Global Status and Trends in Ephemeral Pool Invertebrate Conservation: Implications for Californian Fairy Shrimp

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ABSTRACT. The main threat to all ephemeral pool invertebrates throughout the world is habitat loss caused by land uses that destroy or severely damage these wetland ecosystems. Fairy shrimp and other invertebrates restricted to temporary pools are absolutely vulnerable to habitat loss because the subpopulations of each species are contained completely within the confines of discrete pool basins. The dormant population within each pool basin numbers from tens of thousands to millions of individuals, depending largely on pool basin size. These individuals can live in the cyst stage of their life cycle for decades and possibly centuries, a situation that contrasts sharply with the comparatively few short lived individuals observed as active animals during the ponding phase of the pool. Considering these factors, regulatory take prohibitions covering the four listed Californian fairy shrimp species should be directed at actions threatening the diapausing population in the cyst bank, and recovery planning should focus on habitat protection. The public should be given the opportunity to capture and handle a reasonable number of active fairy shrimps without the necessity of obtaining a permit as this will increase public knowledge of, and support for, fairy shrimp without posing a threat to the listed species. Adopting this approach should increase the survival chances of all ephemeral pool species by increasing public support for vernal pools and other ephemeral wetlands.

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INTRODUCTION

Anostracans, fairy shrimps, are a flagship group for the large branchiopods (Anostraca, Notostraca, and Conchostraca) in particular and for temporary pool invertebrates in general. Globally the status of all these animals is clearly related to human use of the world's various landscapes. Considering the vast lands of the former USSR, Vekhoff and Vekhova (1995) report fairy shrimps are safe for now in out-of-the-way areas like high mountains and arctic regions, but are almost totally confined to nature reserves in areas of high human use like the steppe biome. A similar situation prevails in Italy, where during the past two decades land uses destructive to wetlands have eliminated great numbers of anostracan habitats resulting in the restriction of a once widely distributed species to two localities: a national park and a nature reserve (Mura, 1993). For several years, Dr. Walter Hödl promoted an effort to evaluate and protect the large branchiopods of Austria. The current conclusions of this work are that one fairy shrimp and one clam shrimp are likely extinct in Austria, and that saving the remaining species can only be achieved by habitat protection (Eder and Hödl, 1995). To enlist the aid of the Austrian public in protecting the wetland habitats needed by large branchiopods, the OÖ. Landesmuseum in Linz, Austria published a beautifully illustrated book treating all aspects of the subject (Aescht, 1996). Brendonck and Riddock (1997) report that ranching practices and development schemes threaten the ephemeral wetlands of Botswana to varying degrees, some potentially devastating. In North America, the Great Plains must have once been home to vast numbers of fairy shrimps and other ephemeral pool organisms living in buffalo wallows and other temporary wetlands. Today, an anostracan fauna of widespread species inhabits only parks, rough areas, and pasture lands in what has become a highly developed region of agricultural and urban landscapes. If any fairy shrimp species with restricted distribution and habitat requirements became extinct during settlement of the Great Plains, we will most likely never know the loss occurred. The same can be said for other ephemeral pool invertebrates of the Great Plains.

An Introduction to Invertebrate Conservation (New, 1995) is the first book to consider invertebrate conservation on a global scale. New's major conclusion is that the overriding requirement for protecting invertebrates is habitat conservation. In working to protect inhabitants of ephemeral wetlands, a focus on habitat conservation is beyond question the first priority. It is far more important than protecting individual animals or plants. The significance of this situation is far reaching, because it requires a shift in approach for endangered species programs that have heretofore crafted methodologies based on protecting vertebrate species such as whooping cranes and tigers. The requirement of looking beyond the individual to the habitat in protecting threatened ephemeral pool species is solidly grounded on the fact that these organisms spend most of their often very long lives as dormant cysts or seeds in the sediments of temporary pools; whereas, the active stage in their life cycle is typically a short-lived reproductive period well adapted to high rates of mortality. It is through protecting ephemeral wetlands as functioning systems that any of their species of concern are to be conserved.

During the dry season, the fairy shrimp population of an ephemeral pool consists entirely of dormant embryos. During the wet season, it includes the active individuals hatching from this cyst bank, and the new resting eggs they produce, plus those remaining dormant in the sediments. Important questions for conservation and regulatory planning are: What is the size of the cyst bank in a pool?; and, How long do cysts survive?

HOW LARGE IS THE CYST BANK?

Fortunately, there is a research report that gives us valuable insight into the size of anostracan cyst banks. In this work, Hildrew (1985) carried out a detailed population and life history study of *Streptocephalus vitreus* (Brauer, 1877) living in a temporary rainpool in Kenya. Hildrew's work is an excellent example of the type of study needed for any ephemeral pool species requiring conservation action.

While Hildrew did not estimate the total number of cysts in the Kenyan pool, he reported all the measurements necessary to make these calculations. He took 60 core samples from the upper 1.5 cm of the dry pool sediments along a transect from its center to the high water mark. Each core had a surface area of 7.6 cm^2. He estimated the numbers of viable cysts present in each core by counting the number of nauplii hatching during nine 28-day wet periods separated by 28-day dry periods. The result was an estimate of 438 viable cysts in 456 cm^2 of pool sediment. Hildrew measured the surface area of the pool as 380 m^2. Thus, an estimate of the number of viable cysts in this pool is 3,648,000 (9,600 cysts per m^2 x 380 m^2). This is most likely an underestimate of the actual number present, since it is based on nauplii hatching from sediment samples rather than a physical count of the cysts present. A considerable body of evidence demonstrates that resting eggs of a single female and those in the cyst bank of a single pool hatch over an extended, but as yet undetermined, number of inundation cycles (Belk and Cole, 1975; Hildrew, 1985; Brendonck and Persoone, 1993; Simovich and Hathaway, 1997). This variable hatching response protects each local population from being totally killed off by partial pool fillings that dry before emerging fairy shrimp can reproduce. Partial fillings are common in rain-filled pools.

Hildrew (1985) estimated the number of *Streptocephalus vitreus* emerging from the cyst bank of his Kenyan study pool during the long-rains inundation of 1981, at 107,000. This suggests that only about 3% of the fairy shrimp population present in the cyst bank of the pool hatched. The 1981 filling season was a good one, and Hildrew estimated the reproductive population produced 800,000 resting eggs. Thus, the emergent population replaced itself by over seven times.

HOW OLD ARE INDIVIDUALS IN THE CYST BANK?

While it is generally acknowledged that anostracan resting eggs are able to live for a long time, there is very little information on just how long this might be. Anecdotal information ranges from the reasonably reliable remark of A. S. Jackson, a student of Southern High Plains playas, that fairy shrimp eggs can lie dormant in the basins of playas for twenty years, and then hatch when rainwater finally fills them (Steiert, 1995), to the more suspect note in Browne (1993) that a few *Artemia* cysts gathered from a section of an oil exploration core drilled near the Great Salt Lake in Utah and dated at 10,000 years old, hatched when tested for viability. I searched the literature and found seven papers presenting the published observations available to date (Table 1). The longest record for cysts of a species under natural conditions is eight years for *Eubranchipus neglectus* (misidentified as *E. vernalis*). Dexter (1967) made this observation while monitoring pools in Portage County, Ohio USA, during every year and inundation from 1941 to 1962. Laboratory study of cyst longevity is less demanding; thus, the measured survival times for cysts in the laboratory are the longest. Dexter (1973) reported the record time of 16 years for cysts of *B. packardi* stored under room conditions in dry pool sediments. Other workers reported that the cysts of two species produced better than 20% hatch in a single inundation test after 15 years (Table 1). Besides the published reports, Clyde Eriksen, of the Claremont Colleges, told me about his unpublished experience hatching cysts of *Streptocephalus sealii* from pond soil after storing the sample in a plastic bag at room conditions for 25 years. Observations on the age and mortality rate of copepod cysts suggest that these estimates of anostracan cyst longevity are most likely short of their true duration, probably by a considerable amount.

The copepod *Diaptomus sanguineus* produces a resting egg capable of diapausing in the sediments of water bodies that either remain inundated or dry from time to time. Hairston *et al.* (1995) hatched resting eggs of this copepod recovered from dated core samples of sediments taken in two small lakes in Rhode Island. In one of these lakes, they found the mean age of viable cysts to be 70.4 years. The maximum age of any cyst they hatched was 332 years. They estimated resting egg mortality rates at 1.1 and 1.5% per year for the two lakes by regressing egg density on sediment age. Their work demonstrates that aquatic crustaceans are capable of producing resting eggs that can survive for very long periods with very low rates of mortality. A similar study of anostracan cysts would be useful.

TABLE 1. Published observations on the longevity of anostracan cysts in both pool and laboratory considitions (see sources for details which differ in each case).

	years	% hatch	species	reference
pool:				
	8	nm	*Eubranchipus neglectus*[1]	Dexter, 1967
	6	nm	*Branchinecta lindahli*	Donald, 1983
	5	nm	*Eubranchipus intricatus*	Donald, 1983
	5	nm	*Chirocephalus diaphanus*	Friday et al., 1996
	3	nm	*Eubranchipus bundyi*	Donald, 1983
laboratory:				
	16	nm	*Branchinecta packardi*	Dexter, 1973
	15	22	*Artemia franciscana*[2]	Clegg, 1967
	15	0.8	*Artemia franciscana*[2]	Clegg, 1967
	15	21	*Streptocephalus sealii*	Moore, 1979
	14	nm	*Branchinecta mackini*	Dexter, 1973
	13	nm	*Thamnocephalus platyurus*	Dexter, 1973
	10	59	*Streptocephalus sealii*	Moore, 1979
	6	nm	*Streptocephalus proboscideus*	Brendonck & Persoone, 1993
	4	nm	*Branchinecta lindahli*	Donald, 1983

Notes: nm = not measured; [1] = species misidentified as *Eubranchipus vernalis* in Dexter (1967); [2] = species misidentified as *Artemia salina* in Clegg (1967).

PROTECTING INVERTEBRATES THROUGH HABITAT CONSERVATION

In 1990, the International Union for the Conservation of Nature (IUCN) adopted a resolution on "Conservation of insects and other invertebrates," laying out the actions its members considered necessary for the protection of invertebrate biodiversity (see text and commentary in Collins, 1991). Among other things, this resolution urges governments to draft their wildlife protective legislation taking into account that the primary threat to invertebrates is habitat destruction. In the introduction to his book on invertebrate conservation, New (1995) writes, "Indeed, one could validly claim that habitat conservation is of such overriding importance to invertebrates that concentrating on taxa to any extent is trivial — tinkering around the edges of the problem." While I agree with the general spirit of Dr. New's statement, I would point out, it is often through concentrating on taxa that we come to recognize the habitats needing protection. Without knowledge of the numerous species endemic to vernal pools in California, there would be no recognition of these pools as a singular, unique ecosystem. In practical terms, habitat is often conserved as a result of its importance to some species or group of species that have become the focus of human concern.

Since human concern is key to the conservation of species and the habitats on which they depend, it is extremely important that laws and regulations be very sensitive to the need to maintain public support for the species that become subjects of protective laws. New (1995) notes that legislation has a responsibility "to ensure that collecting prohibitions or restrictions, such as closed seasons or 'bag-limits', are based on the best information available and are likely to be an effective part of management to sustain the species involved." Given these considerations and what we know about fairy shrimp biology, I think regulatory take prohibitions for the listed fairy shrimp species should be directed at actions threatening the diapausing populations in the cyst banks. The capture of a few fairy shrimps for observation followed by release back into the pool, and collection of up to say, 50 fairy shrimps for valid research or teaching purposes, should be considered an allowable taking not requiring a permit. This would allow curious individuals to explore the wonders of ephemeral pools without fear of legal entanglements. Teachers would be free to introduce their students to these interesting animals. Zoologists interested in distribution of ephemeral pool animals would be free to make necessary collections. And all of this could be done without the necessity of regulatory agencies tying up limited human resources to process requests and issue permits for activities which in no way threaten the survival of listed fairy shrimp species. With this approach, vital public awareness of these animals should be advanced because educational and natural history organizations that may not want to become involved in the permitting process would likely take the opportunity thus open to include fairy shrimp in their programs. The public can appreciate an endangered bird through binoculars, but to appreciate and experience a fairy shrimp, the animal must often be captured.

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