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BRIDGES (1994–2009)

BRIDGES is a recurring feature of J-NABS intended to provide a forum for the interchange of ideas and information between basic and applied researchers in benthic science. Articles in this series will focus on topical research areas and linkages between basic and applied aspects of research, monitoring policy, and education. Readers with ideas for topics should contact Associate Editors…

BRIDGES (2009–present)

BRIDGES is a recurring feature of J-NABS intended to provide a forum for the interchange of ideas and information relevant to J-NABS readers, but beyond the usual scope of a scientific paper. Articles in this series will bridge from aquatic ecology to other disciplines, e.g., political science, economics, education, chemistry, or other biological sciences. Papers may be complementary or take alternative viewpoints. Authors with ideas for topics should contact Associate Editors...

BRIDGES: evolution of basic and applied linkages in benthic science

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Abstract. Growing awareness of environmental degradation resulted in stricter environmental regulations and laws for aquatic ecosystems. These regulations were followed by an increase in applied research and monitoring beginning in the early 1970s. The number of applied scientists who were members of the North American Benthological Society grew at a commensurate rate. The editors of *J-NABS* recognized that, despite these increases, submitted manuscripts mostly addressed basic science. In response, the *BRIDGES* section of *J-NABS* was created in 1994 to provide a forum for linking basic ecological principles to applied science problems and issues. We examined the emergence of applied science topics in *J-NABS* and its predecessor, *Freshwater Invertebrate Biology*, from their beginning in 1982 to 2009. We classified papers among 11 categories that included a basic/applied science linkage. In the 1980s, applied papers were predominantly on effects of eutrophication/pollution and landuse changes. When *BRIDGES* was established in 1994, papers were solicited by editors and *BRIDGES* sections usually included >1 paper on a common theme to express complementary or alternate viewpoints. Forty-two papers appeared in *BRIDGES* between 1994 and 2009, but the number per issue declined after 2001. The total number of applied science papers in *J-NABS* has increased since ~1994. Citation analysis of *BRIDGES* papers illustrates how information is being cited, but applied papers often are used in ways that might not lead to citations. *BRIDGES* transitioned to a new format in September 2009 to address new types of complex, multifaceted linkages. All new *BRIDGES* articles will be open access, and authors will be encouraged to produce lay-language fact sheets and to post them on the web.

Key words: *BRIDGES* articles, *J-NABS*, applied science, basic science, bioassessment, monitoring.

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Growing awareness of the importance of the health of our planet's freshwater and marine ecosystems has led to an increase in applied research over the past several decades. This shift in research focus has

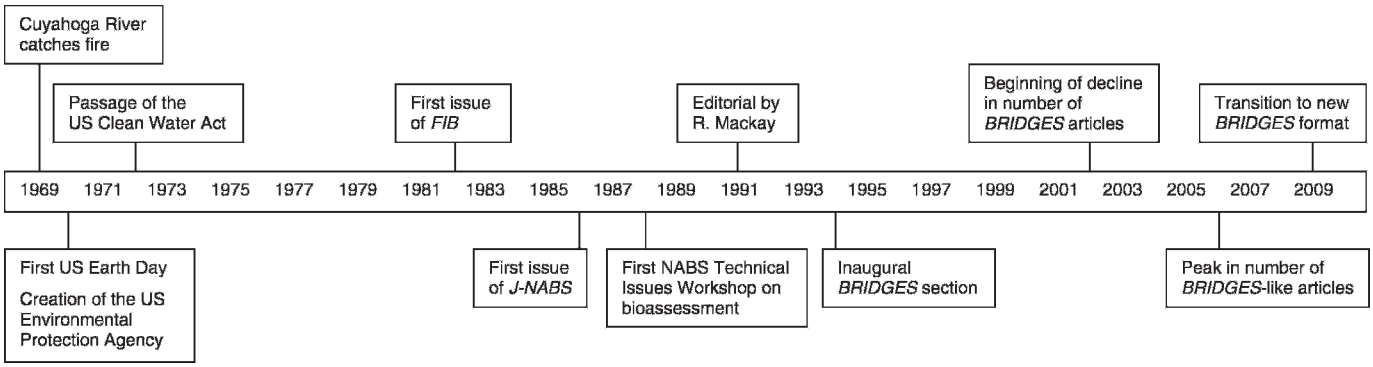

FIG. 1. Timeline of significant events related to publication of papers related to applied issues in *J-NABS*. *FIB = Freshwater Invertebrate Biology*.

produced an increase in science that highlights the challenges to ecosystems and helps guide protection and restoration efforts. The emergence of threats to aquatic ecosystems was gradual or out of the public eye until pollution and degraded water quality became noticeable. Public perception of these problems increased sharply when the Cuyahoga River caught fire in 1969 (Fig. 1). The river had burned several times before 1969, sometimes with even greater damage than in 1969, but this fire became the subject of an editorial in a US national news magazine, which included the description, ''it oozes rather than flows'' (Time 1969). This event and increased environmental awareness of US citizens led to the first Earth Day celebration in Washington, DC, in 1970 (Fig. 1), the transformation of the Water Pollution Control Federation into the US Environmental Protection Agency in 1970 (Fig. 1), and enactment of much more stringent water quality protection legislation in 1972 (US Clean Water Act; US Senate Public Works Committee 1972; Fig. 1).

Growing environmental awareness coupled with more stringent environmental regulations and laws was accompanied by an increase in research and monitoring directed to applied topics. Funding entities probably shifted their priorities to more applied topics at the same time. Scientific publications on applied subjects began to increase in the peer-reviewed literature from the 1970s through the 1980s, and scientific journals that targeted submissions in the applied sciences began to appear in the same time frame. Examples include *Journal of Applied Ecology*, *Journal of Environmental Management*, *Environmental Monitoring and Assessment*, and *Ecological Applications*. The emergence of the applied sciences probably was related to increases in government funding for monitoring and assessment of surface water ecological condition. Public and private funding sources for applied science have increased since the 1970s, but this increase is difficult to quantify and document. A good indicator of this shift is the evolution of the structure and curricula of many academic institutions toward greater emphasis in departments and degree programs on interdisciplinary and applied science components, particularly environmental policy. Shifts in public attitudes and government policy spurred the National Research Council (1992) to highlight the increased need for broadly trained, interdisciplinary scientists to assist with resource management and restoration. Aumen and Havens (**1997**[1]) called for a new cadre of applied scientists and recommended that university departments and faculty foster academic environments that encourage research and student enrollment in the applied sciences.

Natural resource policy and management require application of science-based decision making. Scientific approaches needed for this type of ecosystem-level understanding include a balance of observational and monitoring studies; hypothesis-driven experimental research; and physical, chemical, and ecological modeling (Havens and Aumen 2000). Observational and monitoring studies, especially with long-term, historical data, are important for assessing ecosystem patterns, trends, and changes (e.g., the National Science Foundation's Long-Term Ecological Studies network, http://www.lternet.edu/). Hypothesis-driven experimental research is required to determine cause-and-effect relationships via use of proper experimental design. Modeling can be used as a predictive tool, to understand data needs to improve model performance, and to gauge our understanding of environmental processes. Use of these 3 approaches in combination results in better understanding of ecosystems, their responses to stress, and how to protect and restore them from degraded states than

[1] Boldface indicates article was published in *J-NABS*

does use of any of these approaches alone (Havens and Aumen 2000).

In the early period of applied ecological science, submission of manuscripts based on monitoring or comparative field studies to scientific journals often ended in rejection for low scientific rigor, either because of poor study design or weak data analysis. These shortcomings might have been related to lack of agency funding or underappreciation of sound science by agency management. Some manuscripts might have been rejected because their basic scientific contribution was not new or unique even though the findings might have had new management-related significance. University faculty and graduate students might have thought that applied research was less exciting than basic research and that publication in grey literature would not lead to tenure. However, the need for better linkages between basic and applied science was apparent—applied research requires the same stringent criteria, good experimental design, sound data analysis, and synthesis of results that are required by basic science. Results from applied research that blends basic and applied approaches can have transfer value beyond their specific management or restoration objectives.

Many members of the North American Benthological Society (NABS) had been working in the applied sciences since the Society's 1953 inception as the Midwest Benthological Society. Archival correspondence from the first meeting's organizer indicated interest in "starting an organization composed of all Biologists interested in bottom fauna of streams and lakes, and in general, any biology connected with stream pollution" (Mackay 2005). Mackay noted that the first society members included several employed by state agencies concerned with water pollution. By the 1980s, the number of nonacademic agency scientists who were joining NABS as members and were attending annual meetings was growing. However, topics of manuscripts submitted to the journal were predominantly basic sciences. Members of NABS and the Editor of *J-NABS* recognized the emergence of applied sciences within the society. In response, a section entitled *BRIDGES* was created in *J-NABS* in 1994 to encourage submissions by applied scientists and to facilitate the linkages between the basic and applied sciences.

The objectives of our paper are to: 1) examine the emergence of applied science topics in *J-NABS* from the mid-1980s to the present, 2) discuss the role that *BRIDGES* might have played in that emergence, 3) analyze the effect that *BRIDGES* and *BRIDGES*-like articles have had on applied science published in *J-NABS*, and 4) discuss future directions for *BRIDGES*. Other journals also published applied articles related to aquatic pollution during the same time frame. These applied articles are important to consider but are outside of our analysis.

Evolution of Applied Research Articles before *BRIDGES*

How applied articles were identified and counted

The forerunner of *J-NABS* was *Freshwater Invertebrate Biology* (*FIB*). *FIB* was first published in 1982 (Fig. 1) and *J-NABS* was first published in 1986 (Fig. 1). Our retrospective analysis of the effect of *BRIDGES* included examination of the contribution of applied science in the early days of *J-NABS* and *FIB*. Pre-*BRIDGES* papers were published from 1982 (the first issue of *FIB*) to 1993 (the last issue before the appearance of the *BRIDGES* section). The *BRIDGES* section was first published in 1994 (Fig. 1), but subsequent articles with an applied science component also were published in the regular section of the journal. We refer to papers that dealt with topics similar to *BRIDGES* topics and appeared in the regular section of the journal as *BRIDGES*-like.

We identified articles in *FIB* and in *J-NABS* that had an applied science component in the title or abstract. Both the *BRIDGES* section and *BRIDGES*-like papers published after 1994 in the regular section of the journal were examined to evaluate fully the articles linking applied and basic sciences in *J-NABS* because *BRIDGES* might have influenced the number of *BRIDGES*-like papers in the journal. We assigned each article to ≥ 1 of 11 applied topics: response to disturbance, restoration/rehabilitation, landuse changes/landscapes, dam effects, acidification, eutrophication/pollution, methods, bioassessment/biomonitoring, exotic species, policy/regulatory issues, and miscellaneous. These categories were chosen subjectively, but we think they represent the general range of topics covered by papers with an applied/basic science linkage. We occasionally assigned a paper to >1 topical category, e.g., methods and bioassessments (e.g., **Norris 1995**), or bioassessments and policy/regulatory issues (e.g., **Jackson and Davis 1994**).

We analyzed the number of articles in each topical category for each year of publication. Publication of series of papers on special topics skewed the results for some years. If a special series included topics related to applied/basic science linkages, the numbers for that particular year were unusually high. Likewise, if a special series topic was not related to applied/basic science linkages, publication of those articles could have displaced linkage papers to later volumes and caused the number of applied articles for that year to be unusually low.

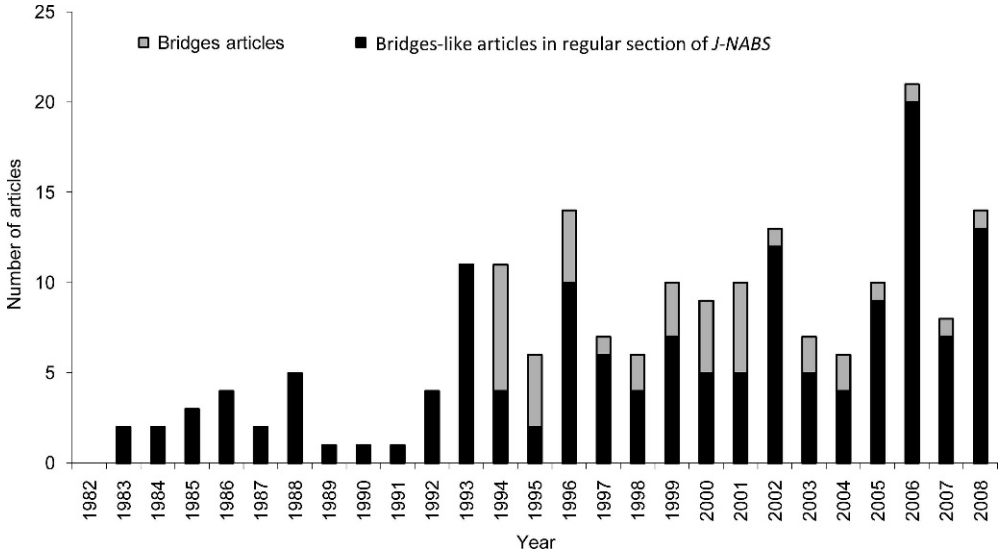

FIG. 2. Number of *BRIDGES*-like articles/y from 1982 through 2008 and number of *BRIDGES* articles/y from the inception of *BRIDGES* in 1994 through 2008.

Trends in applied topics in J-NABS *from 1982 to 1994*

Two papers that had an applied aspect appeared in *FIB* in 1983. One related mayfly distribution to the occurrence of oil in bottom sediments (Hiltunen and Schloesser 1983) and the other examined the use of chironomid taxon richness for pollution assessment (Lenat 1983). Overall, the number of applied science papers per year increased from 1982 through 1993 (Fig. 2). The average number of *BRIDGES*-like papers/y was 3.0 and ranged from 0 to 11 (Fig. 2). These applied papers were mostly on the topics of eutrophication/pollution and the effects of landuse changes (Table 1). Other topics covered were responses to disturbance, effects of dams, and methods. Papers on restoration/rehabilitation, exotic species, and until 1993, policy/regulatory issues were mostly absent during this early period. We categorized only one paper (**Lenat 1993**) as bioassessment. The spike in the number of applied papers in 1993 was from a special series of 9 papers (plus an introduction) ''Perspectives on Freshwater Conservation'' (volume 12, issue 2), resulting from a special session held at a previous NABS annual meeting and published in the Perspectives section of *J-NABS*. These papers promoted cooperation and communication between the scientific community and freshwater conservation programs of nongovernmental organizations (**Pringle and Aumen 1993**). All of these papers included policy/regulatory topics, so that category was well-represented in 1993, just before the first *BRIDGES* section was published. The decisions to include or exclude series of papers from our analysis were difficult. However, this Perspectives series would have been appropriate for the *BRIDGES* section had the section existed at that time, so we included the 9 papers (but not the introduction paper). If this series is excluded from our analysis, the number of applied science papers shows no apparent trend from 1982 until 1993.

Genesis and Evolution of *BRIDGES*

In the 1980s, talks at annual meetings of NABS were based predominantly on academic research and basic aquatic science. Topics of concern to applied benthic scientists, such as those working for government agencies, were not well represented. However, basic science advances in aquatic invertebrate systematics and life histories were laying the groundwork for subsequent applied studies, such as bioassessment. Concerns about the lack of balance between basic and applied topics at annual meetings increased at the 1985 meeting in Corvallis, Oregon, where the program emphasized basic science with few applied papers. Meeting attendance by applied biologists had declined in the late 1970s and early 1980s, as evidenced by a decline in the number of presentations on biological assessment (Wallace 1992), and this trend increased concern that a lack of balance might be to blame.

Karl Simpson, a biologist with the New York Department of Environmental Conservation, and Michael Barbour, an environmental consultant, began a dialogue about how to encourage more participation by state biologists in NABS meetings. Simpson and

TABLE 1. Evolution of applied/basic science topics in *J-NABS* before and after the inclusion of the *BRIDGES* section. *BRIDGES*-like articles are those applied/basic science topics that appeared in the regular section of *J-NABS* before and after the *BRIDGES* section began. *BRIDGES* articles refers solely to those applied/basic science topics appearing in the *BRIDGES* section. Any one article could cover more than one topic, so the numbers in this table do not reflect the actual number of *J-NABS* articles.

Topic	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
BRIDGES-like articles																												
Response to disturbance					1	1					1	1	1					1									1	7
Restoration/rehabilitation												1															1	2
Landuse changes/landscapes				2	2				1		1				2		1	2	1					2	4	2	1	21
Dam effects			1		1		1	1																1	2			7
Acidification						1									1					1							1	4
Eutrophication/pollution		2	1	1			3				1	2	2	1	3	1			2		3	3	1	3	8	1	2	40
Methods							1			1	1				1	1	1	1	1		1				1	1	8	19
Bioassessment/biomonitoring												1		1	4	2	2	1	1	2	3	2	1	3	7	2	16	48
Exotic species															1		1	1		1	4							8
Policy/regulatory issues												9															2	11
Miscellaneous													1					1		1							1	4
BRIDGES articles																												
Response to disturbance																												
Restoration/rehabilitation																							1	1			1	3
Landuse changes/landscapes																		1	2				1					4
Dam effects																												
Acidification																												
Eutrophication/pollution																									1			1
Methods													3	4	3		1	1		5		2						19
Bioassessment/biomonitoring													2	2	3		2	1	1	4	1	2	1			1		20
Exotic species																												
Policy/regulatory issues													7	2	1	1		2	2	1					1			17
Miscellaneous																				1							1	2

Barbour hoped to increase attendance by holding a special session on state biological programs at a future meeting. They organized such a session at the 1986 annual meeting in Lawrence, Kansas, and worked with state and federal agencies to publicize the session. This meeting set the stage for future sessions devoted to agency programs, mainly on the topics of bioassessment and technical issues associated with water-resource management. The 1987 annual meeting in Orono, Maine, was organized by applied biologists from the Maine Department of Environmental Protection in collaboration with researchers from the University of Maine. This meeting successfully united basic and applied researchers with common goals within the benthic sciences and reinforced the importance of applying ecological principles as a basis for making informed decisions regarding water quality. At the 1988 annual meeting in Tuscaloosa, Alabama, the first Technical Issues Workshop (on bioassessment) was organized by Jim Gore and Tom LaPoint (Fig. 1). Attendance was so high that a second room and televised transmission of the presentations were required (Mackay 2005). This response indicated that discussions of applied science commanded more than a passing interest from NABS members.

By the early 1990s, the dialogue on linkages between basic researchers and applied biologists had become a prominent feature of NABS meetings. Bioassessment sessions increased to 6 or 7 sessions at each meeting. Nevertheless, the number of applied papers submitted to *J-NABS* remained low. In a 1991 *J-NABS* editorial, Managing Editor Rosemary Mackay expressed concern about low numbers of applied manuscripts that were submitted and the resulting uneven coverage between basic and applied science (**Mackay 1991**; Fig. 1). She worried that applied scientists might have felt that their contributions were not welcomed by the journal, despite the Society's long tradition of including both basic and applied scientists since its inception in 1953.

The idea of *BRIDGES* originated with Dave Lenat, who worked for the North Carolina Department of Environment, Health, and Natural Resources. In June 1992, he wrote to *J-NABS* Associate Editors Michael Barbour and Marty Gurtz and articulated the views of agency scientists that the journal should try to attract more papers from applied scientists. Lenat proposed that a series of short (2–3-page) position papers be solicited from prominent scientists in both basic and applied sciences, with opportunities for comments to be published in later issues of the journal or the NABS *Bulletin*. A joint proposal was submitted in March 1993 by Lenat, Barbour, and Gurtz for *J-NABS* to create a forum to explore the linkages between basic and applied researchers. With consensus support of the *J-NABS* Editorial Board, the formation of *BRIDGES* was announced at the 1993 Annual Meeting in Calgary, Canada, with Barbour and Gurtz serving as co-editors.

BRIDGES brought several unique features to *J-NABS*. First, the co-editors were given flexibility to select a theme for each issue of *BRIDGES* and to solicit submissions addressing contrasting or complementary aspects of that theme. Submissions were not subjected to anonymous peer reviews because these articles were not expected to include new data or research results. Instead, Barbour and Gurtz worked with the authors directly to prepare manuscripts that were sent to the Editor for final editorial decisions. Other early features included: a preamble explaining the section and providing a synopsis for that issue, brief biographies to provide context for the authors' perspectives, and binding together all articles for each issue of *BRIDGES* in a single reprint, so that recipients would benefit from the complementary or alternative views. As incentives to encourage submissions, no page charges were required, and a small number of the bound reprints were provided free to each author, with an expectation that many of them would reach applied science practitioners having little familiarity with the journal.

The inaugural issue in March 1994 addressed the contributions by basic scientists to the growing field of biological monitoring and the role of applied science in providing a framework and data for testing ecological theories (Table 2). Authors represented an academically respected research institution (David Hart, Academy of Natural Sciences of Philadelphia; **Hart 1994**) and a state agency that was a leader in biological monitoring (David Courtemanch, Maine Department of Environmental Protection; **Courtemanch 1994**). In the inaugural issue, the *J-NABS* editor continued her encouragement for equal contributions to *J-NABS* by basic and applied benthologists (**Mackay 1994**). She presented the following suggestions for topics: 1) research required to achieve legislative mandates, 2) applications of basic research to the design and interpretation of biomonitoring studies, 3) education and training, 4) role of volunteers in biological monitoring and conservation programs, 5) the line between basic and applied research, 6) collaboration in basic and applied research, and 7) applying ecological knowledge to conservation issues. The 2nd issue, in September 1994, highlighted collaboration among government agencies at local, state, and federal levels (Chris Yoder, Ohio Environmental Protection Agency; **Yoder 1994**) and between lotic scientists and conservation biolo-

gists (Charles Dewberry, Pacific Rivers Council, and Catherine Pringle, University of Georgia; **Dewberry and Pringle 1994**) (Table 2).

Subsequent issues of *BRIDGES* addressed topics including biological integrity, volunteer monitoring, and challenges associated with the concepts of aquatic ecosystem health and integrity (Table 2). Other themes included methods and approaches directly applicable to bioassessment. One example was a series about the use of subsampling methods in benthic sample processing for basic research or for applications, such as development of numerical biological criteria. This issue was unusual in that the author (**Courtemanch 1996**) of a paper that originally was submitted as a regular article agreed to have the article appear in *BRIDGES* along with papers presenting contrasting views (**Barbour and Gerritsen 1996**, **Vinson and Hawkins 1996**), mainly regarding the use of organism-based (fixed-count) subsampling procedures. These articles stimulated considerable interest, and 2 subsequent *BRIDGES* articles addressed the same topic (**Larsen and Herlihy 1998**, **Sovell and Vondracek 1999**).

BRIDGES also sparked some international interest. More than ¼ (7) of the first 25 issues of *BRIDGES* had at least one author from outside the US. In some cases, the articles described how a topic of broad interest was being addressed in a particular country, e.g., water law in South Africa (**Palmer 1999**) or comparisons of regions delineated based on physicochemical vs macroinvertebrate indicator data in Australia (**Newall and Wells 2000**).

Most of the themes during the first 2 y of *BRIDGES* were chosen by the co-editors. However, interest in the section led to suggestions of many topics by potential contributors and often resulted in single-paper issues in which one author presented both basic and applied perspectives. At the same time, *BRIDGES* drifted from its initial format of complementary papers on a common theme toward single-paper issues (Table 2). In some cases, e.g., the December 2000 issue devoted to lotic–lentic linkages, the papers were the product of a special session or symposium.

BRIDGES evolved in other ways as well. Some papers included previously unpublished research data and, sometimes, sophisticated data analyses, so peer review became the norm, and *BRIDGES* papers began to be treated identically to all journal submissions. Exemption from page charges was dropped, and reprints were no longer provided gratis after Volume 19 in 2000. Another signal that *BRIDGES* articles were becoming less distinguishable from other *J-NABS* papers was inclusion of abstracts beginning in 2002.

Evolution of Applied Science Articles Subsequent to *BRIDGES*

Pattern and trends of applied articles in J-NABS

The total number of *BRIDGES* articles/y has varied from 1 to 7, with the highest number appearing in 1994 (Fig. 2). Over the most recent 6 y, only 1 or 2 *BRIDGES* articles/y have been published (Fig. 1). In contrast, the number of applied science articles published in *J-NABS* outside the *BRIDGES* section has increased. The peak occurred in 2006 (Fig. 1), with the publication of 20 papers, 11 of which were associated with the series ''Source-water Monitoring: Combining Basic and Applied Research'' (volume 25, issue 4). This series supported the goals of *BRIDGES* by addressing many basic and applied aspects of a common issue—enhanced water-quality monitoring of New York City's water-supply catchment (**Sweeney et al. 2006**). The proportion of total *J-NABS* articles that addressed bioassessment alone increased from about 10% in the mid-1980s to >30% now (**Dolédec and Statzner 2010**). This generally increasing trend of applied science articles in the journal might reflect the influence of the *BRIDGES* section or broader national and international shifts in research focus or funding priorities, or both.

The total number of *J-NABS* pages devoted to *BRIDGES* articles/y has varied from a high of 74 in 2001 to a low of 6 in 2006 (Fig. 3). The peak number of pages/y was in 2001 when 3 papers on the issue of taxonomic resolution (**Bailey et al. 2001**, **Hill et al. 2001**, **Lenat and Resh 2001**) and additional papers on forensic benthic ecology (**Keiper and Casamatta 2001**) and benthic monitoring programs (**Carter and Resh 2001**) were published.

The nature of the content of *BRIDGES* and *BRIDGES*-like papers has evolved. Early *BRIDGES* papers were solicited by *BRIDGES* co-editors, and often had companion papers with other viewpoints. Over time, the co-editors reduced the practice of actively soliciting submissions on specific topics, and subsequent papers tended to include more data and data analyses. Some *BRIDGES* articles were relatively data-rich, as evidenced by the number of data figures and tables per page of *BRIDGES* articles from 1996 to the present (Fig. 4). Other *BRIDGES* articles had tables and figures, but these tools typically were used to present concepts and themes rather than actual data.

Topics addressed by applied articles in *J-NABS* have changed since 1994. Early *BRIDGES* articles addressed methods, bioassessment/monitoring, and policy/regulatory issues (Table 1). The linkage between basic science and policy/regulatory issues was heavily emphasized, but other topics well suited for

TABLE 2. Chronological list of *BRIDGES* articles appearing in *J-NABS* and their associated themes.

No.	Year	Author(s)	Title	Theme
1	1994	Hart	Building a stronger partnership between ecological research and biological monitoring	Building bridges
2	1994	Courtemanch	Bridging the old and new science of biological monitoring	Building bridges
3	1994	Yoder	Toward improved collaboration among local, state, and federal agencies engaged in monitoring and assessment	Success stories
4	1994	Dewberry and Pringle	Lotic science and conservation: moving toward common ground	Success stories
5	1994	Jackson and Davis	Meeting the goal of biological integrity in water-resource programs in the US Environmental Protection Agency	Biological integrity
6	1994	Polls	How people in the regulated community view biological integrity	Biological integrity
7	1994	Steedman	Ecosystem health as a management goal	Biological integrity
8	1995	Firehock and West	A brief history of volunteer biological water monitoring using macroinvertebrates	Volunteer monitoring
9	1995	Penrose and Call	Volunteer monitoring of benthic macroinvertebrates: regulatory biologists' perspectives	Volunteer monitoring
10	1995	Norris	Biological monitoring: the dilemma of data analysis	Data analysis
11	1995	Gerritsen	Additive biological indices for resource management	Data analysis
12	1996	Scrimgeour and Wicklum	Aquatic ecosystem health and integrity: problems and potential solutions	Aquatic ecosystem health and integrity
13	1996	Courtemanch	Commentary on the subsampling procedures used for rapid bioassessments	Subsampling
14	1996	Barbour and Gerritsen	Subsampling of benthic samples: a defense of the fixed-count method	Subsampling
15	1996	Vinson and Hawkins	Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams	Subsampling
16	1997	Aumen and Havens	Needed: a new cadre of applied scientists skilled in basic science, communication, and aquatic resource management	Training benthologists
17	1998	Leff and Lemke	Ecology of aquatic bacterial populations: lessons from applied microbiology	Applied aquatic microbiology
18	1998	Larsen and Herlihy	The dilemma of sampling streams for macroinvertebrate richness	Subsampling
19	1999	Palmer	Application of ecological research to the development of a new South African water law	Water law in South Africa
20	1999	Sovell and Vondracek	Evaluation of the fixed-count method for Rapid Bioassessment Protocol III with benthic macroinvertebrate metrics	Subsampling
21	1999	Kirkman et al.	Biodiversity in southeastern, seasonally ponded, isolated wetlands: management and policy perspectives for research and conservation	Wetlands
22	2000	Dodds and Welch	Establishing nutrient criteria in streams	Nutrient criteria
23	2000	Newall and Wells	Potential for delineating indicator-defined regions for streams in Victoria, Australia	Regionalization
24	2000	Steinman and Rosen	Lotic–lentic linkages associated with Lake Okeechobee, Florida	Lotic–lentic linkages
25	2000	Benenati et al.	Reservoir–river linkages: Lake Powell and the Colorado River, Arizona	Lotic–lentic linkages
26	2001	Cao et al.	Rare species in multivariate analysis for bioassessment: some considerations	Multivariate analysis: rare species
27	2001	Bailey et al.	Taxonomic resolution of benthic macroinvertebrate communities in bioassessments	Taxonomic resolution
28	2001	Lenat and Resh	Taxonomy and stream ecology – the benefits of genus- and species-level identifications	Taxonomic resolution
29	2001	Hill et al.	Comparison of correlations between environmental characteristics and stream diatom assemblages characterized at genus and species levels	Taxonomic resolution
30	2001	Keiper and Casamatta	Benthic organisms as forensic indicators	Forensic benthic ecology
31	2001	Carter and Resh	After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies	Benthic monitoring programs
32	2002	Stevenson and Hauer	Integrating Hydrogeomorphic and Index of Biotic Integrity approaches for environmental assessment of wetlands	Environmental assessment of wetlands

TABLE 2. Continued.

No.	Year	Author(s)	Title	Theme
33	2003	Nerbonne and Vondracek	Volunteer macroinvertebrate monitoring: assessing training needs through examining error and bias in untrained volunteers	Volunteer monitoring
34	2003	Stribling et al.	Determining the quality of taxonomic data	Quality of taxonomic data
35	2004	Fortino et al.	Utility of biological monitoring for detection of timber harvest effects on streams and evaluation of Best Management Practices: a review	Biomonitoring of timber harvest effects
36	2004	Moerke et al.	Restoration of an Indiana, USA, stream: bridging the gap between basic and applied lotic ecology	Stream restoration
37	2005	Booth	Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America	Restoring urban streams
38	2006	Sweeney et al.	Enhanced source-water monitoring for New York City: summary and perspective	Water-quality monitoring
39	2007	Whittier et al.	Selecting reference sites for stream biological assessments: best professional judgment or objective criteria	Reference sites
41	2008	Nerbonne et al.	Effect of sampling protocol and volunteer bias when sampling for macroinvertebrates	Volunteer monitoring
42	2009	Tullos et al.	Analysis of functional traits in reconfigured channels: implications for the bioassessment and disturbance of river restoration	Stream restoration

BRIDGES, such as response to disturbance, dam effects, effects of acidification, and exotic species, remained unexplored. Papers on these topics were either not solicited actively by the co-editors or were unsolicited submissions published in the regular section of the journal. The topic of bioassessment became very popular in both *BRIDGES* and the regular section of the journal. Several *BRIDGES* papers contributed to the development of ecological integrity assessments (**Dolédec and Statzner 2010**). Examples include discussions of data analysis (**Norris 1995**) and taxonomic levels for bioassessment (**Lenat and Resh 2001**).

Citation analysis of BRIDGES *articles*

Citation analysis is one way to examine how applied science articles published in *J-NABS* are being used. We analyzed only those articles published in *BRIDGES* and used the Institute for Scientific Information (ISI) Web of Science (Thomson Reuters 2008) as the database (analyses done in August 2009). Of 42 *BRIDGES* articles through 2009, 6 have received >5 citations/y. Five of these top 6 *BRIDGES* papers addressed bioassessment/biomonitoring, and 1 addressed policy/regulatory issues.

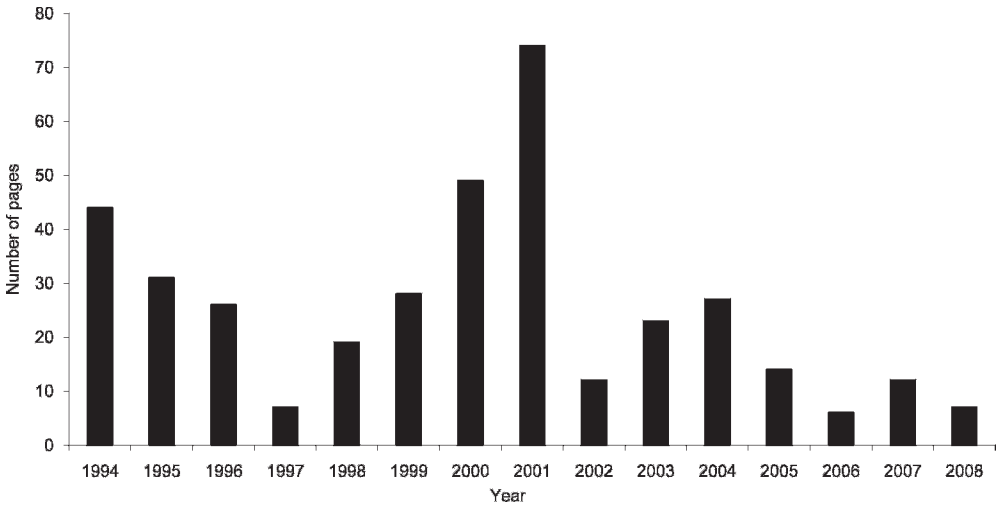

FIG. 3. Total pages of *BRIDGES* articles/y.

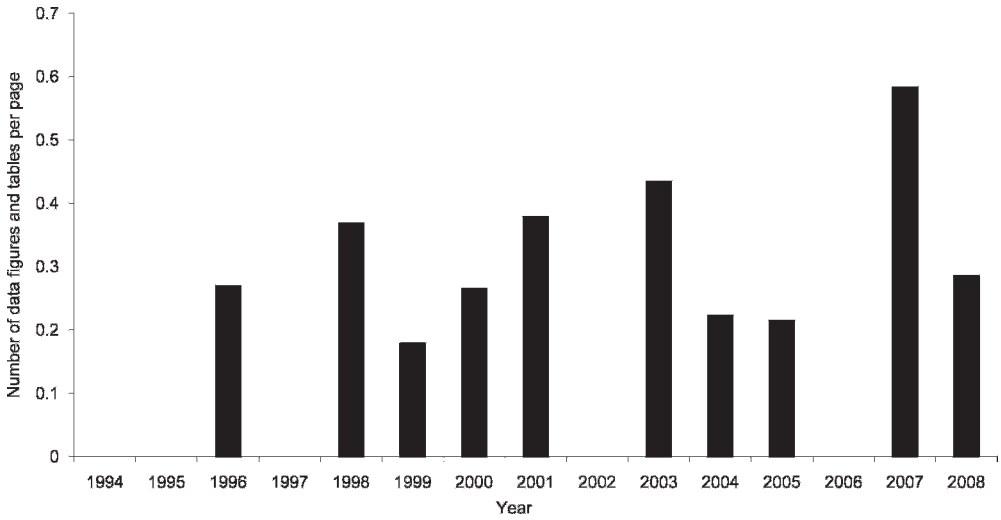

FIG. 4. Average number of data figures and tables per page of *BRIDGES* article/y. Figures that were conceptual in nature with no data were excluded.

Lenat and Resh (**2001**) has received the highest mean number of citations/y (7.89) of any *BRIDGES* article. Lenat and Resh (**2001**) discussed the advantages of genus- and species-level identification over identification only to higher levels in bioassessment studies and the importance of rare species in stream communities, a topic that has proven to be of great interest to investigators involved in bioassessments. Lenat and Resh (**2001**) has been cited by others conducting similar studies and in review articles.

Dodds and Welch (**2000**) has received the 2nd-highest mean number of citations/y (7.70). Dodds and Welch (**2000**) argued for establishing nutrient criteria in streams. This topic was particularly well received by authors interested in nutrient limitation, classification frameworks, and nutrient cycling in streams. Bailey et al. (**2001**) received the 3rd-highest mean number of citations/y (6.78). They analyzed the importance of taxonomic resolution. Rounding out the top 6 were: Vinson and Hawkins (**1996**; 6.57 citations/y), who determined whether variation in sampling area and number of individuals subsampled affect the ability to detect differences among ecoregions (this paper also had the highest number of total citations [92] of any *BRIDGES* paper); Cao et al. (**2001;** 6.44 citations/y) who considered rare species in multivariate analysis; and Carter and Resh (**2001**; 5.11 citations/y), who evaluated biomonitoring methods used by state programs in the US.

The number of times a *BRIDGES* article has been cited helps gauge the use of that published information by others who publish similar or related work in the scientific literature, but this metric does not necessarily equate to level of importance, interest, or even use. For example, judging the impact of an article as low based on lack of citations, e.g., 0.14 citations/y to Nerbonne and Vondracek (**2003**), which addressed the ability of volunteers to sort and identify benthic macroinvertebrates correctly, might understate its impact in the public arena. Their paper might have been read by agency staff, managers, or policy makers, or otherwise have affected implementation of volunteer programs. This potential use is very difficult to assess with standard citation metrics. Nerbonne and Vondracek received a number of reprint requests from agency staff and leaders of similar volunteer programs (J. F. Nerbonne, University of Minnesota, personal communication). A specific example of the use of the Nerbonne and Vondracek *BRIDGES* paper not reflected by citation analysis is the Volunteer Stream Monitoring Partnership (http://wrc.umn.edu/outreach/vsmp/) of the University of Minnesota Water Resources Center, which made changes in their macroinvertebrate identification key based on this *BRIDGES* article (J. F. Nerbonne, personal communication). Nerbonne also pointed out that *BRIDGES* articles published as part of the journal are not easily accessible to those most likely to benefit from their content.

Keiper and Casamatta's paper on forensic benthology (**Keiper and Casamatta 2001**) is another example of a *BRIDGES* paper for which the number of citations (0.56 citations/y) might underrepresent its impact. This paper shows a remarkable level of linkage between the basic science aspects of benthology and the applied science aspects of forensics. The low citation value for this paper probably reflects the low number of scientists publishing at the interface of

benthological and forensic science. As with the previous example, use of standard citation metrics might not be very useful for assessing the impact of this article. The authors receive 3 to 4 reprint requests/y, usually from medical professionals inquiring about the use of benthic organisms as forensic indicators in specific applications (D. Casamatta, University of North Florida, personal communication). The individuals requesting these reprints are likely to be forensic scientists and are not likely to publish their work in peer-reviewed journals monitored in standard citation analyses. For both examples, citations might have appeared in the grey literature, but those sources are not included in standard citation analyses.

The Future of *BRIDGES*

We view the increased number of articles in *J-NABS* that link the basic and applied sciences as a positive development for the journal. In recent years, most of these articles have been published in the regular section of the journal and not in *BRIDGES* (Figs 1, 2). This pattern led us to contemplate the future role of *BRIDGES*. The *BRIDGES* section made great strides in providing aquatic ecologists with an outlet for applied/basic aquatic science topics and has provided a forum for the large percentage of society members who are agency scientists or who work for private companies. It would be presumptuous to ascribe the overall increase in applied articles in *J-NABS* to the *BRIDGES* section, but it is likely that *BRIDGES* played a role in this increase. Has *BRIDGES* served its original purpose, and is the decrease in *BRIDGES* articles published annually a signal that a new dimension of *BRIDGES* should be tapped and new linkages should be addressed?

We think that future *BRIDGES* articles must continue to encourage scientists to incorporate ecological theory into applied research and to connect with a broader audience to help shape the environment in which we live. For example, the policy arena often is quite foreign to many scientists, especially in academia, but both policy makers and scientists acknowledge that collaborative efforts are required to create and evaluate public policies that will survive and thrive in the face of public scrutiny (Clark et al. 1998). In addition, changes to public policy regarding water-resource management have major implications for management of these ecosystems, but policy makers might have little scientific knowledge on which to base their decisions.

Numerous public-policy issues could benefit from aquatic science research. For example, conservation of freshwater biodiversity is an issue receiving a tremendous amount of attention worldwide as threats to water resources increase, but the need for scientific information that can directly shape policy and management of freshwater biodiversity is glaring (**Strayer and Dudgeon 2010**). Examples of other public-policy issues that could benefit from increased scientific information include water withdrawal, nutrient criteria, renewable energy, ballast water impacts, bioterrorism, and food security (aquaculture) regulations. All of these topics link directly back to benthic science and to the aquatic sciences in general.

Novel approaches are needed to increase communication among scientists and policy makers and among scientists and the lay community. The *BRIDGES* section could address this need by exploring innovative techniques for communicating with policy makers and other nonscientists via community education, religion, medicine, or arts.

A final linkage that we suggest is a bridge among scientific disciplines—a showcase for highlighting new disciplines and ideas that more fully integrate aquatic ecology with other disciplines. We envision these manuscripts as research or review papers. Possible subject areas include political science, education, economics, geomorphology, ecohydrology, freshwater–marine linkages, and ecotoxicology. For example, *BRIDGES* could be an outlet for a discussion of ecological valuation of freshwater resources, including the need for scientific data to inform economic models.

As a direct outcome of preparing this article, the authors recommended changes to *BRIDGES* to improve its usefulness to readers of *J-NABS*. In September 2009, *BRIDGES* transitioned to an entirely new format in which to address complex, multifaceted topics (**Moerke and Roy 2009**) (Fig. 1). The coeditors of *BRIDGES* will work with guest editors and authors to develop clusters of articles with complementary or contrasting perspectives around a common theme, such as one of the wide range of potential topics discussed above, or other topics suggested by *J-NABS* readers. To ensure a broad audience, all *BRIDGES* articles will be open access, and authors will be asked to produce clear and concise lay-language fact sheets to be made available on the NABS web site. We hope that this approach will make *BRIDGES* articles more accessible to potential readers and users in the applied/management/policy fields who might benefit from them.

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