Presentation at the

Southern States Communication Association Conference

Communication Theory Division

April 2004

A Longitudinal Examination of High Performance Wireless Network Usage in an Ecological Reserve

Kimberly Mann Bruch

University of California, San Diego

San Diego Supercomputer Center
9500 Gilman Drive
La Jolla, CA 92093-0505
(858) 822-0977
kbruch@ucsd.edu

A Longitudinal Examination of High Performance Wireless Network Usage in an Ecological Reserve

ABSTRACT

This study examines perceptions regarding the diffusion of the High Performance Wireless Research and Education Network (HPWREN) among field scientists at a southern California ecological reserve. Based on Rogers' (1995) diffusion of innovations theoretical framework, field researchers' perceptions of network connectivity, communication channels, and use of the network were assessed before HPWREN connectivity, one year after connectivity was established, and two years thereafter. Paired sample t-tests were conducted to compare perceptions regarding the network's relative advantage, compatibility, complexity, and the participants' adoption decisions - as well as communication channels used to diffuse network information. Though statistical analysis showed positive perceptions during all three surveys, no significant change was found between the pre-connectivity and post-connectivity samples.

A Longitudinal Examination of High Performance Wireless Network Usage in an Ecological Reserve

INTRODUCTION

This paper presents empirical findings guided by the diffusion of innovations theory (Rogers, 1995). Specifically, the study examines perceptions regarding the diffusion of the High Performance Wireless Research and Education Network (HPWREN) among field researchers at a southern California ecological reserve. That is, real-time sensors and cameras deployed at the reserve were recently connected to HPWREN and allow researchers at wildlife reserves throughout the world to conduct studies and receive sensor and camera data via the Internet. Based on Rogers' (1995) diffusion of innovations theoretical framework, field researchers' perceptions of network connectivity, communication channels, and use of the network were assessed before HPWREN connectivity (T1), one year after connectivity was established (T2) and two years after connectivity was established (T3). Paired sample t-tests (see Figure 1) were conducted to compare T1, T2, and T3 perceptions regarding the network's relative advantage, compatibility, complexity, and the participants' adoption decisions - as well as communication channels used to diffuse network information. Analysis of T1, T2, and T3 comparisons showed no significant change in perceptions related to the network, adoption decision, or communication channels used during the diffusion process.

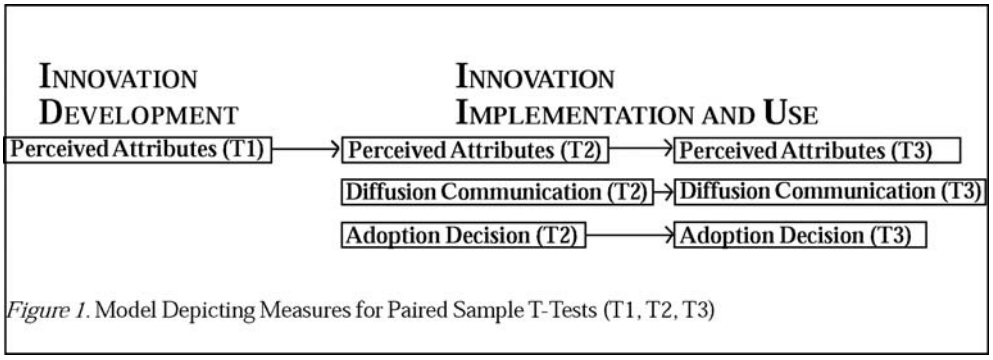

Figure 1. Model Depicting Measures for Paired Sample T-Tests (T1, T2, T3)

PARTICIPANTS

The population from which the intact group sample was drawn consisted of ecological field scientists affiliated with SDSU Field Stations Program, which oversees the Santa Margarita Ecological Reserve (SMER). Thirty-seven subjects (of 40 eligible field scientists) participated in the Fall 2001 (pre-connectivity) and Spring 2002 (post-connectivity) data collection efforts. However, only 15 of these 37 subjects participated in the Summer 2003 study; the author speculates that the SMER user community will continue to change as more researchers learn of the high-speed data connectivity now available there.

Of the 15 respondents that participated in all three surveys (2001, 2002, and 2003), 14 are male and one is female. While 10 of the 15 respondents are faculty members from southern California universities, five are staff at academic, military, and research institutions and agencies.

While eight of the participants sometimes or always take continuous measures for their research efforts, five never take continuous measures.

SETTING

Spanning approximately 4500 acres with elevation ranges from 150 to 2300 feet, the Santa Margarita Ecological Reserve is nestled between the Santa Ana mountains in the northeast portion of San Diego county. Home to one of the last free-flowing streams in southern California, topography at SMER is complex with low hills and intervening drainages. With cool wet winters and warm summers, vegetation at the reserve includes chaparral, coastal sage scrub, and oak woodlands. The reserve is home to a variety of mammals including coyotes, brush rabbits, and bobcats. Many birds, such as the wrentit,

brown towhee, turkey vulture, raven, red-tailed hawk, and scrub jay, are also found at the reserve. Meanwhile, SMER reptiles include the orange-throated whiptail, rosy boa, and San Diego horned lizard. Rattlesnakes and mountain lions also frequent the reserve.

In Fall 2001, HPWREN researchers began development and implementation of a broadband telecommunications infrastructure at SMER and reserve field scientists now have the capability of sending and receiving data at a speed of 45 megabits per second (Figure 2).

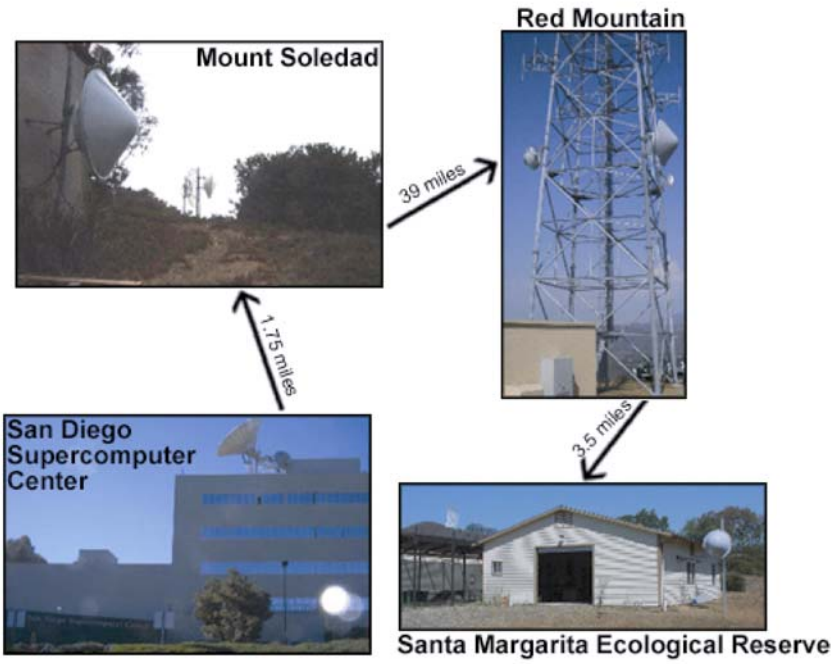

Figure 2. Santa Margarita Ecological Reserve receives its 45 Mbps connectivity via the HPWREN antenna atop the San Diego Supercomputer Center (SDSC). The link hops from SDSC to Mount Soledad to Red Mountain to the reserve.

More than 50 research projects are being conducted at SMER. This research includes a wide array of studies, such as (a) threatened and endangered species; (b) water

quality and public health; (c) agriculture; (d) global change; (e) fundamental ecology, geology and geography; and (f) environmental engineering. Field scientists typically conduct their research using traditional methods of field data collection; that is, they simply go out into the field, make observations, and note their findings in a field notebook. Although several SMER field scientists are adapting their field note procedures to incorporate the use of Personal Digital Assistants (PDAs), most of them continue to manually log observations in the field and then transcribe the information once they are back in their office or laboratory.

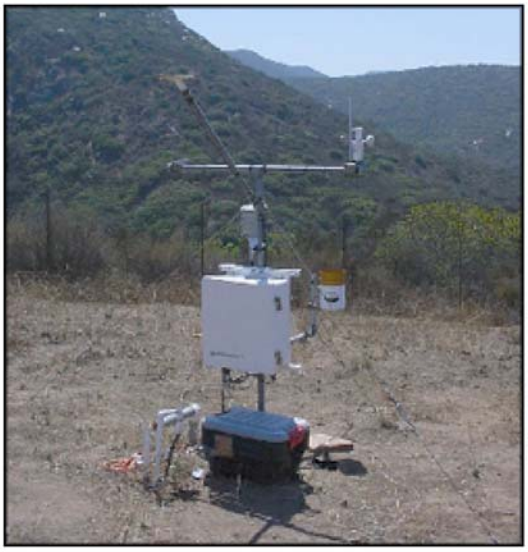

Figure 3. Located near the reserve's north station, this weather station collects data related to wind speed and direction, air temperature and relative humidity, solar radiation, precipitation and atmospheric pressure.

The recently established high-speed data connection at SMER, however, prompts additional SMER researchers to utilize technology as a means of data collection and transmission. For instance, a weather station (Figure 3) represents only one example of the many sensors that continue to be implemented

throughout the reserve. Additional sensors provide researchers with high-resolution time series measurements of physical, chemical, and biological variables found not only in the air, but also in the watershed. Systems that capture both audio and video are also being deployed in the gorge of the reserve so that scientists can remotely monitor habitats. For example, a Swiss researcher now uses a remote camera to study the role of hummingbirds, bees, and moths in the pollination of SMER's bush monkey flower, *Mimulus aurantiacus*. Instead of trave lling to San Diego for his observations, this scientist logs onto the network and monitors the habitat in real-time (Figure 4).

Figure 4. Delivering more than three megapixels per image, the connection of a remote camera to HPWREN allows users to capture the wing of a hummingbird in flight.

Consequently, ecoinformatics development such as this falls right in line with the NSF's recently proposed National Ecological Observatories Network (NEON). With the goal of equipping ecological reserves around the country with computerized instrumentation infrastructures, NEON would network nationwide reserves together via

broadband telecommunications and allow U.S. ecologists to easily share field data collections with one another, students, government agencies, private landowners, and the general public.

METHODOLOGY

Permission to collect participant data regarding broadband connectivity use, diffusion communication, and relative advantage, compatibility, and complexity was granted to researchers, including the author, affiliated with the NSF-funded HPWREN by the University of California, San Diego (UCSD) Human Subjects Program. Pre-connectivity data were collected by HPWREN researchers, including the author, in December 2001 while broadband connectivity via HPWREN was being established at the reserve. Meanwhile, post-connectivity data were collected in March 2002 and the most recent follow-up data was collected in August 2003.

A combination of telephone interviews and email surveys were used to collect the 2001 and 2002 data; specifically, diffusion communication, relative advantage, compatibility, and complexity data was collected via phone interviews so that the subjects were clearly familiarized with the study at hand (Houtkoop-Steenstra, 2000). However, email surveys were primarily used to collect HPWREN usage data, as this data collection took place after the participants were well familiarized with the study. Likewise, all data for the 2003 surveys was collected via email surveys.

The variables were measured using two sets of questions: the 2001 pre-test (see Appendix A) was conducted prior to HPWREN connectivity while the 2002 post-test and

follow-up 2003 test (see Appendix B) was administered after connectivity was established. Pre-test survey questions concerned perceived attributes and were administered during time one (T1). The 2001 pre-test survey (T1) consisted of 24 items related to perceived relative advantage, compatibility, and complexity; this telephone survey was administered during the HPWREN development stage. Meanwhile, 2002 and 2003 surveys (T2 and T3) consisted of 27 items and examined continued perceptions (relative advantage, compatibility and complexity) as well as diffusion communication and adoption decision. The survey questions were developed based upon prior research conducted by Rogers (1995), Valente (1996), Rice (1994), Rice and Gattiker (2001), Spitzberg (1997), and Reagan (1989).

In addition to quantitative data collection, qualitative data were also recorded. This information provided insight regarding the specific real-time data that adopters plan to measure, their use of specialized sensors, needed technical support, and HPWREN training that users consider beneficial. Additionally, qualitative data allowed for a better understanding of the non-adopters' decisions to reject the innovation.

Measures

Using the aforementioned diffusion of innovations theoretical framework (Rogers, 1995), the measures of this research consisted of 1) perceived attributes (relative advantage, compatibility, and complexity); 2) diffusion communication–both interpersonal and mass media channels, and 3) adoption of the innovation: broadband connectivity.

Perceived Attributes

Rogers (1995) defines *relative advantage* as the "degree to which an innovation is perceived as being better than the idea it supersedes" (p. 212) and *compatibility* as the "degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters" (p. 224). Meanwhile, Rogers explains *complexity* as the "degree to which an innovation is perceived as relatively difficult to understand and use" (p. 242).

Several indexes were used to measure relative advantage, compatibility, and complexity. Perceived attributes, which were measured during T1, T2, and T3, refer to the attitudes during the innovation development, implementation, and use stages. Because the field scientists were not heavily involved with the HPWREN development process, however, a significant difference between perceptions at time one and time two surveys was not anticipated. On the other hand, comparison of pre-connectivity perceptions with post-connectivity perceptions proves interesting for HPWREN researchers as they examine the evolution of understanding among broadband telecommunications users and provide the most efficient infrastructure and training materials. Likewise, comparison of T1, T2, and T3 responses also relays interesting findings, which are explicitly discussed in the results and discussion sections of this paper.

Relative Advantage. To determine relative advantage, the author employed five measures (see Appendices A & B): the extent to which HPWREN (a) improves the field scientist's research endeavors; (b) improves teaching efforts; (c) allows for more efficient information dissemination; (d) benefits outweigh costs; and (e) has more advantages than disadvantages.

Cronbach reliability analysis indicated that the five measures for relative advantage were all reliable (alpha=.86 for T1, alpha=.72 for T2, and alpha=.88 for T3).

Compatibility. Likewise, the author used five measures to determine compatibility of HPWREN with the participant's (a) current technology; (b) level of network training; (c) research needs; (d) methods of data collection; and (e) teaching curricula (see Appendices A & B). Cronbach reliability analysis indicated that substantial increase in reliability for the compatibility measure was achieved when one item was removed from the index. Specifically, the question that measured the level of network training was suggested for deletion from the compatibility index. Therefore, this item was omitted for further statistical analysis of the data. Meanwhile, retention of the other four items allowed for reliability (alpha=.83 for T1, alpha=.70 for T2, and alpha=.69 for T3).

Complexity. Similarly, five measures examined complexity and whether or not the participant (a) has questions about HPWREN; (b) perceives the network as difficult to use; (c) must acquire technical assistance to use HPWREN; (d) prefers person-to-person technical assistance; and (e) is not very knowledgeable about networking technology (see Appendices A & B). Cronbach reliability analysis indicated that all items were reliable for T1 (alpha=.71) and T2 (alpha=.78); however, complexity measures taken during T3 were not reliable enough for further analysis (alpha=.23 for T3).

Diffusion Communication

Diffusion communication, which encompasses both interpersonal and mass media communication channels, is often measured by scholars such as Rice (1991) and Valente and Saba (1998) using Likert-scale questions similar to those in this study. To measure interpersonal communication channels specific to innovation perceptions, the participants

were asked about the extent to which information they received about HPWREN was favorable: (a) within their workplace and (b) outside of their workplace. To measure mass media communication channels specific to innovation perceptions, the participants were asked about the extent to which they received favorable information about HPWREN: (a) in print media and (b) electronic media (see Appendix B).

Cronbach reliability analysis indicated that the measures for diffusion communication were all reliable (alpha=.83 for T2 and alpha=.74 for T3).

Adoption Decision

In order to better understand the adoption decision of participants, they were asked about their (a) current use of the network; (b) perceived use in their future work; (c) perceived future use for research endeavors; (d) perceived future use for teaching efforts; and (e) perceived future use for overall purposes. These variables were measured using standard attitude scales on part and future frequency of use that were administered using electronic mail surveys (see Appendix B, questions 22-26). Cronbach reliability analysis indicated that the five measures for adoption decision were all reliable (alpha=.93 for T2 and alpha=.91 for T3).

Paired Sample T-Tests

Given the small sample, it was considered inappropriate to conduct multiple regression, multivariate path analysis, or structural equation modeling. Therefore, to examine the data, paired sample t-tests were performed to detect differences in the means for perceived attributes, diffusion communication, and adoption decision. Data collected during T1 was first compared with data collected during T2; next, T2 and T3 data were compared, and finally T1 data was compared with T3 data. The t-tests showed no overall

valence shift between data collected at T1 and T2, T2 and T3, or T1 and T3. These quantitative results, as well as qualitative results, are explicated in the results and discussion sections of this paper.

RESULTS

Paired sample t-tests revealed no significant change between any of the measures in T1/T2, T2/T3, or T1/T3. Specific results of these t-tests are explained in the following paragraphs.

Relative Advantage Tests

Relative advantage measures were examined via surveys administered during T1, T2, and T3.

HPWREN and Field Research Efforts

The first measure regarding relative advantage examined whether or not HPWREN improves research endeavors (by providing real-time data) of those participating in the survey. The majority (6 of 15) had no opinion during T1, eight of 15 at T2 agreed that HPWREN helped with research efforts, and nine of 15 at T3 had no opinion. It was no surprise, then, that paired sample t-test results garnered insignificant results (T1/T2: $t = -.25$, $p = NS$; T2/T3: $t = 1.20$, $p = NS$; T1/T3: $t = 1.38$, $p = NS$).

HPWREN and Teaching Endeavors

The second relative advantage measure looked at HPWREN and whether or not it helped the participating field scientists improve their teaching efforts by providing real-time data in the classroom environment. The majority (12 of 15) at T1 had no opinion, agreed, or strongly agreed that the network would help them improve their teaching endeavors while the frequencies were completely split during T2 (1 strongly disagreed, 4

disagreed, 4 had no opinion, 4 agreed, and 2 strongly agreed) and then back to no opinion at T3 (10 of 15 had no opinion). Therefore, again, insignificant t-tests results were not surprising (T1/T2: t = 1.58, p = NS; T2/T3: t = .00, p = NS; T1/T3: t = 1.38, p = NS).

HPWREN and Information Dissemination

The third relative advantage measure examined HPWREN's efficiency in allowing participants to better disseminate information to colleagues and applicable publics. At T1, the majority (13 of 15) had no opinion, agreed, or strongly agreed that the network would allow for better information dissemination while very similar results were found at T2 (12 of 15 either had no opinion, agreed, or strongly agreed); meanwhile, T3 results were the same as T1 (13 of 15 either had no opinion, agreed, or strongly agreed). The resulting insignificant t-test scores were expected (T1/T2: t = .27, p = NS; T2/T3: t = 1.72, p = NS; T1/T3: t = 2.47, p = NS).

HPWREN and Benefits Versus Costs

The fourth relative advantage measure looked at whether or not HPWREN's benefits outweigh the network's cost. The majority (14 of 15) of participants at T1 had no opinion, agreed, or strongly agreed that HPWREN benefits outweigh its costs. At T2, these same participants did not have a major change in opinion as 15 of 15 had no opinion, agreed, or strongly agreed that the network's benefits outweighs cost. And, again, at T3, the majority (14 of 15) had no opinion, agreed, or strongly agreed. Resulting t-tests were again insignificant (T1/T2: t = -1.32, p = NS; T2/T3: t = 2.58, p = NS; T1/T3: t = 1.57, p = NS).

HPWREN and Advantages Versus Disadvantages

The final relative advantage measure studied HPWREN advantages versus disadvantages. Again, the T1 majority (14 of 15 participants) had no opinion, agreed, or strongly agreed that HPWREN has more advantages than disadvantages. Meanwhile, all participants (15 of 15) at both T2 and T3 had no opinion, agreed, or strongly agreed that HPWREN's advantages are more so than its disadvantages. T-test results were again insignificant (T1/T2: $t = -1.74$, $p = NS$; T2/T3: $t = 2.26$, $p = NS$; T1/T3: $t = .00$, $p = NS$).

Compatibility Tests

Compatibility measures were examined via surveys administered during T1, T2, and T3.

HPWREN and Compatibility with Current Technology

The first compatibility measure examined the participants' current technology and whether or not the network is compatible with it. At T1, the majority (10 of 15) had no opinion, agreed, or strongly agreed, while the majority (11 of 15) at T2 also had no opinion, agreed, or strongly agreed. Meanwhile, all participants (15 of 15) at T3 had no opinion, agreed, or strongly agreed. T-test results were, again, insignificant (T1/T2: $t = .46$, $p = NS$; T2/T3: $t = -1.31$, $p = NS$; T1/T3: $t = -1.47$, $p = NS$).

HPWREN and Research Needs

The second compatibility measure looked at whether or not HPWREN assisted SMER field scientists in achieving their research goals. While the majority (9 of 15) at both T1 and T2 had no opinion, agreed, or strongly agreed that HPWREN helped participants meet their research goals, the majority (12 of 15) at T3 also had no opinion,

agreed, or strongly agreed. Again, insignificant t-test results were not surprising (T1/T2: t = .00, p = NS; T2/T3: t = .94, p = NS; T1/T3: t = .89, p = NS).

HPWREN and Current Data Collection Method

The third compatibility measure examined how well HPWREN worked with the scientists' current method of data collection. The majority (11 of 15) of participants at T1 had no opinion, agreed, or strongly agreed that they could use HPWREN without changing their current data collection method. Similarly, the majority (8 of 15) at T2 had no opinion or agreed while the majority (12 of 15) at T3 also had no opinion or agreed. T-test results were, yet again, insignificant (T1/T2: t = 1.07, p = NS; T2/T3: t = .27, p = NS; T1/T3: t = 1.71, p = NS).

HPWREN and Current Teaching Curriculum

The final compatibility measure considered HPWREN and whether or not the researchers' teaching curriculum would allow them to easily use the network for classroom purposes. Both T1 and T2 majority (10 of 15) had no opinion, agreed, or strongly agreed that they could use HPWREN without changing their teaching curriculum while T3 majority (11 of 15) had no opinion or agreed. Again, t-tests findings were insignificant (T1/T2: t = .81, p = NS; T2/T3: t = .52, p = NS; T1/T3: t = .94, p = NS).

Complexity Tests

Complexity measures were examined during surveys conducted during T1, T2, and T3. However, as aforementioned, complexity measures taken during T3 were not reliable enough for analysis (Cronbach's alpha .23).

HPWREN and Questions About the Network

The first complexity measure examined whether or not the participants had any questions about HPWREN. Both T1 and T2 majority (10 of 15) had no opinion, agreed, or strongly agreed that they had questions about the network ($t = -.81$, $p = NS$).

HPWREN and Difficult to Use

The second complexity measure looked at participants' perceptions regarding HPWREN's ease of use. While the majority (12 of 15) at T1 had no opinion, agreed, or strongly agreed that HPWREN would be somewhat difficult for them to use, 8 of 15 at T2 had no opinion, agreed, or strongly agreed. ($t = 1.19$, $p = NS$).

HPWREN and Need for Technical Assistance

The third complexity measure studied whether or not participants felt that they would have to acquire technical help when using HPWREN. Both the T1 and T2 majority (12 of 15) had no opinion, agreed, or strongly agreed that they would have to acquire technical help in order to use HPWREN ($t = -1.00$, $p = NS$).

Preference for Person-to-Person Technical Assistance

The fourth complexity measure examined participants' preference for person-to-person technical assistance versus other forms of technical help. Both T1 and T2 majority (14 of 15) agreed or strongly agreed that they prefer person-to-person technical assistance ($t = 2.26$, $p = NS$).

Knowledge of Networking Technology

The fifth complexity measure looked at the participants' knowledge of networking technology. The majority (11 of 15) at T1 disagreed or strongly disagreed that they were not very network knowledgeable while the majority (9 of 15) at T2

disagreed or strongly disagreed that they were not very network knowledgeable. T-tests were, again, insignificant ($t = -1.23$, $p = NS$).

Diffusion Communication Tests

Diffusion communication measures were examined via surveys administered during T2 and T3.

Communication Regarding HPWREN(Within Workplace)

When participants were asked about the way in which they perceived HPWREN diffusion communication, the majority (15 of 15) at T2 had no opinion, agreed, or strongly agreed that communication regarding HPWREN within their workplace was favorable. Very similarly, the T3 majority (14 of 15) also had no opinion, agreed, or strongly agreed. Needless to say, t-test results were insignificant ($t = .49$, $p = NS$).

Communication Regarding HPWREN (Outside Workplace)

Likewise, the majority of participants (15 of 15 at T2 and T3) queried about diffusion communication outside the workplace had no opinion, agreed, or strongly agreed that communication regarding HPWREN was favorable. T-test results were, again, insignificant ($t = 1.58$, $p = NS$).

Print Media and Electronic Communication about HPWREN

Another diffusion communication measure examined perceptions regarding print media communication about HPWREN; both the T2 and T3 majority (15 of 15) had no opinion, agreed, or strongly agreed that print media communication regarding HPWREN was favorable ($t = -1.38$, $p = NS$). Correspondingly, when the participants were asked about electronic diffusion communication, the majority (15 of 15) at T2 had no opinion, agreed, or strongly agreed that HPWREN-related electronic communication was

favorable while the majority (14 of 15) at T3 had no opinion, agreed, or strongly agreed (t = .62, p = NS).

Adoption Decision Tests

Adoption decision measures were examined via surveys administered during T2 and T3.

Current Use of HPWREN

The majority (11 of 15) of participants at T2 were not using the network while the majority (13 of 15) at T3 were also not using HPWREN (t = 1.47, p = NS). The author speculates that this lack of network use is related to the shift of research users within the reserve community; this is further explicated within the discussion section of the paper.

HPWREN Use in Future Work

Similarly, participants are either unsure or not aiming to use the network in their future work, and their decisions regarding adoption did not significantly change from T2 to T3. Specifically, 10 of the T2 participants and 11 of the T3 participants responded that they were either unsure or not going to use the network (t = 1.57, p = NS). Meanwhile, both the T2 and T3 majority (11 of 15) had no opinion, disagreed, or strongly disagreed (t = .72, p = NS) about their future use of HPWREN for research purposes during the upcoming year. Likewise, both the T2 and T3 majority (10 of 15 at T2 and 12 of 15 at T3) had no opinion, disagreed, or strongly disagreed (t = 1.60, p = NS) that they would use HPWREN for teaching purposes during the upcoming year. Finally, both the T2 and T3 majority (11 of 15 at T2 and 10 of 15 at T3 had no opinion, disagreed, or strongly disagreed (t = 1.32, p = NS) that they were likely to use HPWREN to do their work during the upcoming year.

DISCUSSION

Results using t-tests provided quantitative data regarding the participants' perceptions, communication, and use (or lack) of HPWREN at the reserve for the past three years. These results clearly indicate that there has been no significant change in the perceptions, communication, and use (or lack) of HPWREN over the past three years. While the author speculates that the reserve's field scientist user community is simply changing due to the technology implementation, the following qualitative comments collected at T3 provide additional insight regarding *why* these specific 15 field scientists have positive perceptions regarding the network, favorable communication regarding the network, yet they are still not using HPWREN:

> "We work in a situation where this system will not be used, but it is useful for other researchers that need this kindof real-time data." –watershed researcher

> "For various reasons, not related to HPWREN, we do not have any current active research at Santa Margarita." –global change researcher

> "I have not had the chance to use this system yet." –botany curator

> "Use of HPWREN is dependent on whether or not I can scrape up the money for the equipment necessary." –biologist

> "I haven't done any work on SMER for over 2 years now." –fish researcher

> "I know no more about HPWREN now than when I first spoke with you. It just doesn't apply to my research program, at least at present." –plant scientist

On the other hand, the two study participants that are actively using HPWREN, offered these comments (at T3):

> "This is one of the best tools and research efforts in science today in terms of producing capabilities that can empower science." –geography professor

> "Using technology in concert with education (& teaching) is a main area of my research." –biology professor

Perhaps the most important lesson learned during this study is that even though a social system thinks highly of an innovation does not necessarily mean that they are

going to adopt it; the author believes that before adoption occurs, the potential adopter must have a specific application for the innovation. Along these same lines, the author learned via the interviews that additional scientists have started using the reserve for research that requires high-performance networking capabilities; that is, there has been an apparent "turn over" of field scientists at the reserve since the development and implementation of HPWREN at SMER.

Even though this longitudinal study ended up only using 15 of the original 40 subjects, future research should include a more currently sample set of SMER field scientists. Specifically, the author knows of four researchers at the reserve who only recently started conducting their studies at SMER–explicitly using HPWREN to send and receive real-time data. Further research must include these new social system members in order to get a realistic picture of the community's adoption of HPWREN.

Future Implications

Because our society often relates environmental protection with technological innovations (Miller & Garnsey, 2000), it is important that scholars continue to research the diffusion process and publish their findings in applicable journals so that the information is widely disseminated. Further, longitudinal diffusion studies regarding communication during innovation development and implementation stages are sparse and greatly needed to truly understand how long it takes for a community to adopt (or not adopt) an innovation.

Additionally, researchers may be able to learn from the Dutch science shops, which have existed for more than 30 years (Farkas, 1999), and better match the agenda of environmental research with that of the greater community by providing not only

information about the issues and concerns at hand, but immediate ways that individuals can participate in both field science research and environmental protection initiatives.

Further, initiatives like HPWREN and NEON allow societal members other than those with the most education and financial resources to access information that is typically reserved for citizens that are the best-educated and most wealthy (Miller & Garnsey, 2000). That is, once the NSF has NEON sites in place, common citizens can virtually tour ecological observatories around the country, ranging from the mountaintops of Colorado's front range to the swamplands of the Mississippi delta. This type of network will not only be a resource that allows scientists to better communicate with one another and thereby promote interdisciplinary collaborations, but has the potential of serving as a national treasure to be shared by every citizen.

REFERENCES

Farkas, N. (1999). Dutch science shops: Matching community needs with university R&D. *Science Studies, 2,* 256-273.

Miller, D., & Garnsey, E. (2000). Entrepreneurs and technology diffusion: How diffusion research can benefit from a greater understanding of entrepreneurship. *Technology in Society, 22,* 445-465.

Reagan, J. (1989). New technologies and news use: Adopters vs. nonadopters. *Journalism Quarterly, 66,* 871-877.

Rice, R. E. (1994). Network analysis and computer-mediated communication systems. In S. Wasserman & J. Galaskiewicz (Eds.) *Advances in social network analysis* (pp. 167-203). Newbury Park, CA: Sage.

Rice, R. E. (1991). Organic organizations and centralized units: Use, contexts, and outcomes of word processing. In J. Morell & M. Fleischer (Eds.), *Advances in implementation and impact of computer systems* (pp. 111-141.). New York: JAI.

Rice, R. E., & Gattiker, V. E. (2001). New media and organizational structuring. In F. Jablin & L. Putman (Eds.), *The new handbook of organizational communication: Advances in theory, research, and methods* (pp. 544-581). Thousand Oaks, CA: Sage.

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.

Spitzberg, B. (2002). Preliminary Development of a Model and Measure of Computer Mediated Communication (CMC) Competence. Unpublished manuscript, San Diego State University.

Valente, T. W. (1996). Social network thresholds in the diffusion of innovations. *Social Networks, 18,* 69-89.

Valente, T. W., & Saba, W. P. (1998). Mass media and interpersonal influence in a reproductive health communication campaign in Bolivia. *Communication* Research, 25, 96-124.

APPENDIX A

T1 SURVEY QUESTIONS

TELEPHONE QUESTIONNAIRE SCRIPT

< > indicates note to interviewer only - not to be read aloud to subject.

<1. Enter phone number as ID variable.>
<In the case of missing data, indicate 9 in the applicable edge coding section.>

Hi. I'm a graduate student and am following up on an email that I sent you a few days ago regarding an NSF-funded research project that is providing Santa Margarita Ecological Reserve and the Sky Oaks Field Station with high-speed network connectivity.

I'm calling to ask you a few questions about the impact of the network upon your research and your teaching, and which future networking schemes could best benefit your work.

Basically, the two Field Stations are currently being connected to a high-speed network called HPWREN, which is funded by the National Science Foundation. The speed of the network is around 45 Megabits per second and will allow researchers like you to transmit large amounts of real-time information from the field station to the campus database where it can be readily accessed by researchers and students through a website. An in-field station network of automated data acquisition towers are also being developed; these towers are intended to assist researchers like you with data collection methods.

As mentioned in my email, I'd like to ask you a few questions about the impact of this network connectivity upon your research.

2. What will you and your team need to utilize the network? (Answer yes to as many of these as applicable). Do you need...

a. computer equipment
b. specialized sensors
c. technical assistance/support (e.g., technician)
d. training
e. other: _____

3. What are your sources of data for your field experiments? (Again, answer yes to as many of these as applicable). Do you use...

a. soil samples from plots
b.climate data from tower
c. other: _____

4. What are your current datalogging methods? Do you...

a. write in field book, data forms, or maps, and later type into computer
(computer brand/model: _____)
b. type directly into PDA from field
(PDA brand/model:_____)
c. laptop computer
(laptop brand/model:_____)
d. other: _____

5. Does your research...

a. Always
b. Sometimes
c. Seldom or
d. Never

...require continuous measurements (continuous = measurements that are taken more than once per day)?

6. What is your sample interval (how often)?

7. Do you...
    a. Always
    b. Sometimes
    c. Seldom or
    d. Never
...use specific sensors (e.g., cameras, meteorological data, soil probes, etc)?

8. Describe the sensors that you use: past, present, and hopefully future (i.e., what types of data could be useful for you in the future)?

Okay, that sounds really interesting. I'll make sure and relay that information to Sedra and Hans-Werner. Now, I have a few more questions for you. If I were putting words into your mouth about the following statements, would you strongly agree, agree, have no opinion, disagree, or strongly disagree....

9. HPWREN will help me improve my research endeavors by providing me with better access to real-time data than my current system. Do you...
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)
...with that statement?

10. HPWREN will help me improve my teaching efforts by providing me with improved access to real-time data in the classroom setting.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

11. HPWREN will allow me to disseminate research information to colleagues and applicable publics in a more efficient manner.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

12. All things considered, HPWREN benefits outweigh costs.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

13. Overall, HPWREN has more advantages than disadvantages.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

14. HPWREN would be very compatible with my current technology.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

15. I will need little specialized training to use HPWREN technology.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

16. HPWREN meets several technological needs of my research project.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

17. I will be able to use HPWREN for research purposes, without changing the structure of my field data collection procedures.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

18. I will be able to use HPWREN for teaching purposes, without significantly changing the structure of my course curricula.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

19. I have questions about the basic concepts of HPWREN and how real-time field data collection and transmission works.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

20. HPWREN will be somewhat difficult for my staff and me to use for data collection and transmission.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

21. I will have to acquire the help of a technical person to help me with the use of HPWREN.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

22. When I have a problem with a technological device, I prefer person-to-person technical assistance.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

23. I am not very knowledgeable about technology and do not currently feel comfortable using HPWREN.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

Okay, I just have one final question for you...

24. In the context of measuring the impact of broadband connectivity upon your field research, can you think of other things you would like to communicate that I should have asked you about? Or, do you have any comments that you would like to add for my study?

Once the network connectivity is in place, I will be contacting you for a post-test evaluation. I really appreciate your time. Thank you.

APPENDIX B

T2 and T3 SURVEY QUESTIONS

1. HPWREN will help me improve my research endeavors by providing me with better access to real-time data than my current system. Do you...

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1) ...with that statement?

3. HPWREN will help me improve my teaching efforts by providing me with improved access to real-time data in the classroom setting.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

4. HPWREN will allow me to disseminate research information to colleagues and applicable publics in a more efficient manner.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

5. All things considered, HPWREN benefits outweigh the costs.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

6. Overall, HPWREN has more advantages than disadvantages.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

7. HPWREN would be very compatible with my current technology.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

8. I will need little specialized training to use HPWREN technology.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

9. HPWREN meets several technological needs of my research project.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

10. I will be able to use HPWREN for research purposes, without changing the structure of my field data collection procedures.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

11. I will be able to use HPWREN for teaching purposes, without significantly changing the structure of my course curricula.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

12. I have questions about the basic concepts of HPWREN and how real-time field data collection and transmission works.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

13. HPWREN will be somewhat difficult for my staff and me to use for data collection and transmission.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

14. I will have to acquire the help of a technical person to help me with the use of HPWREN.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree, or (2)
    e. Strongly disagree (1)

15. When I have a problem with a technological device, I prefer person-to-person technical assistance.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)

d. Disagree, or (2)
e. Strongly disagree (1)

16. I am not very knowledgeable about technology and do not currently feel comfortable using HPWREN.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

17. The information that I have received and heard about HPWREN from colleagues within my workplace has been favorable.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

18. The information that I have received about HPWREN from acquaintances outside of my workplace has been favorable.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

19. The information that I have received and heard about HPWREN from print media (e.g., newspapers, magazines) has been favorable.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

20. The information that I have received and heard about HPWREN from broadcast media (e.g., television, radio) has been favorable.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

21. The information that I have received and heard about HPWREN from electronic media (e.g., websites, electronic newsletters) has been favorable.

a. Strongly agree (5)
b. Agree (4)
c. Have no opinion (3)
d. Disagree, or (2)
e. Strongly disagree (1)

22. Are you currently using HPWREN?
    a. Yes (2)
    b. No (1)

23. Will you use HPWREN in your future work?
    a. Yes - Definitely (5)
    b. Yes - Probably - (4)
    c. Unsure (3)
    d. No - Probably (2)
    e. No - Definitely (1)

24. I am likely to use HPWREN in my research in the coming year.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree (2)
    e. Strongly disagree (1)

25. I am likely to use HPWREN in my teaching in the coming year.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree (2)
    e. Strongly disagree (1)

26. I am likely to use HPWREN in some way in my work in the coming year.
    a. Strongly agree (5)
    b. Agree (4)
    c. Have no opinion (3)
    d. Disagree (2)
    e. Strongly disagree (1)

Okay, I just have one final question for you...
27. In the context of measuring the impact of broadband connectivity upon your field research, can you think of other things you would like to communicate that I should have asked you about? Or, do you have any comments that you would like to add for my study?