Direct and Indirect Anthropogenic Threats to the Function and Existence of Vernal Pools in the United States

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Summary: Vernal pools are seasonally inundated wetlands found in the western, midwestern, and northeastern areas of the United States. These pools provide critical habitat for many amphibians, birds, mammals, and invertebrates, including threatened and endangered species. Due to their small size and periodic nature, many vernal pools remain unidentified and at high risk of habitat loss or permanent alteration due to urbanization, agricultural/urban runoff, and climate change. More specific vernal pool regulations must be put in place in order to ensure future vernal pool habitats are conserved and past habitats are restored.

What are Vernal Pools?

Vernal pools, or seasonal pools, are a valuable and unique type of freshwater wetland. The U.S. EPA defines seasonal pools with four distinct criteria. Seasonal pools must have surface water isolation, be small/shallow, adhere to periods of drying, and support characteristic biological species (Brown & Jung 2005). In the United States, vernal pools are found most often on the West Coast and in areas of the Midwest and Northeast with a Mediterranean-type climate (Mitsch & Gosselink 2015). The specific conditions that are required of this type of wetland come as a double-edged sword. While they enable vernal pools to provide important functions and value to the environment and biological communities that cannot be offered elsewhere, they also allow for extreme sensitivity to anthropogenic environmental and ecological changes that are occurring across the United States.

Functions of Vernal Pools

Due to the unique criteria of vernal pools, these wetlands provide several valuable functions. One of the most important functions is that they are especially well-suited breeding habitats for amphibians like frogs and salamanders, due to the complete lack of predatory fish. For example, vernal pools are the primary breeding habitat for wood frogs (*Lithobates sylvaticus*), mole salamanders (*Ambystoma spp.*), and invertebrates like fairy shrimp (Anostraca) (Calhoun et al. 2014). Meanwhile, other predatory amphibians like bullfrogs (*Rana catesbeiana* Shaw) and green frogs (*Rana clamitans* Latreille) are kept away as a result of periodic drying (Calhoun et al. 2003). Without vernal pools and a safe haven from predators, many amphibious species would struggle with successful breeding. In fact, 26% of listed threatened and endangered amphibians in the mid-Atlantic region are reliant on vernal pools (Brown & Jung 2005).

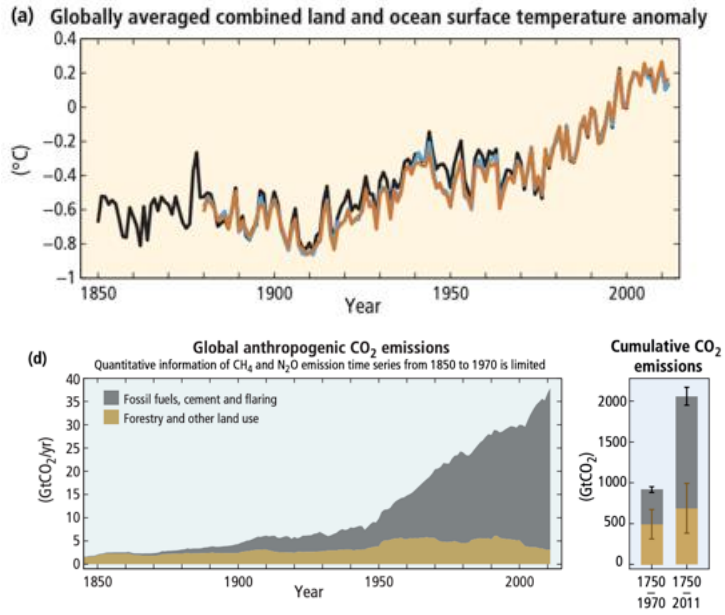
Other species can be found utilizing the resources of vernal pools as well. Migratory waterfowl use the pools to replenish their energy during their long journeys, shorebirds feed on the mudflats when water levels are low, and turtles and snakes use vernal pools to move between adjacent habitats (Biebighauser 2002). Like all bodies of water, vernal pools also have the ability to capture excess water. This has positive effects ranging from replenishing groundwater storage to reducing downstream erosion and flooding (Biebighauser 2002).

Threats to Vernal Pools

Unfortunately, the small size and periodic nature of vernal pools makes them extremely sensitive to environmental changes. One of the biggest threats to the existence of these wetlands is physical habitat loss due to urbanization (Baldwin & deMaynadier 2009). According to the US EPA, over 90% of original vernal pools in California have been lost (Vernal Pools 2018). A significant percentage of this loss is likely due to the direct and indirect effects of urbanization. Adding to this effect is the fact that many vernal pools are undocumented, and therefore unprotected. In a study conducted in 2009, Baldwin & deMaynadier found that over 50% of the potential breeding pools they had delineated in New England were not identified on National Wetland Inventory Maps. They also found that 46% of potential breeding pools and 80% of adjacent habitat were not protected under conservation lands or regulatory protections (Baldwin & deMaynadier 2009). The large percentage of unprotected adjacent habitat is an especially concerning number because vernal pools depend on these habitats in order to survive. In fact, the US EPA recommends the management of a 1000 ft radius area around the edge of vernal pools as upland habitat (Brown & Jung 2005). If surrounding upland habitat is lost, vernal pool habitats will likely be lost too.

Other potential threats to vernal pools are changes in water chemistry due to agricultural or urban runoff. Agricultural runoff is more prominent in areas with dense farmland. Agricultural runoff has the potential to carry fertilizers, herbicides, insecticides, and animal waste into aquatic systems like vernal pools. Comparatively, urban runoff has the potential of introducing road salts, garbage, oil, pesticides, and other household/industrial chemicals. The introduction of these materials can lead to changes in water parameters such as nutrient levels, pH, and dissolved oxygen. Changes in these parameters may affect biota living in vernal pools. For example, one study showed that lower pH values resulted in higher mortality rates for Jefferson and spotted salamander embryos (Hulse et al. 2001).

Another pertinent threat to vernal pools is climate change. Many wetland species rely on environmental cues to successfully carry out their life functions and any changes in those environmental cues are going to have an effect on the organisms that depend on them. According to the Fifth Assessment Report (AR5) published by the Intergovernmental Panel on



(a) Average global land and ocean surface temperature trend from 1850 to 2014. **(b)** Trend in global anthropogenic CO_2 emissions from 1850 to 2014.

Climate Change (IPCC), anthropogenic greenhouse gas (GHG) emissions have been increasing since the pre-industrial era and the average temperatures of our atmosphere and oceans have increased as well. These GHG emissions, along with other anthropogenic drivers, are extremely likely to be the dominant factor behind the overall warming patterns observed since the 1950s (IPCC 2014). One way this threatens vernal pools is through the migration of salamanders. Based on environmental cues, salamanders usually migrate after evening rains when daytime temperatures are moderately over 44.6ºF and nighttime temperatures are over 40.0ºF (Hulse et al. 2001). Therefore, changes in average temperatures and precipitation (another impact of climate change), can shift salamander migration time periods.

Future of Vernal Pools

When considering the future of vernal pools, one of the most crucial areas to discuss is conservation. Conservation of vernal pools is a complicated issue because many vernal pools are not even identified, and/or they are not included under any sort of regulation protection. This is due in part to the isolated nature and small size of many vernal pools (Calhoun et al. 2014). A 2001 US Supreme Court Decision, known as the SWANCC decision, ruled against the protection of isolated waters (Burne & Griffen 2005). This decision brings into question the protection of isolated vernal pools that cannot be categorized under any state jurisdiction. Fortunately, some states have adopted their own models for vernal pool protection. For example, Massachusetts has used a certification process since 1987 to identify and regulate vernal pools (Burne & Griffin 2005). Ultimately, the next step in the process of protecting vernal pools will be the incorporation of protecting surrounding upland habitat as these areas have been shown to be critically important to the biota in vernal pools (Burne & Griffin 2005).

Sometimes it's too late for conservation. When this happens, the next best option is restoration. Restoration does not come without its challenges, however. Often, vernal pool restorations fall short on providing the necessary habitat for amphibians to thrive (Calhoun et

al. 2014). Years of monitoring and adaptive management must take place in order to ensure restored vernal pools meet their expectations. And when comparing natural vernal pools to constructed pools, constructed pools tend to become shallower and inundated for shorter periods of time if hydrological conditions are not maintained post construction (Collinge, Ray, & Marty 2013). Restoration can still be successful under the right conditions and management, but it should be used as a last resort while conservation should ultimately be prioritized.

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