Anthropogenic effects, habitat, conservation measures and population relationship with changing desert and arid environments on endangered species: Desert pupfish (Cyprinodon macularius)

Melissa M. Varela

California Baptist University

Author Note

Melissa M. Varela, Department of Natural Mathematical Science, California Baptist University.

Correspondence concerning this article should be addressed to Melissa M. Varela, Environmental Science, California Baptist University, Riverside, CA 92504. E-mail: Melissamarie.Varela@Calbaptist.edu.

Abstract

In this research, I assessed the population of Desert pupfish (Cyprinodon macularius) and effects from natural and anthropogenic influences and how they correlate with changing habitat conditions, such as salinity, sedimentation, dissolved oxygen, temperatures, pH, agricultural runoff, and native and invasive plants and wildlife. Data collection was provided through various scholarly sources to summarize my research results and raised numerous questions for how conservation could positively affect this depleting resource for the Desert pupfish and how can humans reduce the impacts on the region of these endangered fish.

Introduction

Although, we may conclude that desert landscape cannot promote species biodiversity due to extreme temperatures and dry climate, there is specialized ecosystem containing fish, wildlife (e.g. endangered, species of special concern) and plants, who have adapted to these particular conditions and cannot survive anywhere else. The purpose of my research is to gather information and analyze documented research so that I may facilitate the importance of maintaining and mitigating the anthropogenic effects on these sensitive environments that account for 25-35% of the Earth's landmass and lies between 15° and 30° latitude [13]. The locations, I have focused on are in the deserts of the Southwestern U.S. that primarily lie in the rain shadow of mountain barriers located inland, this creates temperatures that are high during the summer and may drop below freezing in the winter months [13].

Studies and Methodology

Habitat Characteristics: Salt lakes

Inland saline aquatic habitats are generally considered to be salt lake, wetland type environments. These aquatic habitats rang in stability from shallow temporary ponds and low flowing streams to larger permanent salt basins (e.g. terminal lakes, etc.). The salinity levels of these aquatic environments will range considerably from dilute salinities to the extreme stress of salt saturation [2]. Research studies were conducted to classify various brackish waters: (1) hypersaline lagoons with periodic connection to the sea dominated by euryaline marine biota, (2) ancient marine waters, once connected to the sea, now harboring isolated biota of mixed marine/freshwater origins, (3) brinish waters with evaporation pons, solar salt works, highly chlorinated, (4) brinish waters with increased sulfate and carbonate concentrations, (4) mineralized waters of thermal springs [2]. Saline lakes are also referred to as terminal stage in aging of endoheric lake basins with four main types of habitat characterizations: (1) lower salinity (perennial) that consist of low osmotic and ionic regulation, long-lived, larger organismal sizes, slower growth and lower fecundity; (2) high salinity (perennial) has an extensive range of hypoosmotic regulation, slower growth rates under stresses, varied body sizes; (3) low salinity (intermittent) consisting of rapid development, migratory ability, limited osmoregulation, anion preference, dormant life stages; and (4) high salinity (intermittent) where there's an extreme resistance to high salinity, rapid growth during hydrated phases, follow by immediate dormancy [2]. Appropriately, these are named examples of the four main types of inland saline water habitat: low salinity (perennial) deep lakes, such as Pyramid Lake and Walker Lake; high salinity (perennial) medium to deep lakes with chemical composition, such as Mono Lake and Great Salt Lake; low salinity (intermittent), such as Black Rock Deserts and Carson Sink; and high salinity (intermittent) salt crust depressions that collect and evaporate rainwater, such as dry

lakebeds and Owen's Lake [2]. These particular saline inland aquatic environments require that organisms maintain hypotonic blood even at high salinities (corresponding to 0-15 ppt, 15-50 ppt, and >50 ppt salinity levels [2]. Species must be highly adaptive to the extreme environmental conditions of these saline water habitats. The natural state of the location of the Salton Sea, which lies in a rains-shadow coupled with extreme weather events (e.g. wind, sandstorms, desert environments, rain storms), can create currents that disturb the Sea's anaerobic sediments, dramatically depleting dissolved oxygen concentrations in the water column, generating huge fish kills [15]. These natural events in the Coachella Valley contribute to the overall health of the ecosystem (e.g. humans, plants, wildlife).

Desert pupfish: biological analysis

Through my research, I will highlight Desert pupfish (Cyprinodon macularius), their physical characteristics, conservation status, adaptive strategies, habitat preferences, and mitigation techniques and relate their abilities to survive desiccating extreme environmental conditions. Desert pupfish are ray-finned fish with stunning coloration (e.g. blues, oranges, purples and reddish-browns) [1]. They grow to up 3 inches long, deep bodies, with highly arched backs, and only have a lifespan of 6 months to 2 years, maximum life expectancy of 3 years [14]. According to the Bureau of Land Management, Desert pupfish have specialized adapted physical conditions that allow them to eat (omnivorous) Nektonic organism, detritus material, algae, small fish and invertebrates by using their upturned mouths to easily eat surface algae, invertebrates and food material on the surface of the water [14]. They feed on small invertebrates and detritus picked from substrates, and their feedings usually occur during the daylight hours, when water conditions are at their clearest [14]. Juvenile fish grow, and eventually become omnivores over

time (e.g. feeding on insect larvae, algae and mollusks [13]. Their metabolism and activity is concentrated on temperatures of waters, during the winter months (dominant months) they transition to shallow areas of pools late in the day and remain there through the night hours, even bury themselves in loose debris on the bottom of some habitats; however, during the warmer months of the year, pupfish move to areas of preferred water temperatures [14]. As temperate warmer months approach, waters warm and become quite active, for example males display more vivid blue colors, defend their territories, and chase after other fish species while trying to attract female pupfish for spawning [14]. Female pupfish are known to produce anywhere from 50-800 eggs per year and reproduce during their first or second summer, incubation lasts for 10 days [13]. Spawning season begins early March and continues through the summer months [14]. As a result of food reduction, some desert pupfish have been known to eat their own eggs and larvae [13]. Male pupfish don't have the easiest job, according to a study, they spent over 50% of their time chasing mollies away from their territories, which suggests negative effect on breeding activities of pupfish.

Conservation Status

As of 1980, Desert pupfish has been listed in the state of California as an endangered species, and in 1986, they were federally listed. Since 1964, after major biological surveys and analysis, California Department of Fish and Game determined that desert pupfish populations were severely declined [14]. One research study stated that one of the most dramatic declines has been the status of the Desert pupfish complex (*Cyprinodontidae*), a once wide-ranging group that has greatly disappeared from 95% of its historical range in only the past several decades [4]. Historically, pupfish range consisted of Colorado River tributaries, Salton Sea wetlands, Salt

Creek preserve, Baja California, Gulf of California, and some Sonoran desert springs [15]. Observing and quantifying this extreme reduction in distribution and abundance of Desert pupfish, it was listed as a federally endangered species in 1986 [4]. Consequently, poor existing wild populations have contributed to more than 40 populations moving to created habitats and natural habitat conditions [4]. Currently, Desert pupfish primarily inhabit Salton Sea, Salt creek, Cerro Prieto geothermal fields, Rio Hardy, Gila River, San Felipe Creek, some creeks near Baja California, and various types shoreline pools and low flowing agricultural drains [4]. Additionally, most populations are isolated uninhabitable corridors and dry desert barriers and the Salton Sea populations of Desert pupfish have been isolated from the Colorado River delta over the last century [4]. Examples of isolation include: Wetlands near the headwaters of the ephemeral connections at the Rio Handy river were impounded or diversion state water projects since 1990 [10]. Most of these population reductions and environmental impacts are related primarily due to anthropogenic effects, but mostly related to water diversion, soil erosion, habitat, predation, aquatic conditions, biomagnification, overgrazing, overpumping of groundwater, and water pollution from point and non-point sources.

Habitat description and preferences

There's a directly correlation between that the natural population numbers relative to environmental changes suggest that pupfish numbers are linked to habitat sizes and available resources [7]. Higher populations of pupfish will occur where there are fewer in major predators, interspecific competition and changes in environmental and habitat conditions. Their main habitat preference is the Salton Sea, Salt Creek, and irrigation drains leading to the Salton Sea [3]. The Salton Sea, which is a terminal lake, doesn't have an outlet of flowing water, just inflow.

This creates a very interesting ecosystem that inhibits many species from being successful and maintaining a population. Desert pupfish in habit arid desert conditions of the Southwestern U.S. where the summer water temperatures may reach up to 100°F and winter water temperatures may get as cold as 45°F. The annual rainfall for the Coachella Valley (where the Desert pupfish for this study were found) is less that three inches per year, and has a net evaporation rate of 66 inches per year [1]. This poses an extreme treat on the health of the pupfish and it's native habitat, because as water rapidly evaporates, salinity concentrations in the aquatic ecosystems increase, in addition to the accumulation of agricultural and domestic runoff and discharges. The terminal basin Salton Sea has an average pH 8.2 and according to research the overall salinity of Salton Sea is 46 g/L, which is 33% saltier than the ocean [1]. Agricultural drains (containing excessive nutrients, pesticides, fertilizers, selenium and nitrates) are predominantly responsible for the salinity concentrations spike in the Salton Sea. Historically, pre-agricultural selenium introduction was due to the weathering of seleniferous deposits in the Upper Colorado River Basin [11]. According to an Emigration patterns of the Desert pupfish were noticeably high during the summer months, which allowed for higher rates of reproduction, and gradually decreased into the cooler months, when they're less active. According to a study, temperature appeared to influence the emigration very strongly; comparisons in controlled conditions confirmed this to be true. Emigration is vital to the health and fitness of Desert pupfish, the same study determined that closed pool systems without corridors for movement stressed the pupfish, and eventually led to starvation and declines in activity and reproduction [7]. Seasonal fluctuations in water levels of the shoreline pools and drains might affect fish health and/or force pupfish to seek other habitats [12]. Overall, the Desert pupfish prefer the shallow, clearer-water,

low-flowing, shoreline pools that have abundant protective aquatic vegetation (e.g. Bulrush, Cattail, and ditch grass) [10], they use agricultural drains, creeks and shoreline pools for searching food sources and mates.

When conducting biological surveys pertaining to aquatic environments, researchers often gather the following Water quality parameters: temperatures (ambient, water), salinity (ppt), pH dissolved oxygen (mg/L) and depth (m), and electrical conductivity (mS) [9]. Water borne particulates were analyzed for total selenium concentrations, as well as sediments, particulate organic detritus and biota (food-chain matrices) to determine chemical composition [11]. Ecological variations in population and fitness of the Desert pupfish are highly dependent on these parameters, primarily temperature, depth and salinity. These directly influence the marginal pupfish population [1]. Particulate organic matter consists mostly of decaying plant remains, especially leaves and twigs from ditch-bank vegetation and aquatic emergent [11].

Morphology and capabilities to survive desiccating conditions

Desert pupfish can with conditions that most invertebrates and fish cannot, they can survive salinities of up to 70 g/L, which is 33% saltier than the ocean, which is more than double the salt concentration [11], they can also survive in extreme high selenium concentrations due to the discharge (potentially greater than 15 µg/L) [15]. This extreme salt barrier favors the pupfish by impeding the invasion of most exotic species from the neighboring areas. Conditions and food availability contribute to the their morphology. Results from a study determined that low food availability could developmentally generate the dwarfed morphological phenotype that resembles varied sizes of populations based on location of the habitat [3]. Certain pupfish were controlled, by tank studies, under low food ration situations developed larger head and eye sizes,

shallower bodies, and failed to develop paired pelvic fins [3]. Other Desert pupfish were capable of acclimating to higher temperatures, while ingesting more food than those in lover temperatures due to the elevated metabolic rate that are assimilative efficiency for food sources; additional studies concluded that high temperatures habitats can acquire sufficient nutrients to maintain their elevated metabolism connecting with high growth and reproduction rates [3].

Anthropogenic effects

Water diversion (e.g. state water projects, agricultural and domestic demand, water rights acquisition) has led to a total loss of 95% of the Desert pupfish historical range over the century [15]. Water conservation effects from local and state water projects, subsequently, may reduce the amount of wetland habitats and irrigation drains of Desert pupfish, as farmers use less water for agriculture there will be lower water levels for pupfish who use the irrigation drains as their main habitat preference [11]. Although pupfish have been known to prefer certain habitats to others they favored habitat is increased salinity factors, average dissolved oxygen, increased pH, vegetation coverage, and turbidity, as well as lowest sediment dispersal [5].

Soil erosion, another causative anthropogenic limiting factor is displayed from humans digging for artesian wells, which are located a smaller distance above springs, water flows from the well to the surface to join natural springs could cause disturbance in the water availability of the area. Intensive grazing of surrounding vegetation by cattle and horses were also observed, which caused devastating soil compaction by livestock [10]. Dust emissions, a consequence of soil erosion, occur on unstable surface sediment with low moisture content. Unstable lakebed surfaces are a concern regardless of particle size. Unstable is defined as any surface that is not wet, salt-crusted, protected with vegetation, or covered with larger, stable materials (i.e. gravel,

barnacles, fish bones). Dust can be emitted from unstable exposed lakebed surfaces by wind velocities of 17-20 mph, measured at height of 10 meters. Surface stability can change with changes in soil moisture and temperature [15]. Regional development (e.g. urban, industrial, and agricultural) due to demand for scarce land and hydrological resources, reduces the water source and river discharge, consequently, negatively impacting the aquatic and riparian habitats of the lower basins [10].

The Desert pupfish population complex has been highly disturbed by human activities and local populations are now smaller, physically and numbers-wise, and are now subject to the extirpation or genetic bottlenecking [4]. Selenium concentrations in agricultural irrigation drains (runoff from fields), enters the aquatic food chain leading to the fish primarily by accumulating in organic detritus; selenium accumulating averages 20.0 μg Se/L in wetland system [11]. This allows for Desert pupfish to survive under severe aquatic conditions.

As aquatic habitat and water solution chemistry (e.g. salinity, organic and inorganic pollutants, pesticides, and fertilizers) change over time and are driven by anthropogenic activities, the trophic levels are impacted heavily. It begins with water conditions, sediment, selected aquatic food-chain taxa (particulate organic detritus, filamentous algae, net plankton and midge larvae) and moves to smaller fish and invertebrates (Desert pupfish) to larger fish (Orange mouth Corvina) and to migratory birds that are feeding on these fish.

Invasive species introduction

Although pupfish are exposed to extreme environmental conditions, a contributing anthropogenic factor is the modification of trophic levels by the introduction of nonindigenous fish and pollution, which has caused the displacement of extirpation on native populations due to

competition pressures [10]. Several species of fish are introduced into the canal systems and the Salton Sea for benthic vegetation, algae, and sediment cleaning and control. These non-native fish pose major threats to the balance and predation of Desert pupfish and native species. They're also introduced by resource agencies that host fishing events, and remaining fish multiply over the years and augment the stresses on the natural resources of inhabitants.

Avoidance and minimization practices management and mitigation techniques

There are several ways that we can improve the health of the desert habitats, their ecosystems and sub-populations. Industry, agriculture and resource agencies could take the following steps to enhance native habitats by implementing avoidance and minimization mitigation techniques in their practices. First, soil stabilization for lakebed, canals, agricultural drains, crop layouts and grazing parcels, could greatly reduce the amount of soil erosion for the aquatic habitats. Second, the reduction of pesticides, fertilizers, and other contaminants for agriculture purposes could greatly influence the aquatic habitat conditions for pupfish and vegetation. Third, the eradication of predatory and invasive species would boost the total pupfish population. Fourth, the increased created habitat and conservation areas would be beneficial for the health and population of pupfish, but also native desert vegetation as well. Several surviving populations are subjected to created and artificial habitat, as mitigation techniques for removal of native and natural habitats due to anthropogenic effects. Another option is the increased stable flooding conditions in the littoral habitats, allowing for higher prediction of prey availability of desert pupfish. Using avoidance and minimization measures for maintaining stormwater channels will be advantageous for desert habitat mitigation, especially with removal of cattails and other vegetation during routine ditchbank maintenance [5]. Harvesting aquatic vegetation

can physically remove pupfish entrapped in the vegetation and reduction or elimination of natural protective coverage, which will result in pupfish exposure to predation [5]. Restricted access to certain areas where pupfish resides will enhances the total suitable habitat for managing and conserving the desert pupfish.

Conclusion

In conclusion, understanding how environment influences morphology, habitat and food sourcing mechanism may assist researchers and policy makers to incorporate new solutions, mitigation techniques and conservation programs to aid in the maintenance of these desert ecosystems and their biota. As we have discovered human activities, especially agricultural practices and water diversion, are detrimental to all aquatic environments and their complete health. Desert pupfish, which are not only a federally endangered species, but also are considered to an indicator species for their habitat conditions. There's still a lack of information about *Cyprinodontidae* and how extreme conditions affect them, as well as long-term anthropogenic effects on their populations, and how climate change is truly affecting their fitness capabilities and population. Researching long term effects of solution chemistry and global climate change may tell us how to invigorate the Salton Sea and the surrounding Coachella Valley.

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