted caveats with regards to accepting model findings at face value, some reported that it has been useful for visualizing some aspects of water dynamics for higher level decision makers. The use of the Decision Theater (DT) for visualizing data was noted as particular success. The DT has been used as a tool, and a vehicle to display WaterSim and to let decision makers and water managers interact with the model. As such it has been an important contributing factor to the success thus far enjoyed by WaterSim. The visualization capacity of DT has also provided what one respondent described as a space for de-personalizing the science by putting focus on the model and the output as opposed to the person presenting it. Policy makers perceive the theater as a neutral space of great value where they can bring their own models and explore these together with other stakeholders (see quote below). A successful example of this is the interaction between DT and the East Valley Water Forum. This neutrality emerged as an important factor behind the positive response to the Decision Theater in our study. Current efforts to customize and downscale WaterSim is likely to improve its relevance and likely increase its usage by decision makers.

*What is it about DT, the Decision Theater that helps you, or is useful for people like yourself?*

*[respondent] They are able to take the complex information and visualize it. They make no value judgments on the information. They are there to help us facilitate decisions and to visualize that, that information.*

**Network facilitation:** The most frequent way in which respondents claimed DCDC has impacted the water policy community is by facilitating interactions among this group and DCDC affiliated academics. Policy makers regularly reported that DCDC meetings, and water briefings in particular, were important for making ties to other members of the water community and for reestablishing and solidifying existing relations. Survey data corroborate this finding, with 61.5% of water policy members reporting that their interactions with DCDC have increased the size of their network of contacts related to issues of water management. Of the 61.5% of respondents who reported an increase in social networks, all referred to water and climate briefings as the source of this increase.

Interview data also indicate a general feeling that DCDC has added a new and valued node to the network of water related actors in the Phoenix metropolitan area, in part because it represents a new academic perspective in the water policy community.

*... I think it is valuable to have water policy experts, water experts here in Phoenix rather than...historically they were all in Tucson and I think that was a disservice to us here in Phoenix because the communication difficulties were broader and larger and more difficult to get around just because of the distance. and also they are just very different communities. I think that there are very different perspectives about water management and I think at a broad level it's been helpful for us to have people who are a part of our community, living here day-to-day, understanding our water issues rather than having to rely on people a 100 miles away. So I think that's been good*

*... I think they [DCDC] definitely have [added something to the benefit of the water policy community]. They've added a lot of good scientific information, research information. I think they've, it's good that there's another voice coming from the university community other than the University of Arizona*

**Educational outreach:** The final and least direct manner in which DCDC affects water policy and management is by providing information about water usage to the public. This occurs both through DCDC educational efforts at the K-12 levels as well as by drawing media attention to water issues. The advanced water workshops, conducted in conjunction with Project WET in Arizona, is another initiative aimed at stimulating educators to develop modules for their respective audiences. Geography teachers at high school and community college levels are also engaged with DCDC researchers in developing ways of incorporating and translating WaterSim and the SWIP (South West Water Information Project) into useful teaching tools.

## *2.2 Quantitative Assessment of Impact, Satisfaction and Opinions Regarding Knowledge Transfer*

To compliment our qualitative data on the impacts of DCDC research on the policy community, we included a well-established five-item scale of knowledge use in our survey of policy members. This scale measures the extent to which policy makers understand and use DCDC information. The results are presented in Figure 12. Aggregating the response categories of 'sometimes,' 'usually,' and 'always' leads to the following conclusions: Of those policy makers surveyed, 84% received information from DCDC that was pertinent to their work, and 92% reported understanding the information they receive. About half of respondents (60%) participate in discussions of DCDC research, and 24% cite DCDC research in professional reports. Sizable proportions of policy makers also report making efforts to favor the use of DCDC research results (28%), and that DCDC research influences decisions made by their administrative unit (40%). In order to attain a quantitative understanding of factors affecting use of DCDC research we combined these items into a single scale and examined its correlation with other metrics. We found that the best predictors of research use were the number of DCDC members with whom policy makers interacted (.44, sig=.05) and policy makers' degree of betweenness centrality in DCDC member-policy maker interaction networks (.360, sig=.05). In all, substantial proportions of policy makers reported using DCDC information in one of the above manners, with greater use occurring among better connected policy makers

Overall, policy community members who sought information were highly satisfied with their information requests from DCDC (see figure 13 and 14). This includes both the speed with which information was supplied (85.7% reported satisfaction, with 47.6% highly satisfied) and the relevance of information supplied (90% reported satisfaction, with 30% highly satisfied). It is clear that those who sought information from the center were highly satisfied with their experience. These numbers contrast somewhat with DCDC member's satisfaction with the degree to which the

organization has influenced water policy decisions (Figure 15). Among DCDC members 34% reported some level of satisfaction in this category (29.7% somewhat satisfied, 4.1% very satisfied). The majority of respondents indicated neither satisfaction nor dissatisfaction (47.3%), and 17% reported dissatisfaction (13.5% somewhat dissatisfied, with 4.1% very dissatisfied)..

DCDC members and policy makers differed to some degree in their opinions regarding factors influencing the use of DCDC information and. With regards to influences on knowledge use, members of the policy community considered the scientific merit of research and a strong experimental research design to be somewhat more important determinants of information use than strong interpersonal contacts between DCDC members and policy makers and a clear research dissemination strategy (Figures 16-19). The opposite is the case for DCDC affiliates, who place greater value on interpersonal contacts and dissemination strategies than on scientific merit and experimental design . The greatest disparities exist in the areas of strong experimental design and interpersonal contacts. With regards to experimental design, 45.5% of policy members considered this factor to be a very important influence on the use of DCDC research, as compared to 18.9% of DCDC members. Alternately, 62% of DCDC members considered strong inter-personal contacts between DCDC members and policy makers to be very important influences on the use of DCDC information, as opposed to only 33.3% of policy makers.

This section examined the process of spanning the science-policy boundary and assessed to what extent DCDC research and activities have impacted decision making in the Phoenix water policy community. Overall, there is limited knowledge within DCDC about the impact of DCDC work on policy to date. Nonetheless we find that the organization has enjoyed success in the following four main areas: 1) climate research, 2) modelling and visualization, 3) network facilitation, 4) educational outreach. Of the information sought by policy makers from DCDC, 76% related to the areas of model visualization, climate change and water demand, and information related to water/climate briefings. Educational materials were less requested by respondents. In terms of use and uptake of DCDC related research, we found the best predictors of use to be the number of DCDC members with whom policy makers interacted and policy makers' degree of betweenness centrality in DCDC member-policy maker interaction networks. Overall, policy community members who sought information were highly satisfied with their information requests from DCDC, including both the speed with which information was supplied and the relevance of this information. In contrast, DCDC affiliates were less satisfied with the impact of DCDC work on policy. DCDC members and policy makers differed somewhat in their opinions regarding which factors influence the use of DCDC information. Policy makers considered scientific merit of research and a strong experimental research design to be more important determinants of information use than strong interpersonal contacts between DCDC members and policy makers and a clear research dissemination strategy. In contrast, DCDC affiliates placed greater value on interpersonal contacts and dissemination strategies than on scientific merit and experimental design.

## Section III. Tensions and Challenges

This section discusses the tensions and challenges experienced by DCDC members and the policy community in conducting boundary work. We begin by examining policy makers' opinions regarding the salience, legitimacy and credibility of WaterSim. We then examine how DCDC members and members of the policy community perceive each other's roles and the divide between the research and policy arenas. We close with a description of the diverging research outcomes desired by the various communities in which DCDC is embedded and tensions caused in the organization by these competing demands.

### *3.1 Salience, Legitimacy, and Credibility*

In their paper on knowledge transfer processes Cash et al (2003) identify three primary determinants of knowledge use by policy makers. These are the salience, legitimacy, and credibility of available information. ***Salience*** refers to the relevance of information to decision makers. ***Legitimacy*** refers to the extent to which researchers have been respectful of stakeholders' divergent values and beliefs, unbiased in their research, and fair in their treatment of opposing views and interests. ***Credibility*** refers to the scientific adequacy of the technical evidence and arguments. These issues were particularly prominent in discussions related to WaterSim, hence this is where we direct our focus.

#### *Salience*

The main points of concern raised by decision makers with regards to the salience of WaterSim were related to the scale at which the model operates. Many policy makers contended that there were mismatches between the spatial and temporal scales at which WaterSim works and the scales which are of importance for making policy decisions. With regards to time scales, most water management decisions at the city level are dealt with on hourly, daily or weekly timeframes. In contrast, WaterSim typically operates at 1-5 year timeframes. The version of WaterSim presented to decision makers interviewed in this study also operates at a regional scale which is not compatible with the smaller spatial scales at which water management decisions are made. However, most policy members interviewed considered the building of WaterSim a laudable effort and recognized the extreme complexity and costs of modeling water flow in Arizona. In all, many felt that WaterSim in its current regional format did not add much new knowledge or contribute to the improved operations of the water management community (compare this with achievements of WaterSim above). However, policy members indicated that the regional focus and longer times scales incorporated in WaterSim make it a useful tool for scenario building, allowing decision makers to explore possibilities and broadly understand the implications of potential water management decisions.

Another important issue related to salience is the fundamentally dynamic nature of the institutional landscape in which water allocation and decisions are taking place. This is exemplified by the following quotes from members of the policy community:

*I mean because...we've never experienced all of the sucking and the withdrawal at the same time. What's going to happen to the aquifer? We've never modeled it, we've never done it, nobody knows what's going to happen. We're all fairly convinced that the law will be totally worthless when that occurs. So we need to begin addressing that and regional coordination is doing that...*

Interviewees felt that the ability of WaterSim to be salient to their needs was hindered by scale mismatches and the fact that it cannot take immediate account of changing conditions. Instead, respondents noted that the broad scale resolution of WaterSim may be of greater utility for higher level decision makers such as local politicians and city council members who are more likely to make regional water management decisions. However, the members of the policy community who have been primarily targeted for dialogue around WaterSim have been water managers, with highly technical skills and often limited power to step outside their main objective of securing water for their respective citizens. Thus there appears to be a mismatch with regard to the actors targeted to engage in the construction and co-production process of WaterSim and the audience most likely to benefit from interaction with the model.

### *Legitimacy*

Interviews with decision makers regarding WaterSim uncovered only one major issue related to legitimacy: a failure to include the concerns and long-term expertise of decision makers in designing and implementing the model. Research has argued that including decision makers from the inception of the research process is critical for producing salient research products. As two respondents noted,

*Well, nobody was involved. No one was ever asked would a tool like this be useful to you until after it was developed. No one was brought in during the development stage in saying, is this showing the kind of data you want to show? And when they were finally brought in, it was a controlled experiment where they really couldn't interact with it. I wouldn't call that engagement.*

*I think the WaterSim model, before they released it, they should have had a smaller little group as like a steering committee or something to go through some of the assumptions associated with the model to validate some of the results. I think that's where they failed. It's probably a good model, but a model is only as good as the input that you're putting in.*

Thus, by not including stakeholders in the production process legitimacy was not achieved. This in turn renders the model less salient and less credible than might have

been the case had decision makers worked with researchers from the inception of WaterSim.

### *Credibility*

Decision makers noted three credibility issues related to WaterSim. These are the underlying assumptions on which the model is based, the validity of the underlying data, and the decision to design WaterSim from scratch as opposed to modifying an established model currently in use by the policy community. First, many respondents felt that the model was too simplistic and that its assumptions violated the realities of water policy in the Phoenix metro area. More specifically, the model ignores legal restrictions on water movement between cities as well as allocation of water resources based on precedents of prior allocation. Also, WaterSim does not include groundwater and fails to take account of certain water supplies, such as Tonto Creek. As indicated above, members of the water policy community are aware of the difficulty in modelling the complex water system in Phoenix. Therefore, the main critique is not directed at the over-simplicity per se, but rather at the conclusions drawn from it. It was felt that conclusions and consequent publications, which do not explicitly discuss the omissions and limitations of the model, should be made with extreme caution. Doubts were raised as to whether this would in fact occur, and concern about the legitimization of ‘faulty conclusions’ if published under ASU flag were also voiced.

*[WaterSim] models at a very simplistic level. But when you take those concepts and then you say, ‘Okay, based on these concepts, we’re drawing these conclusions. We’re writing the paper as ASU,’ you know, that gives credibility to it. Now, I have got to go back and say, ‘Well, you know that’s not quite true and here’s why it’s not quite true. Yes, on a simplistic basis, that’s correct. But, you know when you factor in the legal structure and then you overlay it with the technical stuff it doesn’t quite work.*

Second, questions were raised as to why a new model was designed as opposed to using one of the established models already trusted and in use by the water policy community. As a result, decision makers are forced to trust WaterSim because of the time and effort it would take to explore its assumptions and data in depth. This is captured succinctly by two respondents,

*So there’s a model of the Colorado River, it’s what the Bureau of Reclamation built, it’s what all the state’s used. That’s not how DCDC chose to model the Colorado River. They looked at all their stuff and wrote their own model. So it’s like, ‘Your model may be better. It may be exactly near what they did. But when they sit in the room, eventually the question they’re going to ask you is, “Oh did you use the Colorado River Model?” “No, we wrote our own.” Oh. So now we’re going to have to either trust you or spend hours going through every assumption*

*you made. Or whenever something counter-intuitive comes out, they're maybe going to assume that either you made the wrong assumption or you got some wrong data. And I think there is this, here's a place where there's a gulf.*

*And I found that so many of the municipalities have developed their own modeling systems that take into account all of these things. And they tend to focus really specifically on the engineering aspect of it. The supply-side of it, and much less on what WaterSim is trying to do --incorporate these other contextual factors that we think are important. I think they are important on a different time and space scale than what the water managers think are necessarily important day-to-day.*

### *3.2 Cultural Perceptions across the Divide*

The briefings put on by DCDC have increased both the volume and speed of communication between the scientific and policy realms. It has thus taken an important step in the direction of bridging the two spheres by creating social interaction which is deemed beneficial, and also essential, for this purpose. However, there are also cultural differences in the perceptions each group has of the other, its practices and agendas. These barriers are not so easily overcome. For instance, during interviews it became increasingly evident that each group had well-developed stereotypes of the other. From the academic standpoint, policy makers were generally viewed as bureaucrats with a narrow focus on very specific issues and little interest in issues of water management at broader scales. From the perspective of policy makers, academics are viewed as operating in an 'ivory tower' mindset that does not recognize the complexities of water management decisions. Both groups tend to think that their knowledge and information is more important and relevant than those of the other. One academic mentioned 'allowing' policy makers 'to feel like they are educating us [academics],' implying that academics have a stronger handle on these issues. The same held true for policy makers, who contended that they often had to educate academics about the realities of water policy decision making. As one explained,

*...I think an awful lot of it has been a one-way street and this is not their fault but the complexity of the real world compared to academic's perspective of what the real world is all about is really on orders of magnitude different. And so there's these perceptions that academics who have been taught in a theoretical environment have about how they solve problems that are how complex the decision-making process is and when they actually start engaging it's really a one-way street. The water managers have to teach the academics what the story is. Now it may be that there's a lot to learn and over time, you know, there's an evening out so there really is a two-way street, but that was my perception as a water manager*

Further, there are also differences in perceptions with regards to how information should be used. Members of the policy community interviewed for this study often return to the issue that academics do not seem to understand the reality under which they operate. Academics expect that the information they provide to policy makers should be put to immediate use, not appreciating the slow pace at which such changes occur. This mirrors policy makers' opinions that it takes academics too long to come up with policy-relevant information. As noted by one policy member,

*I believe that most academic [members] ... are frustrated with the degree or the lack thereof is a better way to describe it, how slowly things change in the policy front and they expect things to change much more quickly... I think they get frustrated by the lack of speed at which change comes about and we get frustrated with them with the length of time it takes them to come up with the scientific information to help push the changes forward, and I don't know how you bridge the gap.*

Finally, policy makers also worry that because academics seek novel findings for publication purposes they were more likely to sensationalize findings in the media and other venues at the expense of the policy community. As one respondent contended,

*And I think your average academic - gross generalizations are gross generalizations - but your average academic looks for that opportunity. 'Oh I found the smoking gun! I found the proof that they don't know what they're talking about!' And the water community is rife with that because I think there's a perception, which is probably there's a lot of validity to it, that you know, the water community is just trying to not tell the truth about things.*

And another,

*Academics are looking for counterintuitive things so they can say, 'Look, the emperor wears no clothes. We're running out of water and you got to get your heads out of the sand and admit it. What's your problem?' And so they're looking for these kinds of results. For the practitioner community, that's their fear of exactly what the university's going to do. But first, if they see a counter-intuitive result, the first thing they're going to think is 'There's a mistake.' And there may not be, but that's what they're going to think first. And it's going to take a long time to eventually—which they may or may not be willing to take—to think through it to say, 'Okay, you did do it right. Well, maybe you got a point here.*

These actions erode trust between the groups and to some extent jeopardize their partnership. Policy members do not view these as malicious activities, but attempts to speed up the process of policy change. However, as a result of these actions academics lose legitimacy and credibility in the eyes of the policy community.

This section reviewed the issues related to the salience, legitimacy and credibility of DCDC activities, with focus on WaterSim. The main points of concern with regards to the salience of WaterSim were related to mismatches between the spatial and temporal scales at which the model operates, and the effects of this on its relevance for decision making. A mismatch was also identified with regards to the actors targeted to engage in the construction and co-production process of WaterSim and the audience most likely to benefit from interaction with the model. Only one major legitimacy issue was identified: the perceived failure to include the concerns and long-term expertise of decision makers in designing and implementing the model. In terms of credibility three issues were voiced in relation to WaterSim. These were 1) the underlying assumptions on which the model is based, 2) the validity of the underlying data, and 3) the decision to design WaterSim from scratch as opposed to modifying an established model currently in use by the policy community. Furthermore, differences in perceptions with regards to how information should be used were seen between DCDC affiliates and policy members. While academics expressed desire that information they provide to policy makers be put to use more rapidly, policy makers felt academics do not appreciate the slow pace at which policy changes occur. In contrast policy makers felt it often takes academics too long to deliver policy-relevant information. Policy makers also worry that because academics seek novel findings for publication purposes they were more likely to sensationalize findings in the media and other venues at the expense of the policy community. This could erode trust between the groups and to some extent jeopardize their partnership.

### *3.3 Tensions in Desired Outcomes, Diverging Rewards Systems and Skewed Accountabilities*

As originally envisioned by Guston (1999), boundary organizations are viewed through the lens of principal-agent theory. In this framework politicians and managers are ‘principals’ seeking goods in the form of information from ‘agents’ in the research community. Researchers are likewise viewed as principals, seeking incentives from agents in the political and management communities. The boundary organization sits between these two sets of principals, acting as agents to each and thus stabilizing the boundary between science and politics. They facilitate information flows across professional and cultural boundaries, providing policy makers with relevant scientific information and researchers with incentives for engaging in management based research. As Guston (2001) notes, “A successful boundary organization will thus succeed in pleasing two sets of principals and remain stable to the external forces astride the internal stability at the actual boundary.” However, we have found that within DCDC providing desired outcomes to both sets of principals and stabilizing external forces involves significant challenges not typically addressed in literature on boundary organizations. This is the case for two reasons. First, the principals whom DCDC serves desire very different sets of outcomes which are sometimes incompatible. Second, these incompatibilities are exacerbated by differences between the stated goals of boundary organizations and the New American

University, and the traditional demands of the scientific rewards system. These challenges result in large part from DCDC’s position as a university-based boundary organization. Existing research has focused on boundary organizations in non-academic settings (e.g. technology transfer offices at the National Institute of Health and extension agencies). Examining tensions in the desired outcomes of DCDC principals and between these demands and the scientific rewards system provides important insight into this new breed of boundary organization. This section details these tensions in relation to the functioning of DCDC.

Table 3. Tensions in Desired Outcomes and Orientations

	<b>New American University</b>	<b>Scientific Community</b>	<b>Policy Makers</b>	<b>National Science Foundation</b>
<b>Disciplinary Integration</b>	Interdisciplinarity	Discipline Specific	No Preference	Interdisciplinarity
<b>Temporal</b>	Both Long Term and Real Time	Long Term Projects, Papers, Collaborations	Real Time Knowledge Production	Both Long Term and Real Time (?)
<b>Basic vs. Applied Knowledge</b>	Basic and Applied	Basic	Applied	Basic and Applied (?)
<b>Professional Orientation</b>	Autonomy and Consultancy	Autonomy	Consultancy	Autonomy and Consultancy (?)

Note that the (?) indicates that although NSF promotes interdisciplinarity and both basic and applied science, their reviews of DCDC have suggested a stronger focus on basic science.

DCDC exists at the nexus of a complicated set of relations and commitments involving funding agencies, policy makers, DCDC researchers, and the upper-level mandates of the New American University. Thus, where traditional boundary organizations typically serve as principals to only two agents (researchers and policy makers), DCDC serves four. As stated by a DCDC affiliate,

*Well, DCDC has many roles. Essentially, one overriding commitment is to NSF and what they expect us to produce, which is science, so that results in simply peer-reviewed journal articles is what they want. And that’s what we spend most of our resources doing. Actually finding researchers from various departments to do DCDC related research. We did that with some of our funding, we do that with funding graduate students, undergraduates, etc. The university has another view of what DCDC should be. Yeah, the university and maybe the administration for GIOS has somewhat other objectives for DCDC and that is I suppose as a bridge between university and the community. And they stress that more than NSF does.*

As a result of this complex set of interaction the desired outcomes of these principals are often in conflict with one another, forcing DCDC to shift attention, efforts,

and allocation of scarce resources according to the agent in question. We have identified four of these areas of tension in desired outcomes in Table 3. This first of these areas is the degree to which DCDC research achieves interdisciplinarity. In requesting proposals for its Decision Making Under Uncertainty program the National Science Foundation explicitly requested an interdisciplinary approach (2003). Similarly, ASU's future vision as the New American University also focuses on the need to overcome traditional disciplinary approaches and embrace interdisciplinary research practices (2004). However, the desire for interdisciplinarity is in tension with the desires and rewards system of the scientific community as represented by researchers' home disciplines and departments. Among these communities the primary form of intellectual capital continues to be related to advancing the state of knowledge within a specific discipline. As one respondent told us,

*To what extent is there interaction among researchers within the different themes?*

*There is some, I would say. I think there could be more. But again, it goes back the scientific awards system. Unless there's a paper being published, it doesn't necessarily facilitate that. You know, so I think part of the challenge is just the scientific awards system which is just above and beyond what DCDC can control.*

The second area of tension is related to speed at which research is conducted and relevant information produced. In order to be of use to water managers and policy makers DCDC must be able to produce relevant information at the same time scale at which water management decisions are made. Policy makers thus require DCDC to supply real time information specific to their rapidly changing needs. Alternately, the desired research outcomes for the scientific community typically take longer periods of time to realize success. This involves the creation and maintenance of long-term projects, papers and collaborations. ASU desires DCDC to work at both time scales, providing policy makers with real time information and also building long-term projects capable of generating traditional academic publications and outcomes. While the National Science Foundation emphasizes the need for the production of both long-term and real time information, it has put greater emphasis on the production of traditional scientific products in its reviews of DCDC.

*So I think it really, it creates extra tension that doesn't necessarily exist with other kinds of more traditional research projects. I know more about it from that end. And then from the policy-end, it seems to me... I get the impression—which I could be totally wrong—that there's an expectation that things should happen, we should be doing things faster or doing things that is a little bit more practical. I don't necessarily think that they view what we're doing as being necessarily solving the problems that they feel are immediately there. So I think it's kind of a tension--that it's like we're almost not doing enough for either sets of demands.*

A third area of tension is in principals' emphasis on the production of basic versus applied research. Policy makers desire applied research and information that speaks to their immediate needs as resource managers. The scientific community desires the opposite,

valuing basic contributions to home disciplines with little or no consideration of the utility of findings. ASU's twin goals of academic excellence and community embeddedness lead it to value both basic and applied research. The National Science Foundation also desires both basic and applied research, but in DCDC reviews and during interactions with DCDC members has expressed a preference for basic over applied work. As a policy member told us,

*Well I mean I think that your pressure is to publish and so I think you're just inherently going to come up with different products and have a different perspective than what we're going to have day-to-day on the ground, which is, you know, a far more, [sigh] I mean, the classic gap I would say between academics and the real world policy really has to do with...you know, academics have to look at things theoretically especially to get published and it has to look very mathematically complicated or else you're not going to get it anywhere and that's well and good and hopefully you're pushing the envelope on those types of things but day-to-day, you know, we got politics and so you can have the best theoretical model [laughs] that shows the best allocation of water or the best amount of water conservation or whatever your model shows you. You know, it's applicability to the real world is always going to be inherently limited.*

*I've had to, for instance, try to become some level of expert in water policy and water management and learn the world that these people are dealing with at the same time, you know, continuing to try to produce, you know, articles for NSF because that's their consideration and um, and make this information or make this knowledge that we're producing somehow useful.*

A final area of tension relates to researchers' professional orientations. The traditional academic model is one of high autonomy, with scientists choosing topics according to their skill sets and personal interests. A very different orientation is required of researchers in boundary organizations. In order to produce information of relevance for decision making, researchers must structure their work around current issues of interest to the policy community. These issues may or may not coincide with issues likely to be of interest to the broader scientific community. This leads to a tension among DCDC principals. The scientific community expects full autonomy and for research to extend existing research domains, while meeting the demands of policy makers necessarily involves some level of consultancy. As the New American University, ASU expects faculty to fill both roles, striving to hit the 'sweet spot' between the two. This is also the stated goal of the National Science Foundation's DMUU protocol, but DCDC reviews by the agency seem to favor traditional academic practice over consultancy.

### *Diverging Rewards Systems and Skewed Accountabilities*

The principal-agent theory of boundary organizations makes two important assumptions about relations between boundary organizations and their principals. These are: 1) that researchers receive incentives for their non-academic research, and 2) that as

agent to both principals the boundary organization is accountable to both. Neither of these assumptions is met in the case of DCDC, causing serious tensions within the organization and in some cases limiting its ability to produce both basic and applied knowledge. With regards to the first assumption, DCDC receives no concrete incentives for producing applied knowledge. While ASU has the stated goal of being relevant to the community, they provide no real incentive to organizations and researchers who work to do so. The same is the case with the National Science Foundation, who has made clear that continued funding is dependent on the production of contributions to basic science rather than applied research. This asymmetry of resource dependency leads DCDC to spend most of its time producing basic research. The same phenomenon occurs at the level of the individual researcher. Tenure and promotion decisions are made by the home departments and institutions of DCDC affiliated researchers. Again, these decisions are made primarily on the basis of the traditional scientific rewards system, in which rewards are based on the volume and quality of contributions to a specific discipline, typically in the form of publications. As reported by several researchers,

*I think [engagement with policy makers] is important but again I think that goes to the scientific reward system. There's no reward, from my perspective, to have my research used in policy. So for me to take the effort to make sure that it's being translated and it's being passed on and it's being interpreted correctly, there's no motivation for me to spend the time to educate those stakeholders on what it is that I have done and why I think that it is relevant.*

*Well I think, often times it's not done because it's not part of our reward system. We don't really get rewarded in the academic institutions for disseminating the information, you know despite the claims that it's important on the behalf of the NSF and you know Crow, as the leader of the new American University. So, you know I think there is value placed on it but when it comes down to it the academic institution is still, has the traditional reward systems that really doesn't value it, so... I mean I think that as a driving factor, in that a lot of scientists and researchers don't disseminate their information to the policy community, let alone the broader public.*

*And so we haven't affected change in that and I don't think that we really aim to affect change, but it's very hard to tell an assistant professor 'Come join this activity, and you know, hopefully the work that you're doing will result in a journal publication because that's what is going to benefit your career.' So it's that kind of thing that I think that we didn't really affect, and I don't know that we really should other than awareness that it's an issue for these kinds of projects.*

The result is that individual researchers must also focus primarily on basic science to attain necessary resources, with applied research taking a back seat. Further, this situation causes problems of recruitment and retention of talented DCDC researchers, who would rather engage in work that counts towards a future academic career. The violation of the second assumption of joint accountability also contributes to these problems. As neither

DCDC nor individual researchers are accountable to policy makers they are more likely to focus attention on basic science to continue to receive the resources and rewards necessary to continue their work. Thus, while Stokes (1997) champions the idea that research can be both basic and applied, achieving such harmony of outcomes becomes much more difficult when access to resources and subjection to accountability are skewed.

This section has detailed the tensions in relation to the functioning of DCDC. The tensions are related to challenges which DCDC face in attempting to provide desired outcomes to its four principals. We found two reasons for this. First, the principals whom DCDC serves desire very different sets of outcomes which are sometimes incompatible. We identified four major areas of tensions in desired outcomes. These were related to disciplinary integration, the speed at which research is conducted and relevant information is produced, principals' divergent emphasis on the production of basic versus applied research, and cultural differences in researchers' and policy makers' professional orientations. Second, these tensions are exacerbated by the demands of the traditional scientific rewards system, skewed accountabilities to particular principals, and weak incentives to engage with the policy community. As a result of this situation both DCDC as a boundary organization and its individual research affiliates face serious challenges in spanning the science-policy divide.

## Section IV. Ways Forward

In the previous sections we have presented the most prominent ways in which DCDC has impacted policy by highlighting successful initiatives, activities and outputs. We have also discussed some of the challenges which the organization has faced in pursuing their goal of producing quality science while also being relevant to the broader water policy community and fulfilling the aspirations of the New American University. The impediments to success in this respect have been largely related to salience, credibility and legitimacy issues of WaterSim, but also include differences in cultural perceptions among DCDC members and policy makers, as well as tensions created by diverging reward systems and skewed accountabilities among the principals which it serves. Through our interviews and survey we gathered data on DCDC members' and policy makers' suggestions as to how DCDC might improve its outreach and boundary activities. This section synthesizes these suggestions. Some of these suggestions can be more readily implemented while others would likely require some fundamental changes. Suggestions fall into three main categories: 1) improvement of WaterSim, 2) improvement of water/climate briefings, and 3) general improvement of the boundary management work of DCDC. The final category includes a variety of suggestions which aim to improve the overall salience, legitimacy and credibility of DCDC operations.

### *4.1 Improvements of WaterSim*

**Salience, credibility and legitimacy:** Many policy members questioned whether a model like WaterSim will ever be able to fully satisfy water managers' needs for two reasons: 1) there is a feeling that the regional picture may not be much use for a water manager operating on different spatial scales and under various legal and temporal constraints, and 2) they already have models tailored specifically to the context of their cities. Policy makers recommended including more information on the statutory restrictions or limitations involved in implementing recommendations produced by WaterSim.

**WaterSim as a scenario tool:** Concern was voiced about the value of using WaterSim as a primary output of the DCDC boundary work, thereby focusing interaction around the model output which potentially moves DCDC away from the original goal of being as much of a social science endeavor as one of physical science. While some questioned the utility of WaterSim for understanding of how decisions are made, it was felt that it could better function as a scenario building tool. This idea was widely subscribed to among policy members. Used in such a way, the regional and temporal scales of WaterSim might be better capitalized on and could be used to better understand the implications of different possible future courses of action. The potential of WaterSim is enhanced in combination with the Decision Theater. The combined use of WaterSim and DT were described as a valuable means by which to consider future water management in the valley.

## 4.2 Improvement of water/climate briefings

Water briefings were designed as a forum where scientists and members of the water policy community could meet and interact. They were part of an explicit strategy to establish trust, credibility, and achieve legitimacy with policy makers. By providing lunch and a neutral space for interaction, DCDC brings the water policy community together to share their knowledge, expertise and data. All evidence indicates that these meetings have in themselves been one of the main successes of the organization. DCDC has created new networks of interaction between the policy community and an interdisciplinary group of researchers that had not previously existed. While happy with the results of these meetings, policy members made suggestions as to how they might be further improved.

Policy members suggested two major ways to improve the effectiveness of water briefings. First, changes should be made to the format and settings of water briefings. There is broad agreement that the current meeting design limits informal interaction. Rather than focus on formal presentations, policy members suggested activities that involved more audience participation. This might include a mix of presentations, panel debates and round table discussions. A focus on two-way interaction between DCDC members and the policy community is essential for catalyzing knowledge transfer and deepening trust among these communities. Second, DCDC should be careful about the political implications of how it frames its presentations. Many policy members reported feeling that some presentations exhibited an inherent bias in the direction of a pending water management crisis. Water managers contended that such talks were misleading and had the potential to make their work more difficult. As one told us,

*...I know the titles are to attract people...but right there, you know, I'm thinking, 'okay.' As I read though the descriptor, there's this bias towards... we're going to dry up and blow away, at least that's kind of the interpretation, maybe not. But again, you know, as a water provider, I am constantly being interviewed by the news media, I am constantly dealing with the public, I am constantly giving presentations for various business organizations, locally and regionally, and I would like to make sure that we are all saying the same thing. And I'm not out there to not tell, to provide a biased viewpoint. I'm out there to tell them the best viewpoint I can based off of the information that we have and based off of the 100 years of background knowledge and the information that we're gathering from the universities to help us plan better. But if others are out there saying, making blanket statements that are in contradiction to what we're trying to say, then that bridge has a crack in it.*

While DCDC should not stray away from important topics, its members should be aware that the manner in which they frame their work has the potential to effect their relations with the policy community and their ability to affect change.

### 4.3 General improvement of DCDC boundary work

#### **1) Increased partnerships and opportunities for co-production and interaction:**

There is a strong consensus among those we spoke with and surveyed about the need to engage the policy community from the inception of their search process and to maintain this engagement throughout. In this way policy members would be equal contributors to knowledge production and model development rather than passive recipients of information. Advice about ways to achieve this parity were the most common type of suggestion provided by both DCDC affiliates and policy members. They vary from calls for more fundamental changes in DCDC strategies for stakeholder engagement to more practical suggestions for how to improve specific aspects of the co-production process and interaction. These are listed in bullet points below.

- Because research cannot always be summed up in a brief, clear-cut statement and recommendations can be contingent upon other things, one on one dialogue with policy/decision makers would be beneficial
- Create more opportunities for direct engagement and embed DCDC in the community rather than approach the community on an as needed basis
- Increase participation within the policy community by DCDC researchers. DCDC affiliates could become members of community organizations in order to increase the public's exposure to and knowledge of the organization's activities. This would likely require that such interaction be acknowledged and incentivised by the university.
- Initiation of WaterSim panel discussions with state officials and policy/decision makers from AZ State Agencies should be conducted in order for them to discuss what DCDC has done and why the research is important
- A more comprehensive website that better engages people could go a long way in advancing interaction. This includes making DCDC related research easily available for down-loading online
- Establishment of a mechanism to identify all research, its current status (completed, on-going, etc.), and provide information on how to get the research reports (pdf files) and contact researchers
- DCDC researchers could compile a list of policy recommendations emerging from research to date

**2) Broadening the types of stakeholder groups with which DCDC interacts:** Many suggestions relate to a broadening of the set of stakeholders with whom DCDC engages. DCDC has established a good connection with the "technocrats" in the policy community (i.e. city staff and water managers whose jobs deal with delivery of water on shorter time scales). However, it would be beneficial for DCDC to engage the individuals who operate at higher political levels also.

**3) Extending DCDC interactions with the policy community beyond WaterSim:**

Many suggestions from both DCDC affiliates and policy members concern the likely benefits of broadening the focus of DCDC's interactions with the policy community to extend beyond WaterSim. This is also reflected in suggested improvements of WaterSim, above.

**4) Focus more on studying decision-making:** Several suggestions reflect the perceived need to clearly understand how decisions are made and where DCDC can contribute and influence those decisions. This is a matter of spatial scale, timeliness, and essential nature of input and requires a systematic study of the decision-making process. This is an area where DCDC has not put much effort to date.

**5) Bridging of perception gaps:** Differences in DCDC affiliates' and policy makers' perceptions of each other and the realities in which they work emerge as a potential factor hindering their collaboration. Interviews indicate that such differences in perceptions exist among DCDC affiliates and policy community alike. However, they also indicate that these perceptions may be changing. Working to further bridge these perception gaps could therefore be one way for DCDC to enhance the boundary spanning process. This is unlikely to produce short-term scientific benefits, but will ultimately build a firm platform on which the knowledge co-production process and associated outputs can rest firmly.

**6) Synergies from resource pooling:** There is a recognition among policy members that resources within their own community are decreasing and that joining forces with academia can be seen as a strategic and sound way of creating useful information for themselves. It also serves to help create the types of employees that the industry and policy community will ultimately need to replace the aging work force now dominating the water management community in the Phoenix metropolitan area. This represents an opportunity for DCDC to establish itself as an organization to which members of the policy community can turn to jointly pursue new research, and thus as an important boundary player in the field of climate and water related science and policy in Phoenix.

**7) Improved clarity of organizational mission and goals:** Two things which contribute to an organization's success are: 1) a clear goal to which members of the organization feel they can contribute and work towards, and 2) a clear message about this goal communicated to the target audience. This allows the target audience an informed opinion about the organization and its potential benefits to their own organization. We asked members of both DCDC and the policy community about DCDCs organizational mission and goals. According to its mission statement, DCDC has three goals: the production of scientific knowledge, the promotion of inter/trans-disciplinary research, and social embeddedness through the involvement of decision-makers in the knowledge production process. We found that both DCDC affiliates and policy makers audience claim to have poor, if any, understanding of the goals of the organization. Several different factors contribute to this. First, many respondents report confusion about the many different centers and institutes operating under the umbrella of ASU (e.g. DCDC,

GIoS, and the Decision Theater), but also others which are not solely linked to ASU, such as the Arizona Water Institute (AWI). In addition, DCDC is often confused with the Decision Theater (DT) as a result of the close physical proximity of the DCDC and DT offices, the similarities in names as well as the use of the DT as tool to interact with decision makers around WaterSim. A consequence of the confusion over many different organizations and acronyms is that many policy makers are not clear about which organization is responsible for the water/climate briefings. Others perceive DCDC as an organization which exists simply to convene such lunch symposia, hence not acknowledging that the goal and purpose of the organization also involves extensive research and outreach. As two members of the water community said,

*I'm aware from briefings and other things, the heat island effect and I'm generally aware of a lot of the things that are going on within ASU relative to water, but I can't really tell you what's DCDC, what's GIOS, and I don't know much of it more than superficially [member of policy community]*

*To some of us in the water community that are looking at the DCDC and trying to figure out, 'Okay. What is it that they're trying to do?' It's not real clear to us. ...You know, from the outside, we're confused--I'm confused at least about where the DCDC is versus the Morrison Institute [laughs] versus all those other groups that you have at the various universities. And we really can't see which one do we go to when we have a question [member of policy community]*

Policy members share a view of ASU as a monolithic structure, which makes it difficult to discern which center or institute to approach in order to pursue an idea or discuss potential collaborations. Several policy members feel they do not possess a good enough understanding of the structure of ASU to be able to efficiently navigate the organizational landscape and access the expertise needed for collaboration. As explained by others,

*... we all look at each other and say who do we go to, to actually pull all that database together that will, that will believe where we get the results from. And it's obvious that we could go to the University. [slight pause] Where? [laughs] Which group? The Water Institute? The DCDC? Who?*

*and frankly I don't even know how to approach the university, you know, to get the project funded or to look at our needs. I don't even really know what the expertise is that's available for us to perhaps take advantage of. I'm not really as familiar with how the academic...I don't really understand and I think a lot of us don't understand the mechanisms available for us to partner with the university*

In summary, working to clarify the goals of the organization and disseminating those in interactions with the policy community appears as an important and urgent way for DCDC to improve many aspects of its boundary work. This could reduce feelings of skepticism and distrust within the water policy community generated by the lack of understanding of DCDC's mission. The production and dissemination to policy makers of

written reports such as those produced by the Morrison Institute would also improve the understanding of how research conducted within the organization may directly contribute to public policy.

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## APPENDIX: Legend for networks

All figures are presented in separate appendix. Coding for networks is as follows;

**1) DISCIPLINES:** School of Human Evolution and Social Change = black, School of Earth and Space Exploration = light grey, School of Life Science = light green, School of Sustainability = pink, Education = teal, Planning, Policy and Community Development = yellow, Business and Economics = Dark Blue, Geography = red, History = dark green, Decision Theater = orange, Decision Theater for a Desert City = purple, Mathematics and computing = baby blue, City of Phoenix = dark grey, Other = white.

**2) POSITIONS:** Faculty = circle, Staff = square, Upward triangle = graduate students and postdoctoral researchers, Other = Downward triangle; Policy member = Hour glass.

**3) CENTRALITY:** Betweenness centrality is used as our measure of centrality when creating the networks. The size of the node indicates its relative degree of centrality.

As noted in the text, some schools and institutes were collapsed into single 'disciplines' for analytic purposes. These categories were collapsed as follows:

- 1) **School of Human Evolution and Social Change** = School of Human Evolution and Social Change
- 2) **School of Earth and Space Exploration** = School of Earth and Space Exploration
- 3) **School of Life Sciences** = School of Life Sciences
- 4) **School of Sustainability** = School of Sustainability
- 5) **Education** = Department of Education and Department of Curriculum and Instruction
- 6) **Planning, Policy and Community Development** = American Indian Policy Institute, Consortium for Science, Policy and Outcomes, Morrison Institute of Public Policy, School of Community Resources and Development, School of Public Affairs
- 7) **Business and Economics** = Department of Business and Department of Economics
- 8) **Geography** = School of Geographic Sciences
- 9) **History** = Department of History
- 10) **Decision Theater** = Decision Theater
- 11) **Decision Center for a Desert City** = Decision Center for a Desert City
- 12) **Mathematics and Computing** = Department of Mathematics, School of Computing and Informatics
- 13) **City of Phoenix** = City of Phoenix
- 14) **Other** = Psychology, Institute for Social Science Research, Department of Philosophy, College of Design, School of Family and Social Dynamics

## APPENDIX:

# All things to all people

- An assessment of DCDC as a boundary organization

## FIGURES

Figure 1. Network of interaction between DCDC affiliates and policy makers

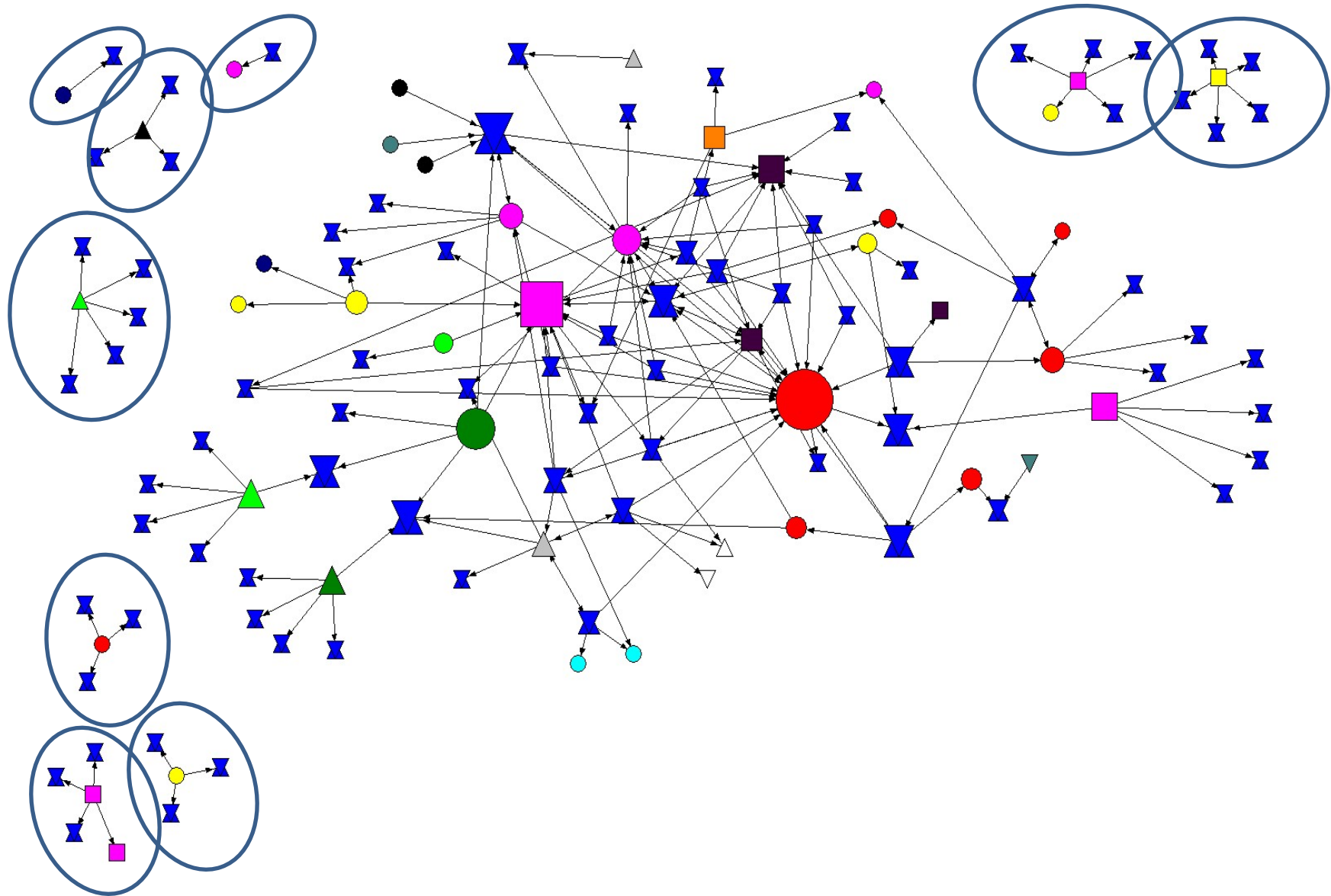


Figure 2.

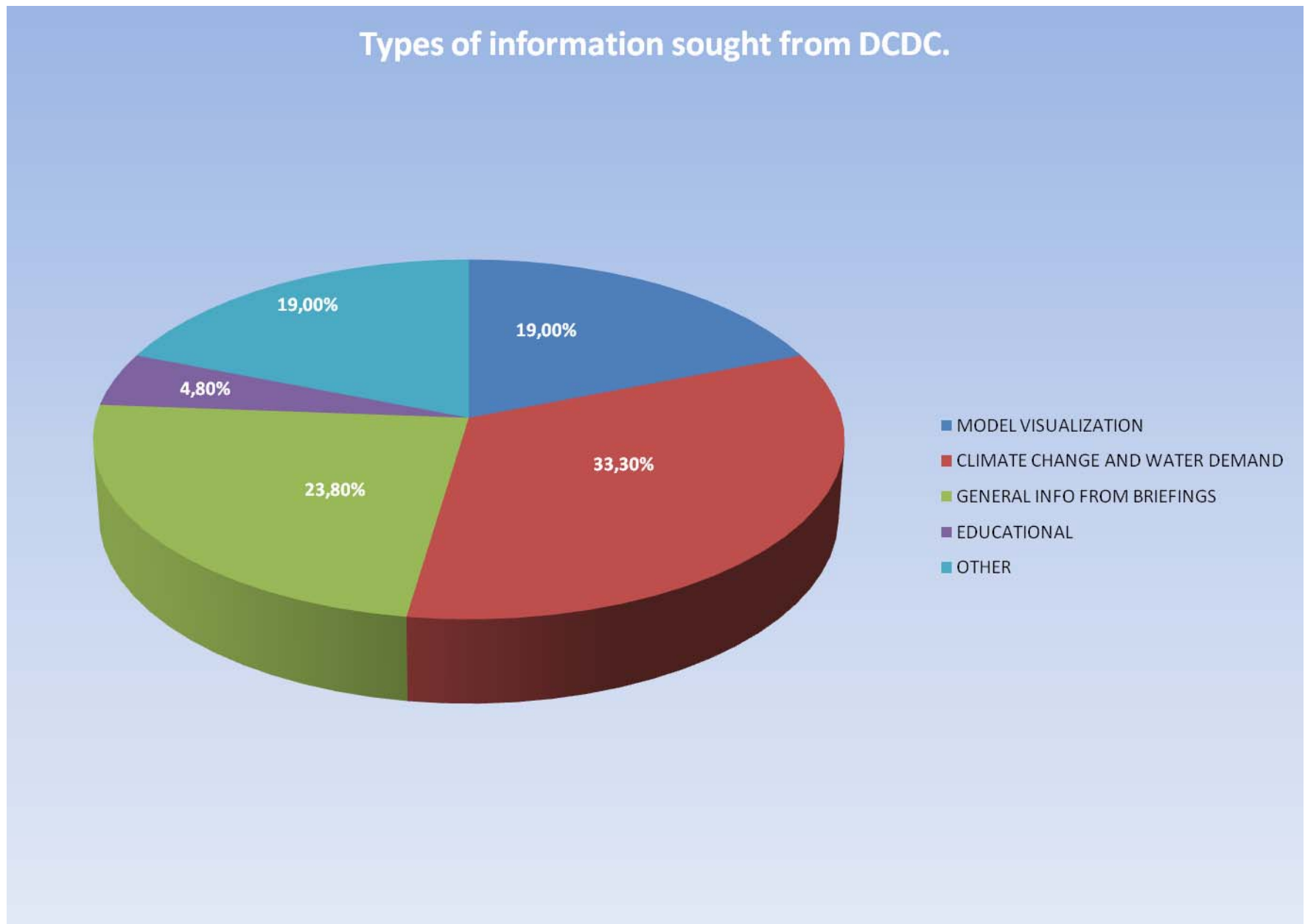


Figure 3.

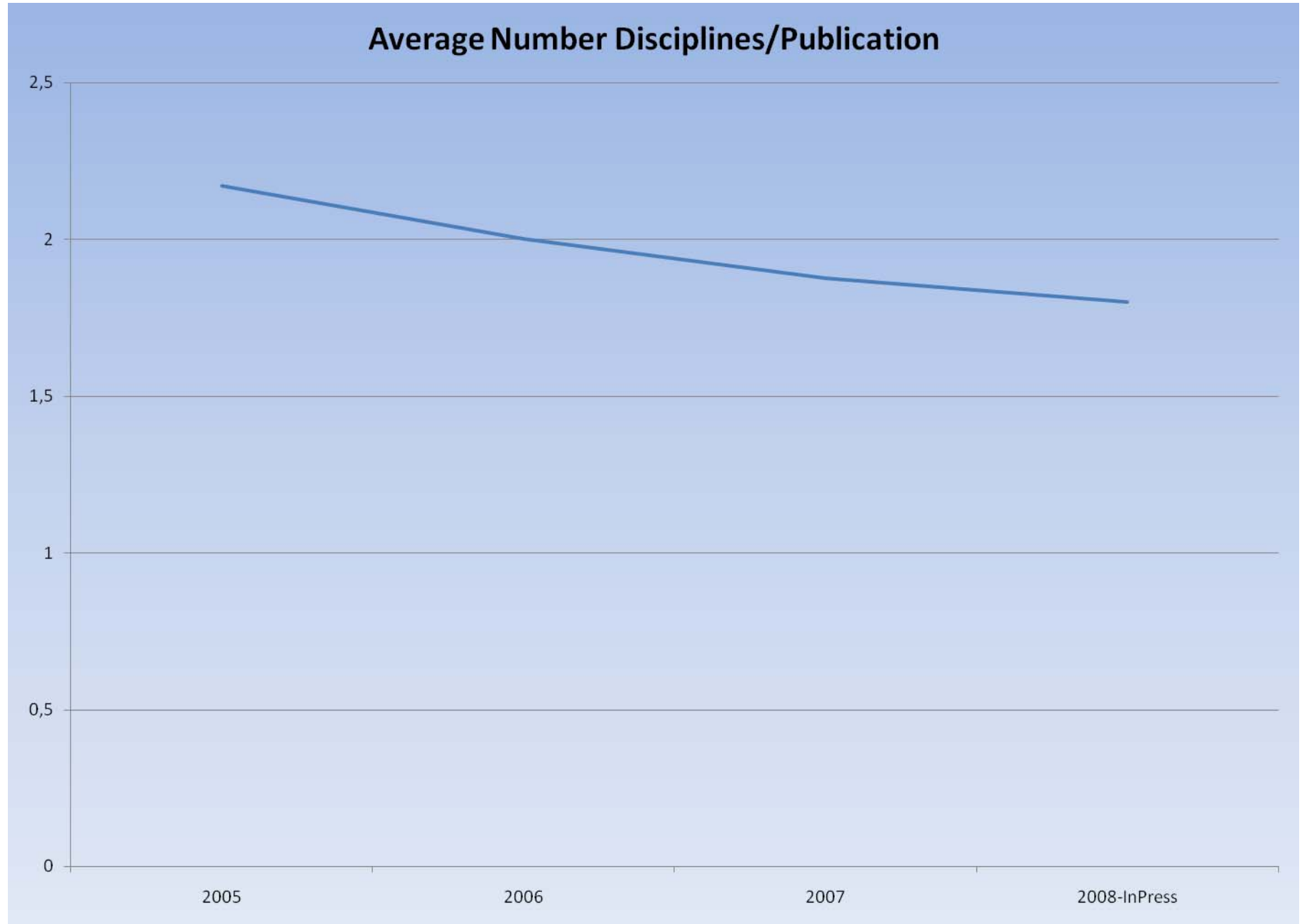


Figure 4. Number of authors (by discipline) represented on DCDC publications

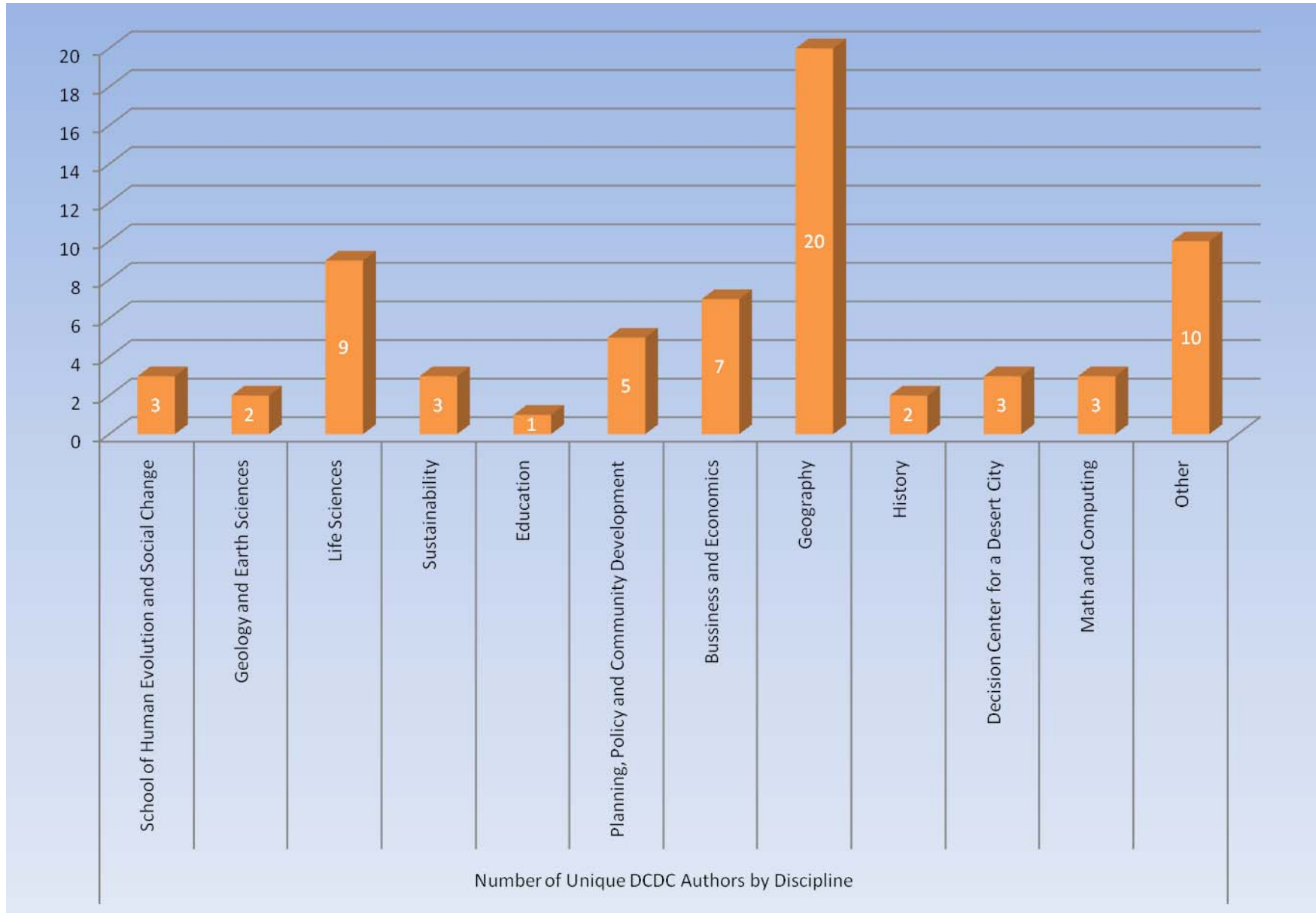


Figure 5. Percentage of all publications on which each discipline collaborates

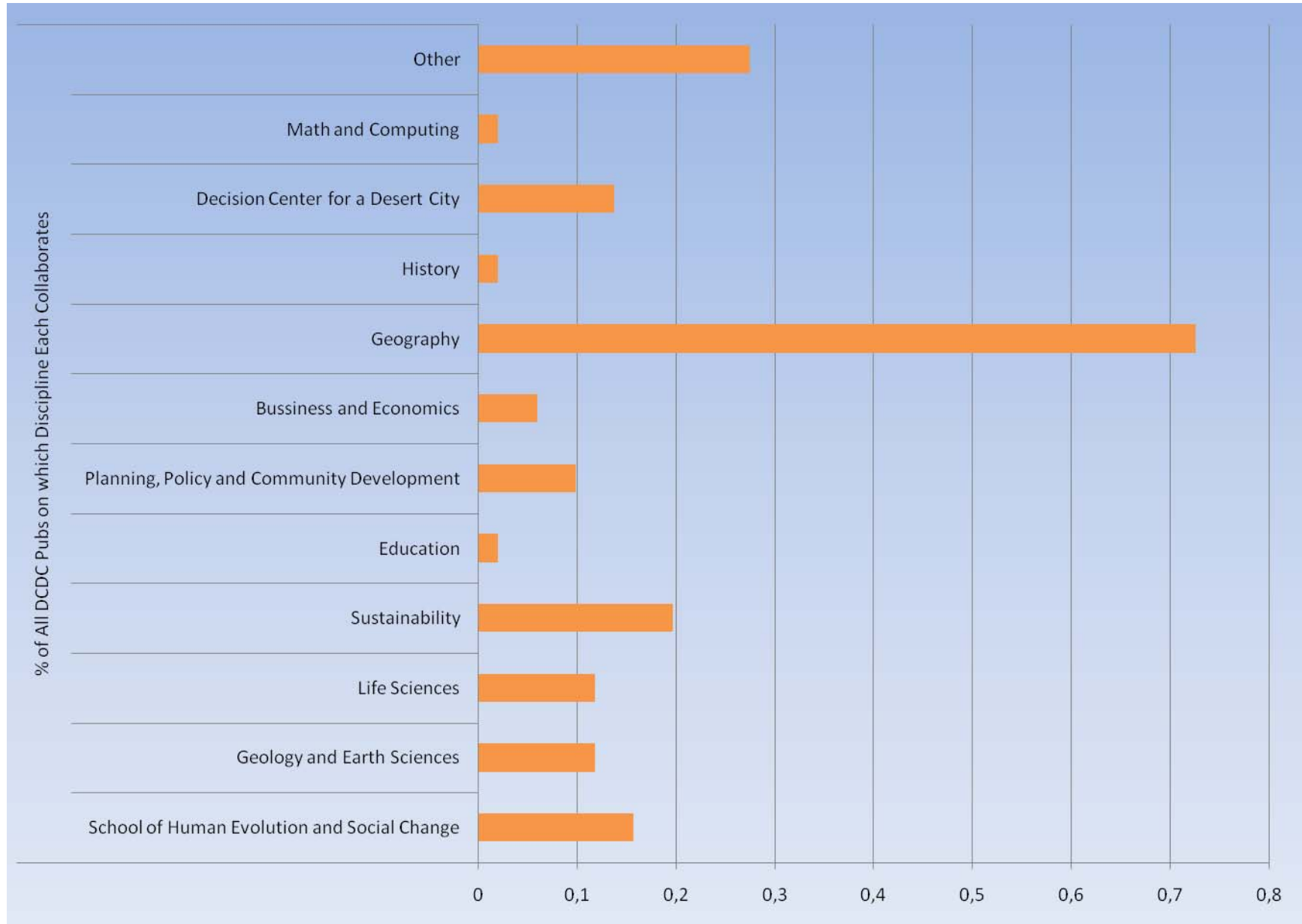


Figure 6. Co-authorship network for DCDC

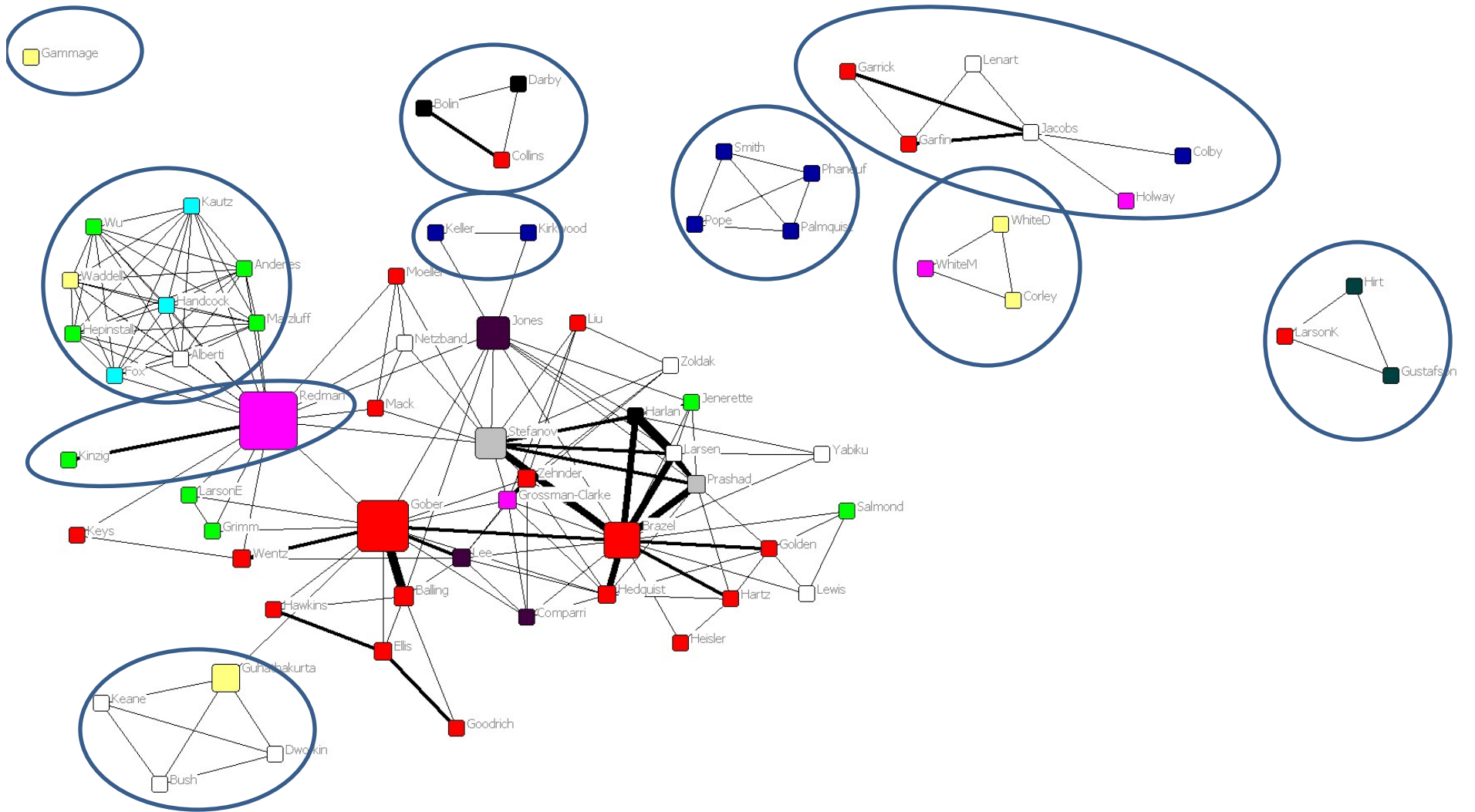


Figure 7.

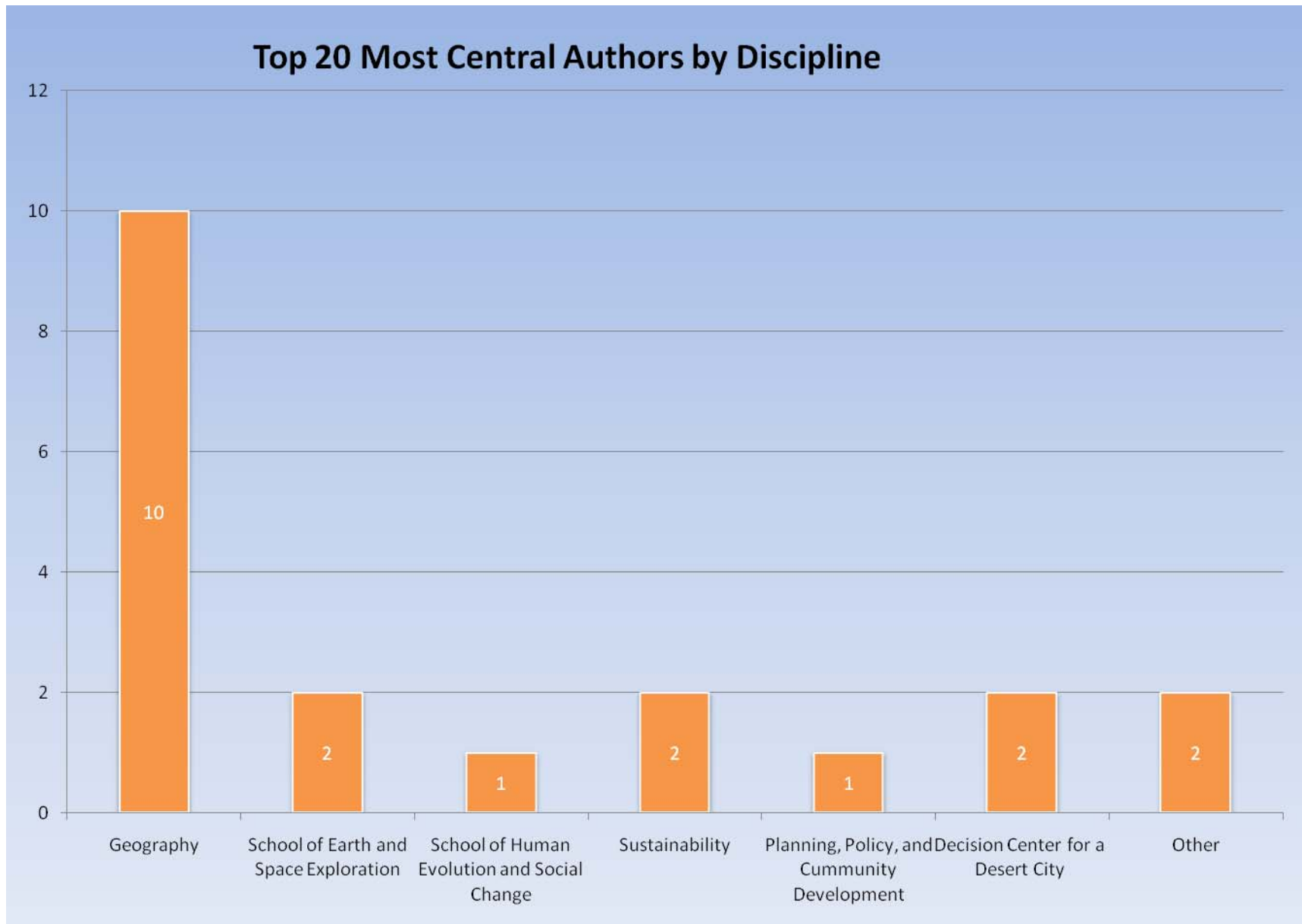


Figure 8.

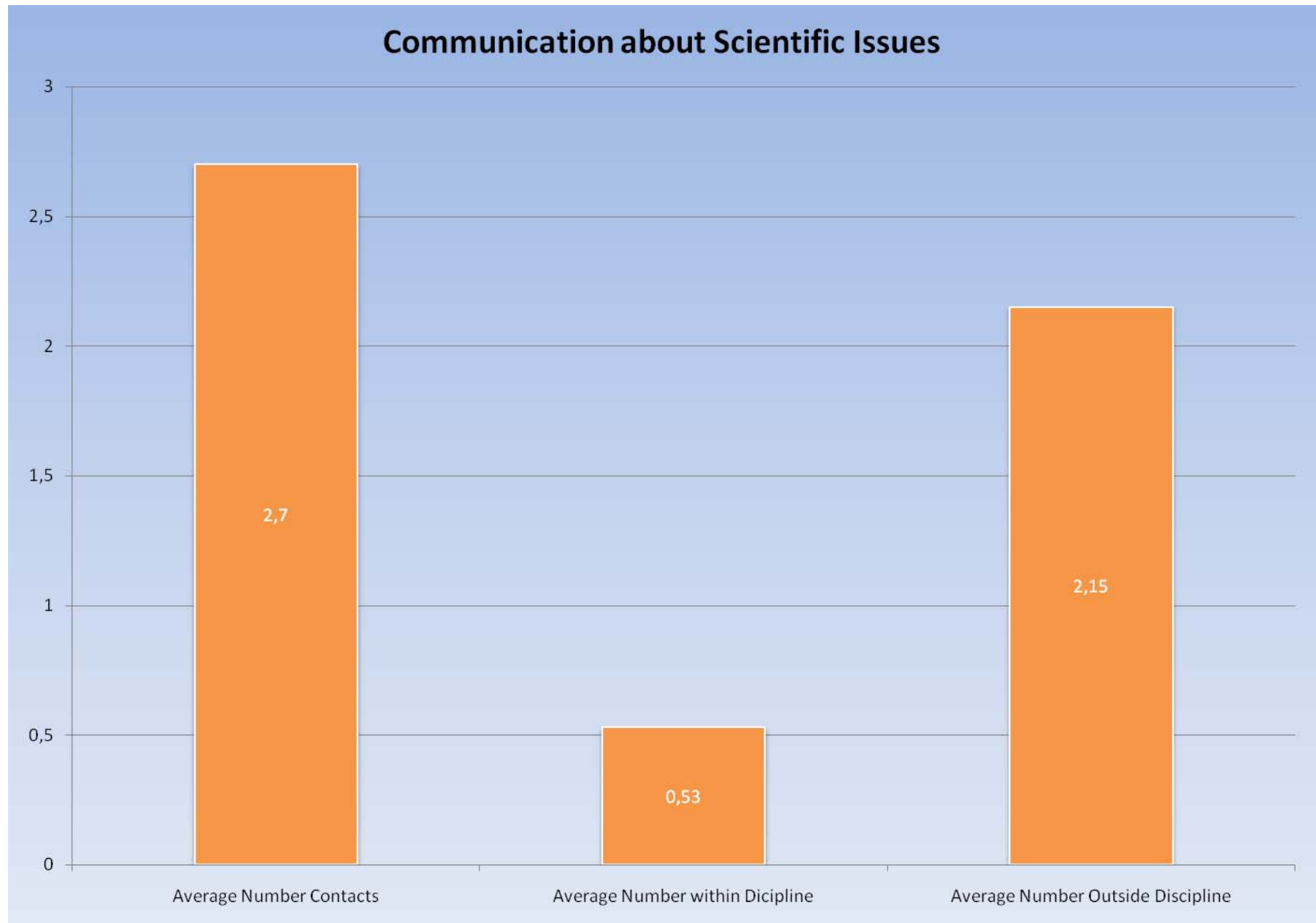


Figure 9. Network of communication among DCDC affiliates regarding scientific aspects of their work

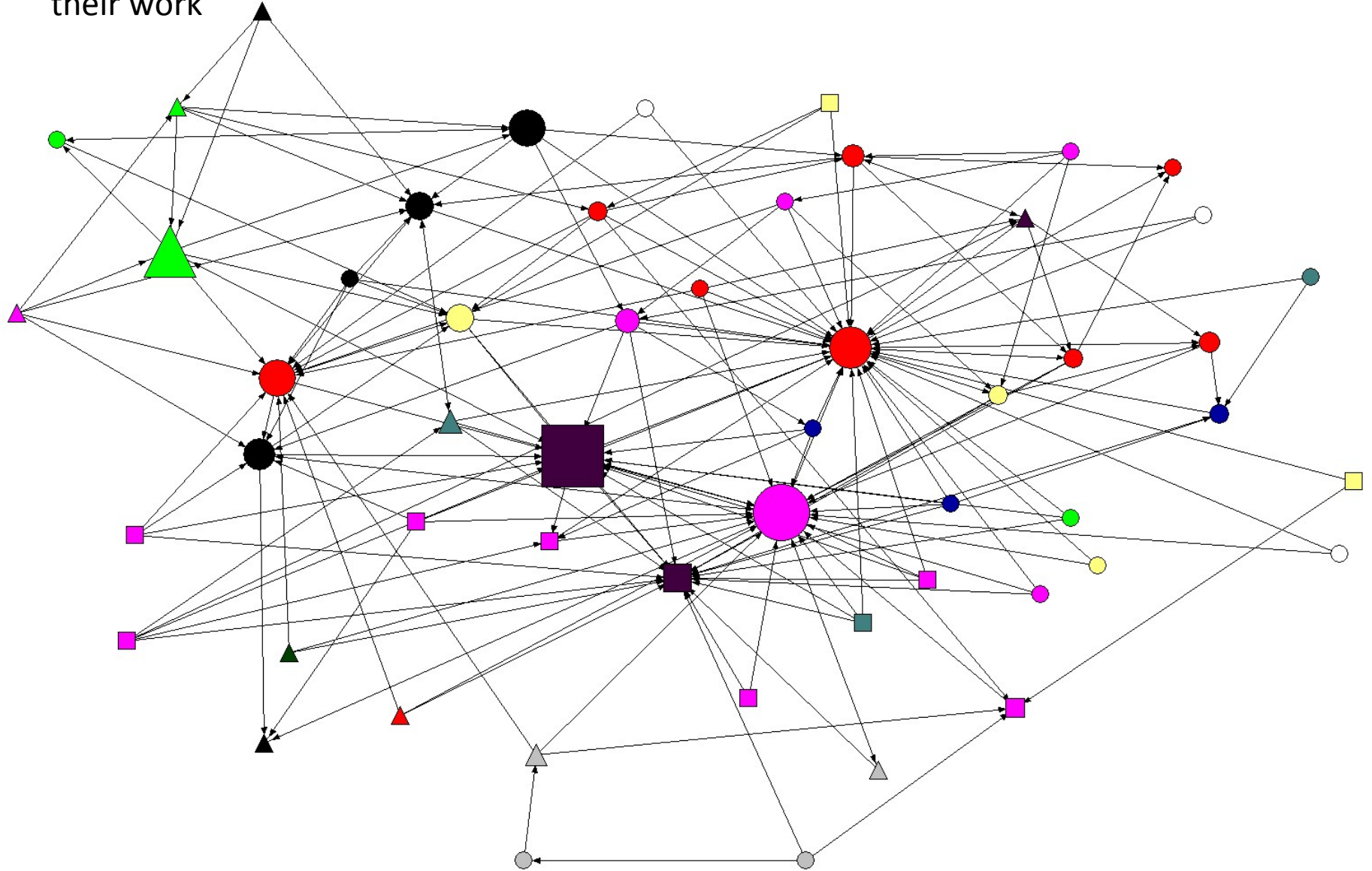


Figure 10. Network of communication among DCDC affiliates regarding policy implications of their work

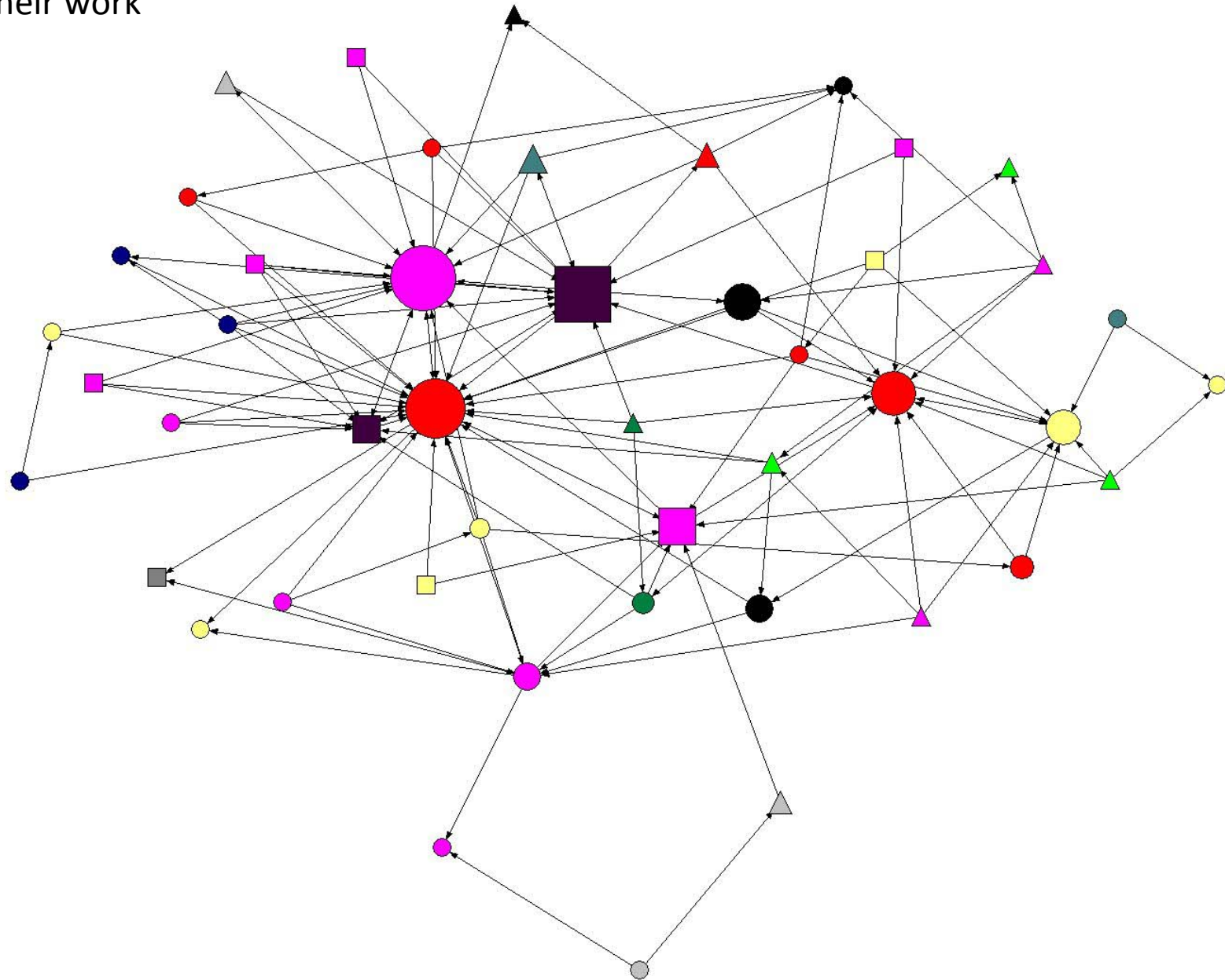


Figure 11.

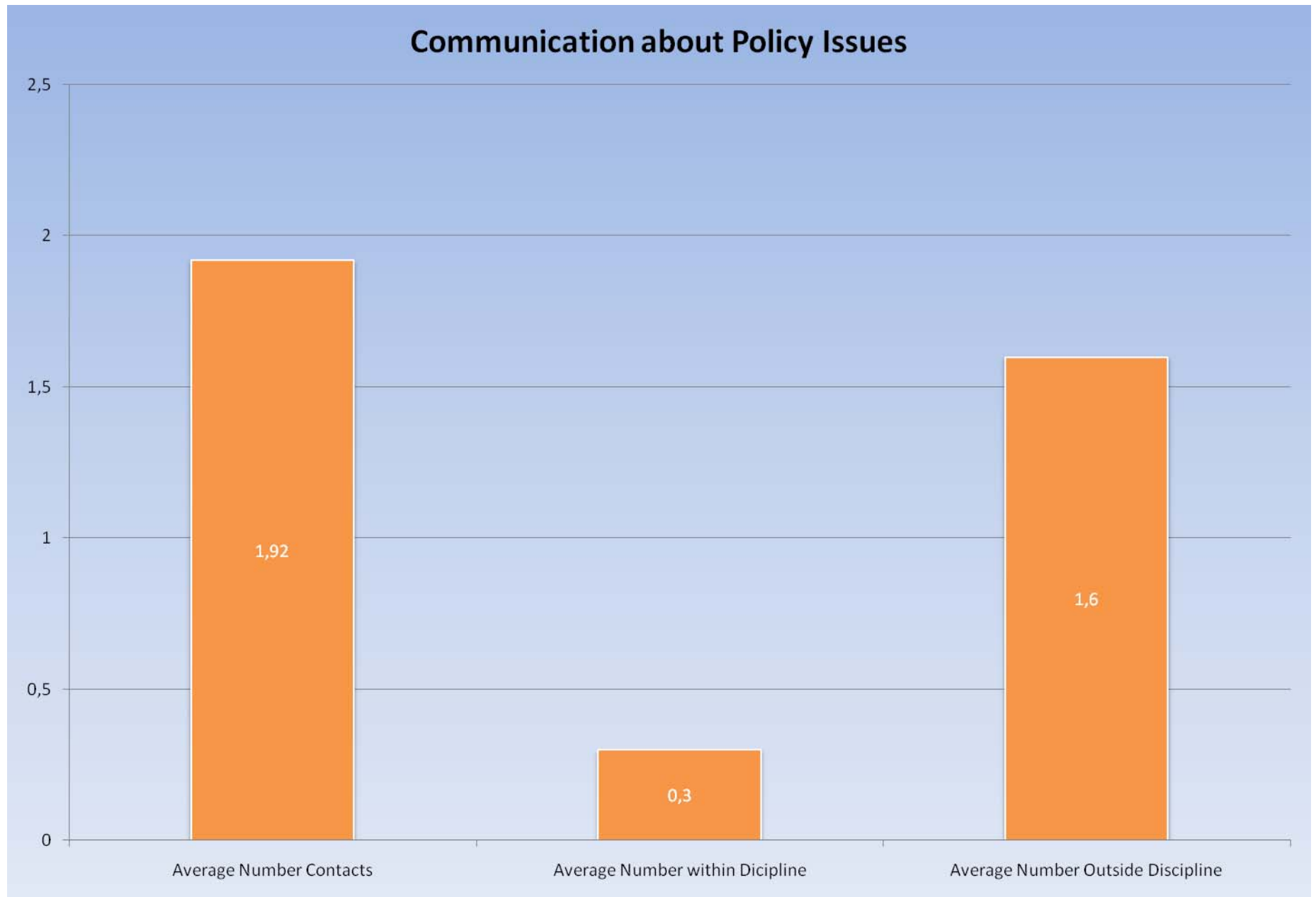


Figure 12. Percentage of respondents indicating levels of use and uptake of DCDC produced information

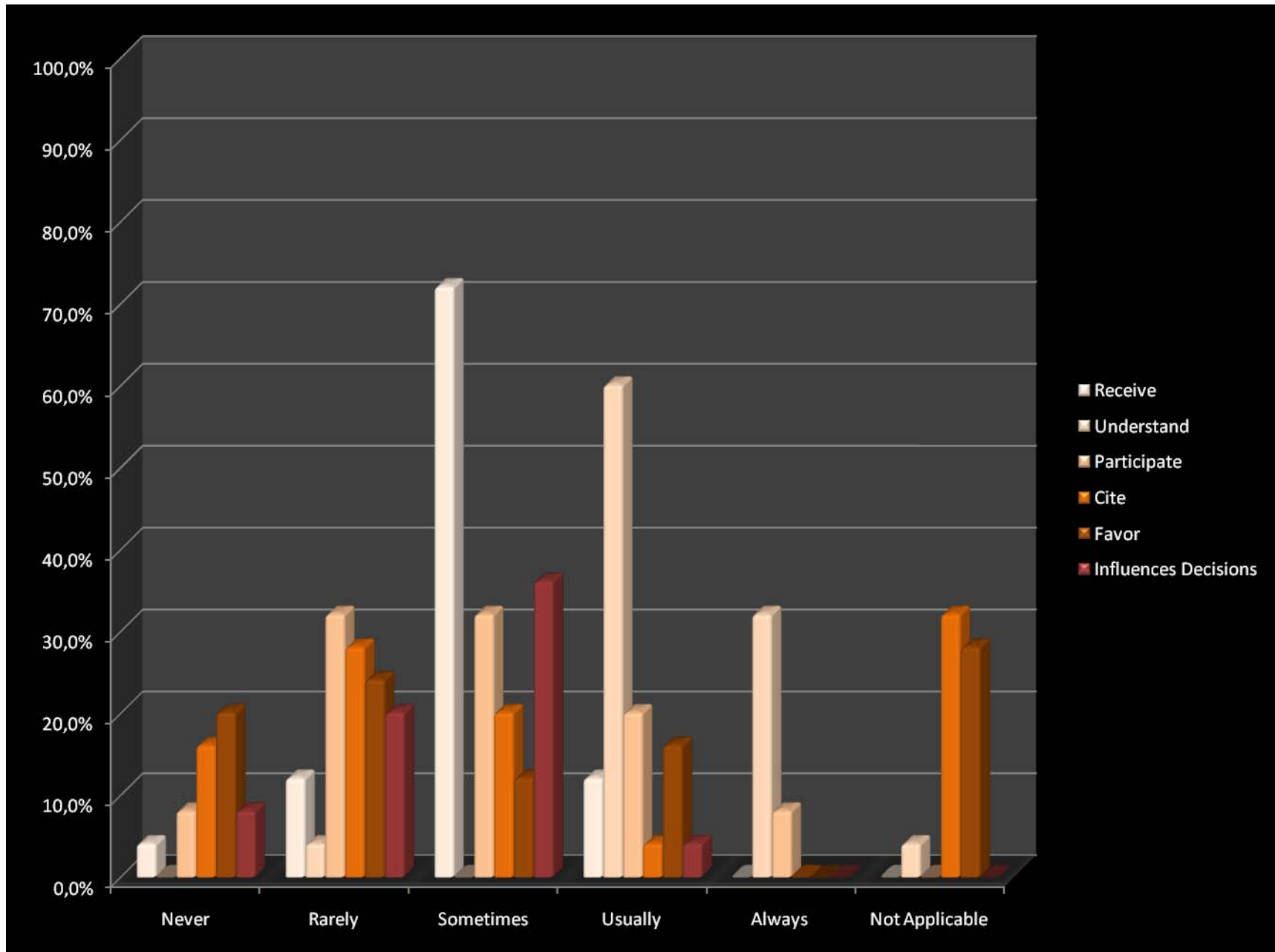


Figure 13.



Figure 14.



Figure 15.

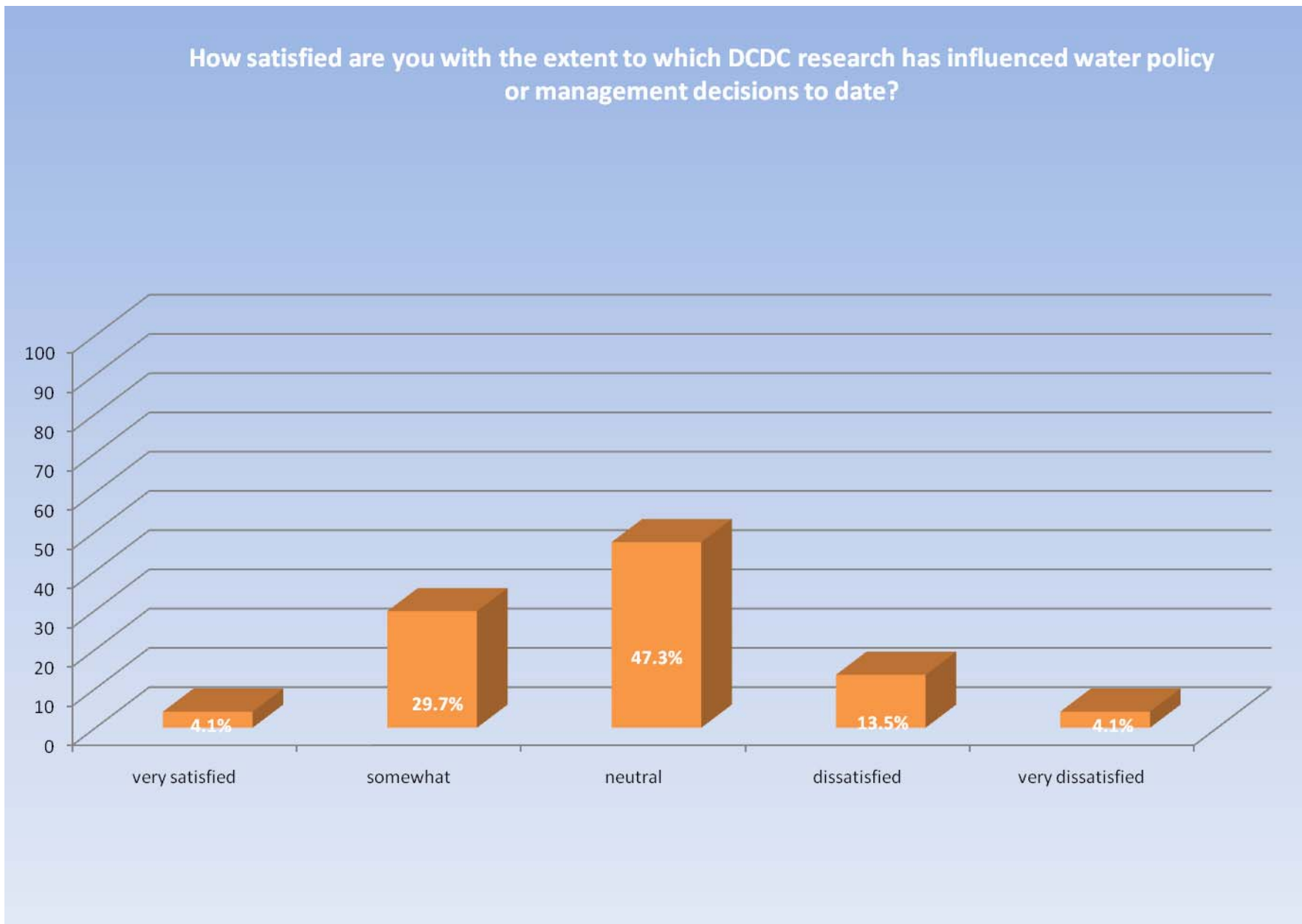


Figure 16.

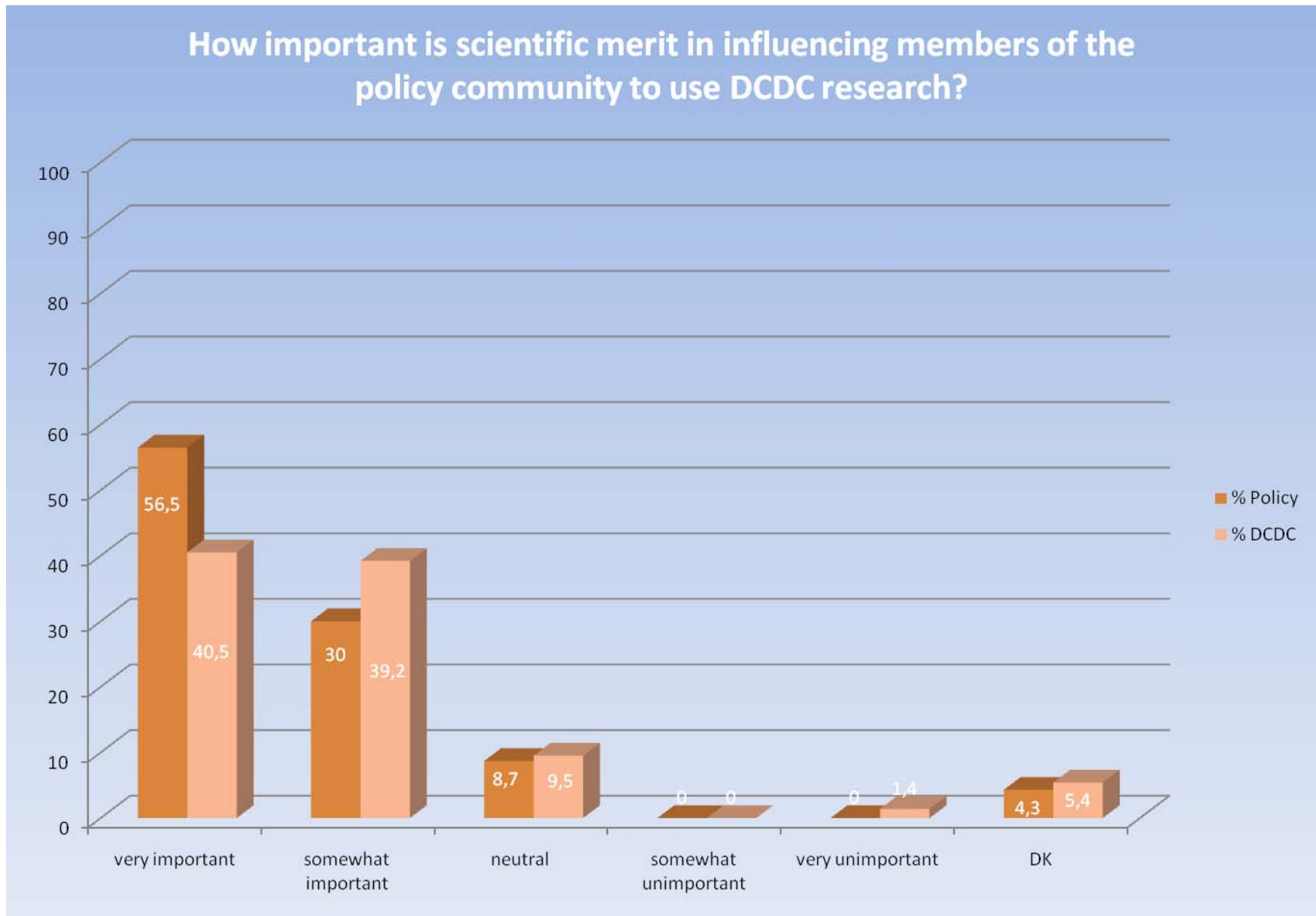


Figure 17.

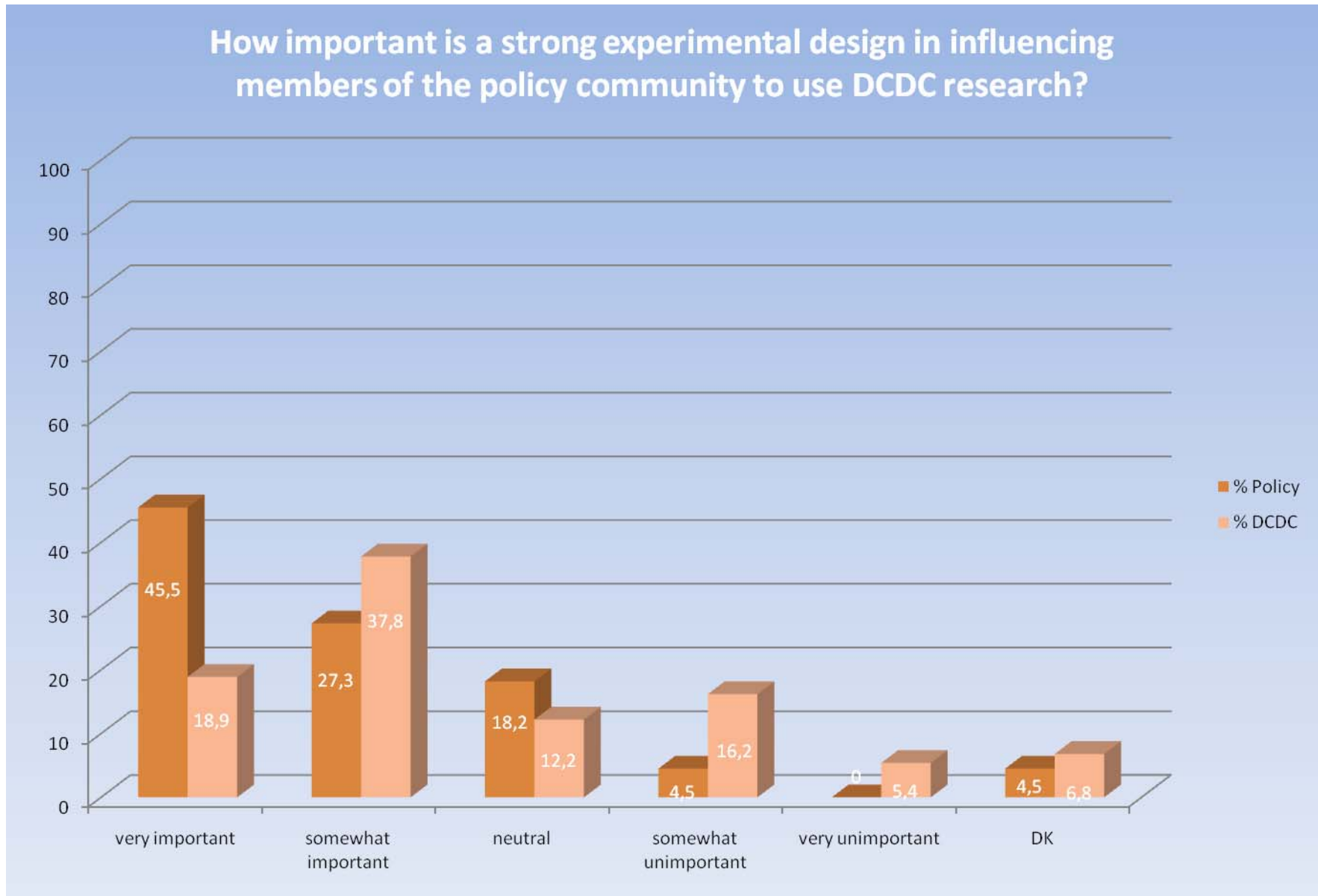


Figure 18.

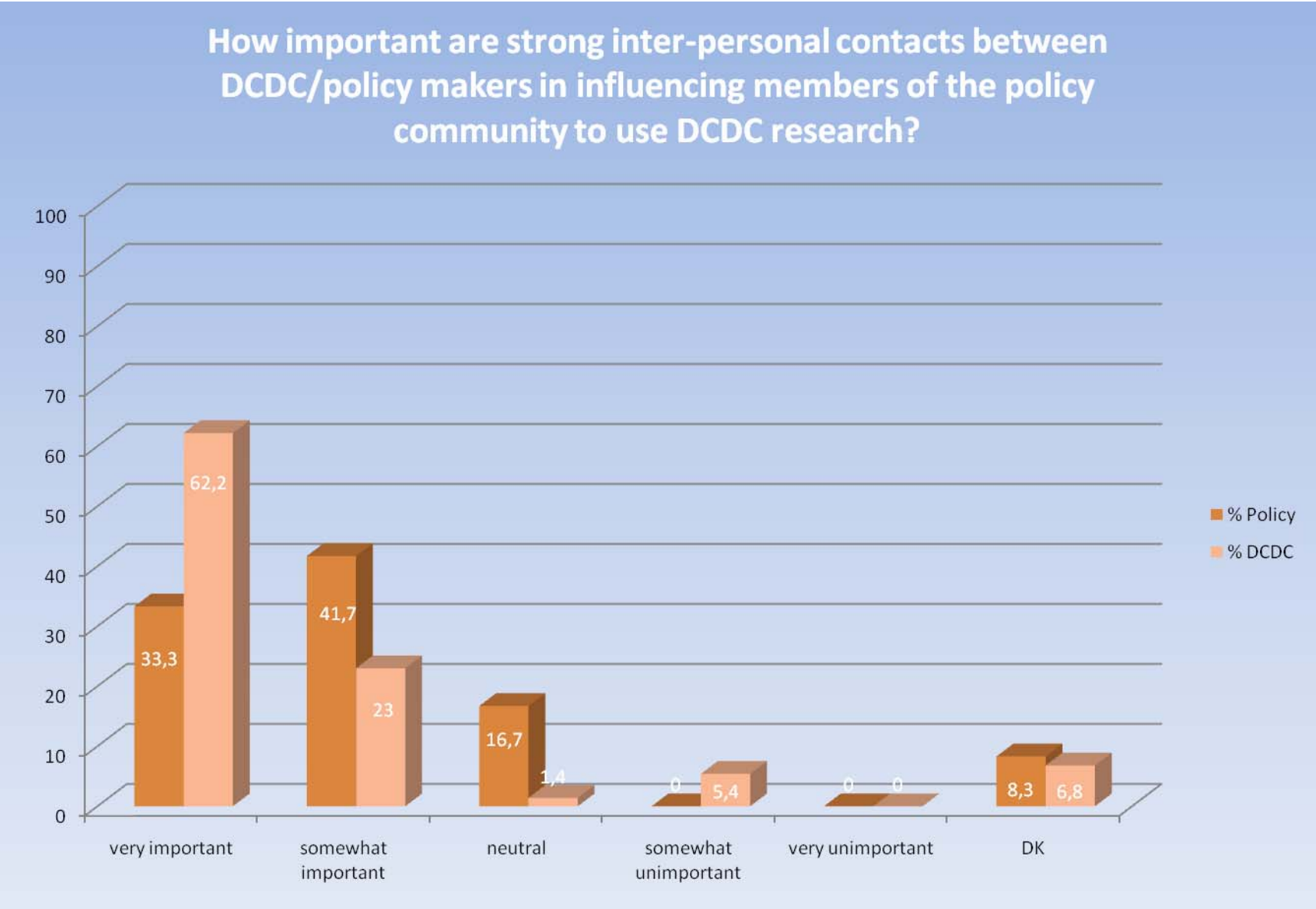


Figure 19.

