How Low Can You Go? Intermittent Streams in Climate Change Limbo

Though intermittent streams, true to their name, cease flow during certain portions of the year, they comprise a significant portion of the drainage network and have a large impact on wildlife, biogeochemistry, and water quality. The hydrology of intermittent streams is dictated by seasonal fluctuations in rainfall, temperature, and evapotranspiration, as these streams often dry during summer months but flow the remainder of the year. The timing and magnitude of flow in intermittent streams is influenced by weather patterns on a number of scales (e.g., local rainfall, watershed snowfall, and regional climate). Many intermittent streams are subject to intense spring flooding resulting from the combination of melting snowpack and increased rainfall. This flooding can morphologically alter the stream channel (Levick et al., 2008). Therefore, intermittent streams have the quality of both spatial and temporal heterogeneity within very brief timeframes. Unfortunately, the spatial and temporal heterogeneity of intermittent streams has rendered them difficult research subjects, and consequently the ecology of intermittent streams is currently not well understood (Mazor et al., 2014). This lack of knowledge becomes a critical deficiency when attempting to manage or mitigate the effects of climate change on intermittent stream ecosystems. Climate change forecasts include reduced precipitation, longer dry periods, and an increased frequency of extreme weather events. The potential adverse effects on intermittent stream ecologies from these aspects of climate change could be wide-ranging and substantial. Mazor (2014) observes that “degradation of nonperennial reaches may have disproportionate impacts on the health of the entire watershed.”

I am interested in intermittent streams on a personal level because my wife and I have an intermittent stream flowing through our yard. The stream ceases to flow usually in July or August, resuming in September. Periodic heavy rains cause the stream to flood and sometimes significantly
alter riparian zone vegetation. The stream is host to a wide variety of macroinvertebrates and provides drinking water to local deer, skunk, opossum, fox, coyote and raccoon. The stream also serves as a birdbath for numerous avian species. I have not previously investigated the ecology and hydrology of these dynamic systems, so this topic appealed to me.

Intermittent streams provide a number of important ecosystem services. Hydrologically, they provide for surface and sub-surface water storage and control. They can absorb a significant amount of rainwater and snowmelt and therefore provide critical flood abatement. They also provide sediment control and assist in the recharge of underground aquifers (DiStefano et al., 2009). Additionally, these streams provide connectivity for the flow of nutrients, sediment, and aquatic organisms through the landscape. These hydrological ecosystem services are particularly critical in arid areas which receive between 30 and 50 percent of their annual rainfall within a two month period (Levick et al., 2008).

For native aquatic wildlife, intermittent streams provide habitat, nutrient cycling, shelter, refuge from predators, and movement and migration corridors (Levick et al., 2008). Intermittent streams serve as critical spawning and nursery sites for many species (Wigington et al., 2006; Dexter et al., 2013). Intermittent streams are also home to macroinvertebrate assemblages responsible for the decomposition of leaves, woody debris and other plant material, releasing nutrients and organic materials for the benefit of downstream inhabitants and the ecological health of larger perennial streams and rivers (Mazor et al., 2014). For terrestrial wildlife, intermittent streams serve as a critical source of food and drinking water (DiStefano et al., 2009).

Intermittent streams also play an important role in support of riparian vegetation. A healthy riparian zone provides terrestrial wildlife habitat and connectivity, and controls erosion (Levick et al., 2008). Riparian zones further benefit the environment by providing pollution control through the retention of storm and snowmelt runoff and removal of excessive agricultural nutrients.
Climate change is a significant threat to the health of intermittent streams. Streams are already showing warming effects, and runoff is decreasing in most temperate areas (Mas-Marti et al., 2015). Due to decreased runoff, more perennial streams are becoming intermittent streams, causing loss of hydrologic connectivity and reduction of habitat for species dependent on perennial flow (Verdonschot et al., 2015). Fish native to intermittent streams show high levels of both resistance – the ability to tolerate temperature variations and hypoxic conditions, and resilience – the ability to recover/recolonize quickly following a disturbance or cease-to-flow period (Bertrand et al., 2013). In comparison, fish native to perennial streams have relatively poor resilience and resistance. As a result, the shift of a stream from perennial to intermittent has substantial consequences for the overall stream ecology (Hille et al., 2015).

Organisms survive cease-to-flow periods using a variety of strategies. Since no vertebrate intermittent stream inhabitants (fish) can live out of water, they seek refuge during dry periods in isolated permanent pools. As dry periods become longer and flows reduced, these pools become warmer, shallower and smaller. Even though these fish have developed increased tolerance to these conditions, there is a point beyond which these pools become incapable of sustaining vertebrate life, and the fish die and become extinct in the stream. Since fish often comprise the top trophic level in the stream, such extinctions can have large-scale ecosystem impacts. (Rodriguez-Lozano et al., 2015).

Crayfish survive the dry period by burrowing into the saturated hyporheic zone below the streambed (DiStefano et al., 2009). The reduced flow regimes caused by climate change and anthropogenic disturbance threatens the crayfish by increasing the depth to groundwater. Other organisms seek refuge in moist leaf packs and woody debris, shallow streambed sediments, and riparian soils (Storey and Quinn, 2013). All these refugia are at risk with the increasing severity and duration of summer dry periods.
Higher temperatures increase the metabolic rate of intermittent stream inhabitants. In severe cases, metabolic rates have been found to increase faster than the organisms’ ability to compensate through increased consumption, leading to increased mortality. Higher temperatures have also been found to degrade the quality of the food (e.g., leaves, organic debris) available to the organism (Mas-Marti et al., 2015). The lower flows accompanying climate change also inhibit a stream’s ability to filter out organic and nutrient pollution (Matono et al., 2014).

Exacerbating the climate change problem is the increasing degradation of intermittent streams due to anthropogenic activities. Water extraction to provide drinking water to growing populations adds to the stress already caused by increased drought. Intensive agriculture and logging can cause significant changes in flow regimes, nutrient loading, and riparian zone health. For instance, in Australia, the watering of cattle at the permanent pools of intermittent streams was found to significantly degrade these pools through both water extraction and nutrient loading. Also, the cattle movement in and around these pools was found to adversely impact riparian vegetation to the point where soil erosion became a serious problem (Bond and Cottingham, 2008). In Europe, large-scale land clearing, dam construction, and industrialized agriculture have significantly degraded fluvial landscapes, threatening native fish populations with extinction (Matono et al., 2014).

There are steps environmental managers can take to moderate the effects of climate change on the health of intermittent streams. Several researchers noted that the watershed or landscape is the most appropriate scale for managing intermittent streams (Labbe and Fausch, 2000; Levick et al., 2008). Since the threats to intermittent streams, both due to climate change and anthropogenic activities, are widespread, watershed-scale management is appropriate. Further, since impacts on intermittent streams can have direct impacts on downstream water quality and ecosystem health, focusing on specific sites, such as a specific stream, is not going to be effective.
Reduction of the rates of water extractions from these critical waterways appears to be one management step that can yield meaningful improvement in intermittent stream health. Unfortunately, current research does not inform us as to how much water can be extracted without significantly degrading ecosystem services (Bond and Cottingham, 2008). Therefore managers are forced to make often unpopular recommendations with little scientific support. A second alternative is to maintain or restore intermittent stream riparian landscapes. A healthy riparian zone has been shown to mitigate the warming effects of climate change as well as provide refuge to intermittent stream biota (Storey and Quinn, 2013). Livestock also need to be kept out of riparian zones by use of fencing or other means. In streams where top trophic level fish have become extinct, restocking efforts have been shown to be successful (Rodriguez-Lozano et al., 2015). The removal of dams and weirs may also aid intermittent stream health by restoring connectivity. These structures may block critical access to refuge habitats or hinder recolonization following disturbance, but little research has been conducted in this area (Bond and Cottingham, 2008).

A continuing management problem is the lack of information on the health of intermittent streams. Intermittent streams are not currently included in many biological or ecosystem monitoring programs (Mazor et al., 2015). Consequently, managers lack adequate knowledge on the current health of streams as well as the information needed to make accurate predictions of the impacts of climate change. Therefore, there is a critical need to increase our research efforts into understanding the extent of how the health of intermittent streams impacts food webs, water and nutrient cycles, disturbance/recovery cycles and biological diversity. Through these efforts we can better understand the true scale of the threat posed by climate change and initiate or strengthen those efforts which best ameliorate those threats. Also, we must better understand the consequences of anthropogenic activity on the ability of intermittent streams to provide vital ecosystem services on both the local, landscape and watershed scales.
Annotated Bibliography


The cycle of drying and rewetting that typifies intermittent streams creates harsh conditions for inhabitants. Lengthy cease-to-flow periods on one hand, and scouring floods on the other, present the extremes to which native organisms must adapt. The authors note that while climate change models for the United States Great Plains states do not predict change in annual rainfall, they do predict longer periods of drought followed by more intense flooding.

The authors provide a brief overview of the strategies used by intermittent stream inhabitants to cope with these radical hydrological extremes noting both strategies that enhance resistance – the ability to withstand these extremes, and resilience – the ability to recolonize and re-establish pre-event populations.

Even though intermittent stream inhabitants have developed successful strategies to enhance persistence and resilience, some of these strategies render the organism sensitive to predicted climate changes, particularly if these climate changes are exacerbated by anthropometric activity.


This paper was a review of the current state of knowledge concerning the ecology and hydrology of temporary streams conducted for the Victorian government in Australia to inform water management programs. I found this review helpful in framing the ecological significance of temporary streams and the need for their management and conservation. The authors also noted the current lack of information concerning the effects of anthropometric disturbance on the ability of temporary streams to provide ecosystem services.

The unique feature of temporary streams is, of course, the fact that flow ceases for a major part of the year. Various vertebrate and invertebrate organisms have adapted to this aspect through both behavior (e.g., timing of reproduction or dormancy) and physiology (e.g., development of increased tolerance to heat and low oxygen conditions). Intermittency also carries the benefits of limiting predation by large-bodied vertebrates and impeding the spread of invasive species.

Even though temporary (including ephemeral) streams make up a significant portion of the drainage network in many watersheds (in Arizona, an estimated 99%), significant gaps exist in our understanding of their hydrology and ecology. Although studies suggest the ecosystem services provided by temporary streams are critical to the health of perennial waterways, there is little information on the nature and extent of these services.
Cease-to-flow periods are known to be critical to the life-cycles of certain organisms populating intermittent streams. However, little is known about how lengthened dry periods caused by climate change and anthropometric disturbance will affect these populations.


Intermittent streams have the inherent characteristic of periodically losing their longitudinal hydrologic connectivity. In order to persist, therefore, inhabitants of these streams must evolve specific mechanisms to cope with periodic fragmentation and restoration of their range.

An Australian fish, the mountain galaxias (Galaxias olidus), inhabits intermittent streams in the southeastern regions of that continent. The authors studied the life-cycle and swimming abilities of this fish, as well as the southern pygmy perch, a similar-sized fish which inhabits only perennial streams.

The mountain galaxias was found to be an exceptionally strong swimmer, and able to migrate to upland waters and spawn in upland persistent pools during the dry season. When stream flow is restored, larvae are washed downstream where they feed and develop until the juveniles migrate upward again the next season. The southern pygmy perch was found to be a relatively slow swimmer, and therefore confined to perennial waters over its entire life-cycle.

The authors speculated that the migratory life-cycle of the mountain galaxias leaves it at increased risk during periods of drought. In drought years juveniles are not able to migrate to the persistent upland pools and are instead confined to lowland pools which tend to dry out, with a severe adverse impact on population numbers.


The behavior of residents of intermittent streams during dry periods is an important research topic since climate change projections include both extreme heat events and increased anthropometric water demand – each with the potential of extending the dry period of intermittent streams.

The ecology of intermittent streams is not well understood – surprising since intermittent streams comprise over 2/3 of stream length in river watersheds. Also surprising since they provide a broad range of ecosystem services – flood control, groundwater recharge, sediment reduction, water quality maintenance, nutrition and habitat.

As a consequence of our lack of knowledge, intermittent streams are not afforded the same environmental protections as perennial waters. There is even some confusion over whether intermittent streams are afforded the same protections as perennial waters under the Clean Water Act.

Crayfish play an important role in intermittent stream ecology. They are a keystone species, sometimes comprising over 50% of the biomass in certain reaches. They serve as prey for over 200 species of animals, and decompose and process organic matter which supports other invertebrates in the stream.
However, they are also imperiled in many areas. They survive dry periods by burrowing into the hyporheic zone beneath the stream bed. This survival mechanism was unknown until only recently.

The use of crayfishes of intermittent streams and the hyporheic zone during periods of drying indicate that intermittent streams serve as an important habitat and should be considered in conservation planning.


Recognizing that small, permanent streams are at risk of becoming intermittent streams due to hydrological changes caused by climate change and anthropometric disruption (water extraction), the authors diverted the flow of a permanent stream to create stagnant and drought conditions. After two weeks they examined the community composition of benthic invertebrates.

The authors found that community composition changed significantly under both reduced-flow regimens. Particularly degraded were those macroinvertebrate taxa which normally relied on flow conditions for feeding and respiration. Of interest, diversity and abundance were not found to be affected under reduced-flow conditions. However, the changes in community composition were found to degrade ecosystem services provided by the stream, particularly in the areas of organic matter decomposition and nutrient cycling.


This paper was useful in that the authors advocate landscape level responses to the threats posed to intermittent stream habitats by climate change. They note that past conservation practice has been to focus on local environmental factors while recent research has indicated that fish that inhabit intermittent streams respond to landscape features at much larger scales than previously thought.

This study focused on two intermittent Colorado plains streams and the life-cycle of the threatened Arkansas darter at multiple scales: (1) pools (typically 5-50 m in length), (2) reaches (1-2 km comprising several pools), (3) segments (10-15 km comprising several reaches), and (4) watershed.

The authors conclude that successful conservation of intermittent stream species must rely on efforts conducted at multiple scales. Limiting research and management to pools or reaches risks missing important physical and biological landscape processes critical for species survival.

This document summarizes the current thinking on the ecology and hydrology of intermittent and ephemeral streams in the American Southwest. The document was important to my research because it provided a review of pre-2008 research concerning the importance of intermittent streams to the environment.

The document provides a good review of the ecosystem services provided by intermittent streams, highlights gaps in our knowledge, and discusses the impacts on intermittent streams from climate change and anthropometric activity.

The document also noted that watersheds are becoming the most appropriate spatial unit for land management, and, more critically, water resource management.


I found this paper especially useful for its cogent summary of the potential impacts of climate change on intermittent streams, particularly with respect to microbial populations. They note that microbes can potentially adapt to climate change conditions through both physiological and behavioral changes.

To test the ability of microbes to adapt to environmental changes caused by global warming, the authors fed high and lower quality leaves to microbial leaf shredder assemblages at two different temperatures – 15 and 20 degrees centigrade, yielding four experimental groups.

The authors found that behaviorally, microbes at the lower temperature compensated for lower quality food through higher ingestion rates. The microbes did not compensate physiologically through enhanced or preferential nutrient assimilation. However, at higher temperatures, these higher consumption rates did not adequately compensate for temperature induced increases in microbial growth rate and metabolic activity, leading to reduced survival.


Temporary streams show high spatial and temporal heterogeneity. Certain fish species have become adapted to this heterogeneity. However, natural sustainability of these populations is tenuous due to the varied hydrological regimes inherent in temporary streams. Thus, these populations are especially sensitive to anthropological disruptions such as water extraction, morphological modification, invasions of non-native species, degradation of riparian zone vegetation, and conversion of native landscapes to intensive agricultural production.

This was a 12-year study during which the authors sampled numerous temporary streams in southern Portugal. Fish assemblages were compared to a scale of anthropometric disturbance comprised of land use, urban area, riparian vegetation, longitudinal connectivity, sediment load, hydrologic regime, morphological condition, toxicity and acidification levels and nutrient load.
I found the article especially useful since the authors provided background information about how fish behave in a temporary stream.


This paper was important to my research since the authors noted: (1) there are significant knowledge gaps in our understanding about the biological and hydrological aspects of intermittent streams, (2) intermittent streams are routinely omitted from bio-monitoring, watershed assessment and resource protection programs, (3) intermittent streams are responsible for the drainage of large portions of watersheds in both arid and wet landscapes, (4) intermittent streams are especially sensitive to environmental impacts due to their disproportionately large interface with land ecosystems, (5) intermittent streams provide vital ecosystem services in terms of leaf-litter breakdown, nutrient cycling and biomass production, and (6) intermittent stream degradation has disproportionate impact on the health of the entire landscape.

In this study, using standard biological assessment metrics (IBI scores, nonmetric multidimensional scaling) the authors attempted to determine how similar stressed and non-stressed intermittent streams were to perennial streams.

The authors found that intermittent streams in the eurheic (full-flow) and oligorheic (reduced flow) states were biologically similar to perennial streams. Therefore assessment of intermittent streams during these states can expand the ability of resource personnel to manage a greater extent of the watershed.

Of interest, the authors found intermittent streams to be highly sensitive to non-natural flow regimes. Intermittent streams showing stable year-to-year hydrographs had higher IBI scores, even when stressed. Lower IBI scores were found where disturbances altered the hydrology of intermittent streams, with or without additional stress.


Top predator loss is a major global problem, and current trends point to continued top predator extinctions in high trophic levels due to human activity. While much research has been conducted on the extinction or near-extinction of large-bodied predators, the effects of top predator extinction in intermittent streams has received little attention. This lack of attention is likely due to the fact that top predators in intermittent streams tend to be small fish of little or no commercial value.

The authors address how the loss of a small-bodied top predator can affect ecosystem function in intermittent streams. In this case, the authors examined how the loss of a small, endangered fish, the Mediterranean barbel, a top predator in intermittent streams, affected the ecosystem’s structure and function. Their study included the creation of mesocosms open to mesopredator (invertebrate predators), prey and periphyton migration, but which either contained or excluded the barbel. The enclosures included stones for macroinvertebrate colonization and glass plates for periphyton colonization. Periphyton and macroinvertebrates were allowed to colonize the enclosures for three
weeks, and then two weeks were allowed for barbel interaction. Macroinvertebrates were then counted and identified, and periphyton density determined.

The authors found that absence of the top predator, the barbel, significantly altered the ecosystem. The absence resulted in both a mesopredator release and a prey release, resulting ultimately in a decline in periphyton primary production. The loss of primary production in an ecosystem presages a major adverse effect on ecosystem function. The authors conclude that reintroduction programs should be strongly considered for intermittent streams in which top predators are severely threatened or have become extinct.


Intermittent streams not only dry out, but also heat up. Therefore, the tolerances of aquatic macroinvertebrate species to both dry and elevated temperature conditions is critical considering prospective climate change conditions. The authors note that aquatic macroinvertebrates are able to make use of several different types of refugia to survive the dry season, including permanent pools, leaf packs, woody debris, shallow streambed sediments, deep streambed sediments (hyporheic zone), and riparian vegetation.

To test the resistance of macroinvertebrates to high temperatures, the authors exposed dry streambed sediments to temperatures as high as 30 degrees centigrade. They then re-wetted the sediments and examined the surviving macroinvertebrates.

The findings of the experiment were that shallow streambed sediments were a key refuge for invertebrates in intermittent streams and that protecting riparian vegetation is a key element in ensuring these sediments remain at temperatures tolerated by the macroinvertebrates. Therefore, the authors conclude that the restoration and maintenance of health riparian vegetation is key to maintaining the biodiversity and ecological functioning of intermittent streams.


The authors begin by noting that the number of perennial streams experiencing intermittent flow is likely to rise due to climate change and heightened anthropometric activity. Although macroinvertebrate responses to streambed drying and intermittent flow have been well studied in seasonally intermittent streams, the effects of a shift from perennial to intermittent flow have not.

To examine the effect of the disruption of flow, the authors diverted a perennially flowing stream to create conditions of stagnation (cessation of flow with little water loss) and dry streambed with small, isolated, remnant pools. They then sampled the macroinvertebrate population richness and abundance periodically over a period of 29 days.
The authors found that macroinvertebrate assemblages remained relatively unchanged in the stagnant reach, but became significantly degraded in the isolated pools.


All of the other papers I reviewed for this report dealt with small fish I had never heard of or stream macroinvertebrates. This paper I found interesting because it dealt with a fish I recognized and a fish that had commercial importance.

Many coho salmon young spend their first year of life in intermittent streams. They survive in isolated permanent pools. This paper attempted to quantify the contribution of intermittent streams to coho salmon populations in a small (67 km²) catchment area in Oregon.

The authors found that intermittent streams provided key habitat area for coho salmon, and that many years the coho salmon that grew in intermittent streams were larger than their perennial stream counterparts, likely due to the increased concentration of food in shrinking isolated pools.