A Perspective on El Niño and La Niña: Global Implications for Stream Ecology

Manuel C. Molles, Jr.; Clifford N. Dahm


Stable URL:
http://links.jstor.org/sici?sici=0887-3593%28199003%299%3A1%3C68%3AAPOENA%3E2.0.CO%3B2-T


Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/about/terms.html. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/journals/nabs.html.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

The JSTOR Archive is a trusted digital repository providing for long-term preservation and access to leading academic journals and scholarly literature from around the world. The Archive is supported by libraries, scholarly societies, publishers, and foundations. It is an initiative of JSTOR, a not-for-profit organization with a mission to help the scholarly community take advantage of advances in technology. For more information regarding JSTOR, please contact support@jstor.org.
PERSPECTIVES

This new section of the journal is available for the expression of new ideas, points of view, and comments on topics of interest to benthologists. The editorial board invites new and original papers as well as comments on items already published in J-NABS. Format and style may be less formal than conventional research papers; massive data sets are not appropriate. Speculation is welcome if it is likely to stimulate worthwhile discussion. Alternative viewpoints should be instructive rather than merely contradictory or argumentative. Authors will be invited to reply to comments. All submissions will receive the usual reviews and editorial assessments.—Ed.

A perspective on El Niño and La Niña: global implications for stream ecology

MANUEL C. MOLLES, JR. AND CLIFFORD N. DAHM

Department of Biology, The University of New Mexico, Albuquerque, New Mexico 87131 USA

Abstract. Analyses of flow data for the Gila (60 years) and Pecos (68 years) Rivers in New Mexico showed that spring flows during snowmelt were significantly increased during El Niño years (periods of elevated sea surface temperature and reduced barometric pressure in the eastern tropical Pacific) and significantly decreased during La Niña years (periods of reduced sea surface temperature and elevated barometric pressure). Over the period of record for these two rivers, mean spring runoff during El Niño years was 2.3–3.2 \times \text{ higher than during medial years and 6.0–7.4 \times \text{ higher than during La Niña years.}}

The results of this study indicate a strong correspondence between El Niño-Southern Oscillation (ENSO) phenomena and stream flow in New Mexico. These results also suggest that, in this region, the increasingly accurate, and remote forecasting of ENSO phenomena, often months in advance of the event, could be used to place future studies of biotic responses to variation in flow on a more predictive basis. Since it has been shown that the ENSO phenomenon affects the weather of large portions of the North American continent and tropical and subtropical regions worldwide, a similar potential for improved study design exists for other regions.

Key words: El Niño, La Niña, ENSO, disturbance, stream flow, New Mexico.

Variations in discharge, particularly extreme discharge conditions during floods and droughts, have profound effects on the function of stream ecosystems, on the structure of stream communities, and on the dynamics of stream populations (e.g., Power et al. 1988, Resh et al. 1988). Flow plays a central role in stream ecology because discharge controls many key structural attributes and integrates complex environmental conditions (Poff and Ward 1989). Relating processes and community patterns in streams to variation in streamflow remains a major concern for stream ecologists (Covich 1988, Power et al. 1988, Resh et al. 1988).

A considerable number of studies have documented the consequences of severe flooding in streams. Processes such as nitrogen dynamics (Grimm 1987), nitrification (Cooper 1983), and seston movement (Wallace et al. 1982) have been shown to respond to disturbance by floods. Algal assemblages are altered, and algal biomass decreased, following flash floods (Fisher et al. 1982, Power and Stewart 1987, Fisher and Grimm 1988). Invertebrate communities are susceptible to distinct changes in structure from sudden flash floods (spates). Floods have been shown to reduce numbers and diversity of benthic invertebrates and rates of post-flood recovery by stream communities appear dependent upon local flood frequency (Siegfried and Knight 1977, Gray and Fisher 1981, Fisher et al. 1982, Molles 1985). Flow conditions have also been shown to mediate competitive interactions between stream invertebrates (Hemphill and Cooper
Fish communities are also impacted by the magnitude and frequency of floods. Collins et al. (1981) documented the elimination of an endangered fish species due to a severe flash flood. Competitive interactions between stream fishes have also been shown to be mediated by flow conditions (Seegrist and Gard 1972, Meffe 1984). Flooding, particularly large, rapid increases in discharge as seen during flash floods (spates), has major impacts on nutrient cycling, productivity, decomposition, invertebrate communities, and fish communities in stream ecosystems.

Drying as a disturbance has received less attention from stream researchers than flooding, but similar disruptions of the function, structure, and dynamics of stream ecosystems, communities, and populations during drought conditions have been reported. Functional attributes such as leaf decomposition rates (Herbst and Reice 1982, Tate and Gurtz 1986) and primary production and respiration (Lewis and Gerting 1979, Hill and Gardner 1987) have been compared in intermittent and perennial reaches of streams. Chemical changes have also been documented (Towns 1986, Chessman and Robinson 1987) along with effects of desiccation on algal communities (Morison and Sheath 1985, Peterson 1987) during droughts. Faunal effects from drought have also received some attention (Harrison 1966, Ladle and Bass 1981, Kownacki 1985). Drought may be as important an organizing factor in some streams as flooding. Thus, it appears that a great deal of the year-to-year variability in stream ecosystems, communities, and populations is linked to variability in discharge. Improved understanding of the mechanisms behind this variation in discharge would sharpen our grasp of the driving forces behind stream system dynamics.

There has been recent progress toward long-range forecasting of weather and, in particular, a growing understanding of the atmosphere-ocean coupling that maintains the El Niño-Southern Oscillation (ENSO) cycle (Cane 1983, Quinn and Neal 1983, Rasmussen and Wallace 1983, Cane and Zebiak 1985, Namias 1985, Graham and White 1988, Enfield 1989). The ENSO system involves variations in sea surface temperature and barometric pressure across the central Pacific (Rasmussen 1985). The name "El Niño" derives from the timing of an occasional warm current that typically appears off the coast of Peru during the Christmas season. The term "Southern Oscillation" refers to fluctuations in barometric pressure across the Pacific and Indian Oceans. During the mature phase of an El Niño, the eastern tropical Pacific is characterized by elevated sea surface temperatures and reduced barometric pressure—ideal conditions for storm generation in regions of the ocean which affect much of tropical and subtropical North and South America. Under the opposite conditions (La Niña), reduced sea surface temperatures and elevated barometric pressure prevail and storm formation is inhibited (Quinn et al. 1981, Quinn and Neal 1983, Namias 1986).

There is strong evidence that the ENSO cycle is linked to variation in precipitation across a substantial portion of the world, including much of the North American continent (Ropelewski and Halpert 1987, Nicholls 1988). El Niño events have been shown to be associated with increased precipitation in the Great Basin, southwestern, and parts of the southeastern regions of the United States (Ropelewski and Halpert 1986, Andrade and Sellers 1988). In addition, it has been recently suggested that La Niña episodes may produce drought in these same regions of North America. The record of La Niña occurrences has been documented only recently and this research has emphasized just the latest episodes (Kerr 1988). Our analysis is an attempt to explore the relationship between stream discharge and both the El Niño and La Niña phases of the ENSO phenomenon. These connections with North American precipitation are especially interesting because of the present capability for predicting extreme ENSO conditions several months before the onset of a major event (Barnett et al. 1988b). Streamflow, while not a traditional meteorological variable, may be even more predictable than local precipitation because it integrates rather "noisy" precipitation events over relatively long periods and large areas (Cayan and Peterson 1987).

An appreciation for the coupling of global and meso-scale climatic phenomena with local weather and stream flow may be particularly helpful to research on the influence of disturbance on stream systems (e.g., Fisher et al. 1982, Molles 1985, Bain et al. 1988, Resh et al. 1988). For example, advance notice of the onset of an El Niño or La Niña could place the study of disturbance due to extreme flow conditions (both floods and droughts) on a more predictive
basis. In addition, a focus on ENSO, a global scale phenomenon, will stimulate maturation of our view of stream disturbance by allowing us to shift attention beyond single-stream case studies (e.g., Molles 1985) to regional and continental patterns of disturbance. For example, it has been recently shown that, across the globe, areas affected by ENSO experience precipitation regimes that are considerably more variable than those experienced by areas outside the influence of the ENSO system (Nicholls 1988). Richey et al. (1989) demonstrated that variability from the ENSO system affects year-to-year oscillations in the hydrograph even at the scale of the Amazon basin.

This study had three objectives: 1) to determine whether El Niño and La Niña phases of the Southern Oscillation correspond with variations in spring discharge in the long-term records of streams draining two mountainous regions of New Mexico; 2) to evaluate new predictive tools developed by climatologists to monitor ENSO phenomena in relationship to regional discharge patterns; and 3) to bring these diagnostic procedures to the attention of stream ecologists, since they offer the potential for predicting regional stream discharge, for many areas, many months in advance.

Methods

**ENSO years**

Past occurrences of El Niño and La Niña were recently determined by Quinn et al. (1987) who, on the basis of historical records, reconstructed a 450-yr history of El Niño off the coast of Peru. Since the focus of Quinn et al. (1987) was on El Niño per se, which has typically appeared off coastal Peru during the Christmas season, our designations of “El Niño years” assume that the main effects of ENSO appear in southwestern United States during the first winter and spring following the appearance of El Niño off Peru. For example, the El Niño of 1972-1973, which began building in late 1972, has been designated as an El Niño year in the spring snowmelt for 1973 for montane New Mexico streams and rivers. Our analysis was restricted to El Niños ranked by Quinn et al. (1987) as strong to very strong and to ones that continued from one year into the next.

Past occurrences of La Niña episodes were determined using a record of barometric pressure differences between Tahiti and Darwin, Australia, provided by Quinn et al. (1978) and the Climate Diagnostics Bulletin published monthly by the National Weather Service. Again, we assumed that the effects of La Niña would appear in New Mexico during the first winter-spring period following its occurrence and be reflected in spring snowmelt runoff from the montane catchments examined in this study.

**Runoff stations**

The Gila River, near Gila in southwestern New Mexico (catchment area = 4843 km²), and the Pecos River, near Pecos in northern New Mexico (catchment area = 490 km²), were chosen for study for several reasons: (1) long-term flow records are available; (2) both rivers drain high altitude wilderness areas and thus have suffered little human impact on runoff patterns; and (3) the two rivers occur at opposite ends of the state and should therefore represent the range of influences of ENSO on flow patterns of mountain streams in this region. Flow data prior to 1971 were taken from United States Geological Survey Water Supply Papers. Data for 1971 and later came from U.S.G.S. Water Resources Data for New Mexico.

**Data analysis**

ENSO has been typically associated with variation in winter-spring precipitation in the northern hemisphere (Rasmussen 1985). The bulk of winter precipitation in the upper Pecos and Gila catchments occurs as snowfall which remains frozen until spring. Therefore, our analyses were focused on spring flows, which were operationally defined as total flow during April–June.

Flow data for each stream were tabulated and years assigned to El Niño, medial, or La Niña categories using publications by Quinn et al. (1978), Quinn et al. (1987), and the Climate Diagnostics Bulletin. The Climate Diagnostics Bulletin provides a number of indicators of the current state of the ENSO phenomenon. One of the most useful is the “Southern Oscillation Index” which is the difference between the standardized sea level pressure anomalies at Tahiti and Darwin, Australia. Values of the South-
A list of strong to very strong El Niño events off the coast of northern South America that extended from one year to the next during the period covered by the present study (Quinn et al. 1987, personal communication) along with La Niña events during the same period (Quinn et al. 1978, Climate Diagnostics Bulletin 1989). Designations for corresponding El Niño and La Niña years in New Mexico are also given. (See text for explanation.)

<table>
<thead>
<tr>
<th>El Niño Year</th>
<th>La Niña Year</th>
<th>El Niño Year</th>
<th>La Niña Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1925–1926</td>
<td>1924–1925</td>
<td>1926</td>
<td>1925</td>
</tr>
<tr>
<td>1940–1941</td>
<td>1937–1938</td>
<td>1941</td>
<td>1938</td>
</tr>
</tbody>
</table>

The Southern Oscillation Index are standardized relative to the mean annual standard deviation. The index used in this study was the five-month running mean of the Southern Oscillation Index. We took positive Tahiti-Darwin values that were greater than or equal to approximately 1.0 standard deviation as indicators of the existence of a La Niña. The term “medial” was used simply to indicate intermediate states of the ENSO phenomenon, that is, years not designated by Quinn et al. (1987) as strong or very strong El Niños or during which the Southern Oscillation Index was not unusually high. Flow data were ln(n + 1) transformed and, for each river, differences among ENSO categories were analyzed using Analysis of Variance.

Results

Results of assigning years to ENSO categories are shown in Table 1. Runoff records analyzed for the Gila River extended from 1928 to 1987 and records for the Pecos River from 1920 to 1987. The Gila records included 5 El Niño years, 12 La Niña years, and 44 medial years. The Pecos records included 5 El Niño years, 13 La Niña years, and 50 medial years.

Flow differences among El Niño, medial, and La Niña years were significant in both rivers (p < 0.001). Over the period of record, mean spring runoff during El Niño years was 2.3–3.2 x higher than during medial years and 6.0–7.4 x higher than during La Niña years (Fig. 1). Thus, not only was flow in mountain streams of this region elevated during El Niño years, it was also substantially reduced during La Niña years. Further, these differences in flow were approximately twice as great as precipitation differences over the same period (M. C. Molles and C. N. Dahm, unpublished data), indicating that stream systems amplify variation in precipitation (Nemec 1986).

Plotting spring runoff in the Gila and Pecos Rivers by years shows that El Niños and La Niñas were associated with substantially elevated and reduced flows, respectively (Fig. 2). For the Gila River, the El Niño years of 1941, 1958, 1973, and 1983 produced the four highest spring flows on record. These same years produced four out of five of the highest spring flows in the Pecos River. If 1926 is included, ENSO years account for five of eight of the highest spring runoff periods for the Pecos. La Niñas were consistently associated with reduced streamflow, especially on the Gila. Particularly notable were the extended droughts during the La Niña periods of 1950–1951 and 1954–1957.
Discussion

Despite remarkable similarity in the fluvial behavior of the Gila and Pecos Rivers (Figs. 1, 2), close inspection of their histories reveals some interesting differences. First, high flows on the Gila River corresponded more consistently to the occurrence of El Niños than did high flows on the Pecos River (Fig. 2). Second, compared to the Pecos, the low flows in the Gila during La Niñas were more clearly distinguished from flows during medial years (Fig. 2). These data suggest that flow behavior of the Gila River more clearly reflects ENSO climatic signals. Differences in flow behavior between the Pecos and Gila Rivers likely reflect the more southerly and westerly position of the Gila basin, since the Pecos basin is probably near the northern boundary of the ENSO influence in the southwestern United States (Ropelewski and Halpert 1986).

The value of the perspective offered by the connection between ENSO phenomena and streamflow in the southwestern region is well-demonstrated by Figure 2. Overlaying the occurrence of El Niños and La Niñas on the records of spring flow in the Gila and Pecos Rivers accounts for a substantial amount of the variance in both data sets. This result echoes the suggestion of others (Margalef 1960, Fisher 1983, Sedell and Froggatt 1984, Statzner and Higler 1985) that a solid basis for the study of stream ecosystems often lies in the development of a long-term temporal perspective.

Climatologists are interested in understanding, predicting, and tracking ENSO phenomena throughout the globe (e.g., Rasmussen 1985, Cane and Zebiak 1985, Ropelewski and Halpert 1987, Nicholls 1988, Enfield 1989). A valuable method for tracking ENSO conditions is the pressure differential between selected weather stations in the tropical and sub-tropical Pacific. One long-term record that has proven particularly valuable is the Southern Oscillation In-
index (see methods), which is provided monthly by The Climate Diagnostics Bulletin of the National Weather Service. Figure 3 presents a plot of the five-month running mean for the Southern Oscillation Index along with spring discharge of the Gila River for the past 20 years. A strong correspondence can be seen between El Niños (1972–1973, 1982–1983, and 1986–1987, rated as a moderately strong event by Quinn et al. 1987) and high riverine discharge and between La Niñas (1970–early 1972, 1973–1974, and 1975–1976) and low riverine discharge. In addition, the index shows major changes that apparently precede its effects on weather in southwestern United States by several months. For example, strong La Niña conditions began to set-up in the last half of 1988. The index was strongly positive and comparable to the strong La Niñas of the early 1970s. Subsequently, precipitation was below normal across all of central and southern New Mexico during winter and spring of 1989 and spring discharge was below average in both the Pecos and Gila. Precipitation and riverine discharge in regions influenced by the ENSO phenomenon need not be viewed as entirely stochastic, but rather, annual variability may be predictable using the Southern Oscillation Index.

The success of the present analysis should not divert attention from the potential influence of other large scale phenomena on local precipitation and streamflow. For example, recent analyses indicate that the extent of Eurasian snow cover may have substantial effects on North American climate (Barnett et al. 1988a). Volcanism appears to have profound effects on climate that have been long-recognized. Benjamin Franklin (1784) linked unusually cold weather in Europe with the 1783 eruption of the Icelandic volcano Lakagigar. A century later, the recent eruption of El Chichon produced world-wide changes in weather (Simkin and Fiske 1983). And finally, the recent eruption of El Chichon has had a multi-year effect on global temperature and precipitation (Mitchell 1982).

Clearly, influences on other aspects of the stream environment, besides flow, should be given consideration. For example, Strub et al. (1985) demonstrated a significant influence of ENSO on the heat budget of Castle Lake, California. Similar effects on the heat budgets of streams are possible, with concomitant effects on the life histories of benthic organisms. Cayanan and Peterson (1987) pointed out that the variations in streamflow associated with ENSO also produce marked changes in water chemistry. Their observation anticipated a recent demonstration by C. S. White, University of New Mexico (unpublished data), that the 1983 El Niño episode was a period of unusually high sulfate deposition via precipitation that reduced alkalinity of alpine streams in northern New Mexico.

We hope that the results of this study will encourage other stream ecologists to use the increasingly accurate and long-range forecasting of certain regional weather patterns to help put their studies, particularly those of biological responses to extreme flow regimes, on a more predictive basis. For example, McElravy et al. (1989), who studied the influence of discharge and storm frequency on year-to-year (1977–1983) variation in stream macroinvertebrate populations, might have used this forecasting approach to anticipate, by several months, periods of high discharge and high storm frequency.
The highest discharges and greatest storm frequencies during their study were in 1978 and 1983. These were also years of reduced numbers and diversity of macroinvertebrates. Figure 3 shows that the winters of 1978 and 1983 were preceded by several months of the greatest negative pressure differentials between Tahiti and Darwin to occur during the study interval. These conditions were diagnostic of the two El Niños that eventually affected precipitation patterns and disturbance frequency in these California streams. Thus, in the years ahead, growing understanding of ocean/atmosphere/climate interactions on a global basis can serve stream ecologists as a valuable tool for potentially anticipating periods of both high and low stream flow and for refining our approaches to the study of biological responses to disturbance from floods and droughts.

Finally, the importance of ENSO phenomena in regulating stream and river discharge throughout a large portion of the planet should be considered as global climate change scenarios are discussed. Global circulation models (GCMs) show reasonable agreement on the extent of global warming associated with various rates of buildup of greenhouse gases (e.g., Schlesinger and Mitchell 1987, Hansen et al. 1989). The GCMs in use today, however, do not simulate a realistic oceanic circulation pattern. ENSO phenomena cannot be represented with present GCMs. Therefore, the inability of GCMs to accurately reproduce present day precipitation patterns in ENSO-affected regions should not be surprising (Neilsen et al. 1989). Until ENSO conditions can be more accurately incorporated into GCMs, predictions of future changes in regional precipitation and streamflow where the ENSO phenomenon exerts a strong influence must be viewed as highly suspect.

Acknowledgements

We thank Jim Stanton for his assistance in assembling the data analyzed in this paper. Dr. William H. Quinn was especially helpful in his advice concerning the periods of anti-ENSO conditions (La Niña) and in his encouraging us to analyze the relation of the ENSO phenomenon to weather in the Southwest. We also thank J. H. Brown, C. S. Crawford, S. G. Fisher, J. R. Gosz, S. V. Gregory, N. B. Grimm, M. E. Gurtz, L. N. Poff, V. H. Resh, J. R. Sedell, F. J. Swanson, E. H. Trotter, S. G. Wells, and C. S. Wisdom for helpful advice and encouragement. This study was partially supported by research grant BSR-8616438 from the National Science Foundation. This is publication number 7 of the Sevilleta National Wildlife Refuge Long-Term Ecological Research project.

Literature Cited

COVICH, A. P. 1988. Geographical and historical comparisons of neotropical streams: biotic diversity and detrital processing in highly variable


Received: 7 July 1988
Accepted: 22 November 1989
A Perspective on El Niño and La Niña: Global Implications for Stream Ecology
Manuel C. Molles, Jr.; Clifford N. Dahm
Stable URL:
http://links.jstor.org/sici?sici=0887-3593%28199003%299%3A1%3C68%3AAPOENA%3E2.0.CO%3B2-T

This article references the following linked citations. If you are trying to access articles from an
off-campus location, you may be required to first logon via your library web site to access JSTOR. Please
visit your library's website or contact a librarian to learn about options for remote access to JSTOR.

Literature Cited

Streamflow Regulation and Fish Community Structure
Mark B. Bain; John T. Finn; Henry E. Booke
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28198804%2969%3A2%3C382%3ASRAFCS%3E2.0.CO%3B2-K

The Effect of Eurasian Snow Cover on Global Climate
T. P. Barnett; L. Dümenil; U. Schlese; E. Roeckner
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819880129%293%3A239%3A4839%3C504%3ATEOESC%3E2.0.CO%3B2-G

T. Barnett; N. Graham; M. Cane; S. Zebiak; S. Dolan; J. O'Brien; D. Legler
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819880708%293%3A241%3A4862%3C192%3AOTPOTE%3E2.0.CO%3B2-%23

Oceanographic Events during El Niño
Mark A. Cane
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819831216%293%3A222%3A4629%3C1189%3AOEDEN%3E2.0.CO%3B2-P
A Theory for El Niño and the Southern Oscillation
Mark A. Cane; Stephen E. Zebiak
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819850531%293%3A228%3A4703%3C1085%3AATFENA%3E2.0.CO%3B2-9

Geographical and Historical Comparisons of Neotropical Streams: Biotic Diversity and Detrital Processing in Highly Variable Habitats
Alan P. Covich
Stable URL:
http://links.jstor.org/sici?sici=0887-3593%28198812%297%3A4%3C361%3AGAHCON%3E2.0.CO%3B2-F

Temporal Succession in a Desert Stream Ecosystem Following Flash Flooding
Stuart G. Fisher; Lawrence J. Gray; Nancy B. Grimm; David E. Busch
Stable URL:
http://links.jstor.org/sici?sici=0012-9615%28198203%2952%3A1%3C93%3ATSIADS%3E2.0.CO%3B2-6

The El Niño Cycle: A Natural Oscillator of the Pacific Ocean-Atmosphere System
Nicholas E. Graham; Warren B. White
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819880603%293%3A240%3A4857%3C1293%3ATENCAN%3E2.0.CO%3B2-Q

Postflood Recolonization Pathways of Macroinvertebrates in a Lowland Sonoran Desert Stream
Lawrence J. Gray; Stuart G. Fisher
Stable URL:
http://links.jstor.org/sici?sici=0003-0031%28198110%29106%3A2%3C249%3APRPOMI%3E2.0.CO%3B2-4
Nitrogen Dynamics During Succession in a Desert Stream
Nancy B. Grimm
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28198710%2968%3A5%3C1157%3ANDDSIA%3E2.0.CO%3B2-C

La Niña's Big Chill Replaces El Niño
Richard A. Kerr
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819880826%293%3A241%3A1037%3ALNBCRE%3E2.0.CO%3B2-Q

Primary Productivity in a Polluted Intermittent Desert Stream
Michael A. Lewis; Shelby D. Gerking
Stable URL:
http://links.jstor.org/sici?sici=0003-0031%28197907%29102%3A1%3C172%3APPIAPI%3E2.0.CO%3B2-F

Competition for Space, Disturbance, and the Structure of a Benthic Stream Community
Joseph R. McAuliffe
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28198406%2965%3A3%3C894%3ACFSDAT%3E2.0.CO%3B2-L

Year-to-Year Variation in the Aquatic Macroinvertebrate Fauna of a Northern California Stream
Eric P. McElravy; Gary A. Lamberti; Vincent H. Resh
Stable URL:
http://links.jstor.org/sici?sici=0887-3593%28198903%298%3A1%3C51%3AYVITAM%3E2.0.CO%3B2-N

Effects of Abiotic Disturbance on Coexistence of Predator-Prey Fish Species
Gary K. Meffe
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28198410%2965%3A5%3C1525%3AEADOC%3E2.0.CO%3B2-6
Influences of Flow Regime on Development and Desiccation Response of Lotic Diatom Communities
Christopher G. Peterson
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28198708%2968%3A4%3C946%3AIOFROD%3E2.0.CO%3B2-N

Disturbance and Recovery of an Algal Assemblage Following Flooding in an Oklahoma Stream
Mary E. Power; Arthur J. Stewart
Stable URL:
http://links.jstor.org/sici?sici=0003-0031%28198704%29117%3A2%3C333%3ARDAROA%3E2.0.CO%3B2-O

Biotic and Abiotic Controls in River and Stream Communities
Mary E. Power; R. Jean Stout; Colbert E. Cushing; Peter P. Harper; F. Richard Hauer; William J. Matthews; Peter B. Moyle; Bernhard Statzner; Irene R. Wais De Badgen
Stable URL:
http://links.jstor.org/sici?sici=0887-3593%28198812%297%3A4%3C456%3AABACIR%3E2.0.CO%3B2-I

The Role of Disturbance in Stream Ecology
Vincent H. Resh; Arthur V. Brown; Alan P. Covich; Martin E. Gurtz; Hiram W. Li; G. Wayne Minshall; Seth R. Reice; Andrew L. Sheldon; J. Bruce Wallace; Robert C. Wissmar
Stable URL:
http://links.jstor.org/sici?sici=0887-3593%28198812%297%3A4%3C433%3ATRODIS%3E2.0.CO%3B2-C

Amazon River Discharge and Climate Variability: 1903 to 1985
Jeffrey E. Richey; Carlos Nobre; Clara Deser
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819891006%29246%3A4926%3C101%3AARDACV%3E2.0.CO%3B2-8
The Greenhouse Effect: Science and Policy
Stephen H. Schneider
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819890210%293%3A243%3A4892%3C771%3ATGESAP%3E2.0.CO%3B2-2

The Effects of Washout in a Sierra Foothill Stream
Clifford A. Siegfried; Allen W. Knight
Stable URL:
http://links.jstor.org/sici?sici=0003-0031%28197707%2998%3A1%3C200%3ATEOWIA%3E2.0.CO%3B2-Q

Climatic Forcing: Effects of El Niño on a Small, Temperate Lake
P. Ted Strub; Thomas Powell; Charles R. Goldman
Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819850104%293%3A227%3A4682%3C55%3ACFEOEN%3E2.0.CO%3B2-B

Seston and Dissolved Organic Carbon Dynamics in a Southern Appalachian Stream
J. Bruce Wallace; Douglas H. Ross; Judy L. Meyer
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28198206%2963%3A3%3C824%3ASADOCD%3E2.0.CO%3B2-3