United States Department of the Interior

NATIONAL PARK SERVICE
Death Valley National Park
PO Box 579
Death Valley, California 92328

IN REPLY REFER TO:
N1423
xL7617

October 26, 2010

Dear Interested Parties,

The National Park Service (NPS), Death Valley National Park has prepared an environmental assessment (EA) for the Long-Term Ecosystem Monitoring Plan (LTEMP) for Devils Hole, NV. The enclosed document is now available for public review and comment through November 30, 2010.

The NPS proposes to implement a Long-Term Ecosystem Monitoring Plan (LTEMP) for Devils Hole because it is believed that a more holistic commitment to scientific understanding is necessary to effectively steward the Devils Hole ecosystem and the resident endangered Devils Hole pupfish. Long-term monitoring would provide a more accurate and current understanding of complex ecological patterns and processes occurring in Devils Hole.

In accordance with the National Environmental Policy Act (NEPA), the EA evaluates two alternatives: No Action, continuation of the current monitoring program, and the Proposed Action, implementation of the LTEMP. The proposed LTEMP would establish long-term monitoring goals, increase the number of parameters that are monitored and contain several models to convey the current understanding of the Devils Hole ecosystem.

Copies of the EA can also be obtained from the NPS Planning, Environment and Public Comment website at http://parkplanning.nps.gov/deva/, at park headquarters in Death Valley, CA, or by contacting Victoria Wilkins at (760)-786-3227 or victoria_wilkins@nps.gov, to request a copy. Comments can be submitted on the website listed above or mailed to: Park Superintendent, ATTENTION: Devils Hole Devils Hole LTEMP EA, Death Valley National Park, P.O. Box 579, Death Valley, CA 92328. Comments will be accepted until November 30, 2010.

Before including your address, phone number, e-mail address or other personal identifying information in your comment, you should be aware your entire comment - including your personal identifying information - may be made publicly available at any time. While you can ask us in your comment to withhold personal identifying information from public review, we cannot guarantee that we will be able to do so. *If you want us to withhold your name and/or address, you must state this prominently at the beginning or your comment(s).* We will make all submissions from organizations or businesses, and from individuals identifying themselves as representatives or officials of organizations or businesses, available for public inspection in their entirety.

We appreciate your input on this project. If you have any questions regarding the project or would like to be removed from our mailing list, please contact Victoria Wilkins at (760) 786-3227 or victoria_wilkins@nps.gov.

Sincerely,

Sarah Craighead
Park Superintendent

U.S. Department of Interior
National Park Service

Environmental Assessment
Devils Hole Long Term Ecosystem Monitoring Plan

Devils Hole, Death Valley National Park
Nye County, Nevada

Summary

Death Valley National Park proposes to initiate a Long Term Ecosystem Monitoring Plan (LTEMP) for Devils Hole, Nye County Nevada. The purpose of the LTEMP is to develop a holistic ecosystem research plan for Devils Hole. This holistic approach will be used to develop and expand on current conceptual models that address ecosystem processes within Devils Hole. Understanding these processes is fundamental in developing and making management decisions for the critically endangered Devils Hole pupfish (*Cyprinodon diabolis*).

The Park has written a LTEMP for Devils Hole to provide much needed data for future issues regarding the endangered Devils Hole pupfish. The purpose of this EA is to examine the possible impacts of the LTEMP on the Devils Hole ecosystem and more specifically the pupfish.

Two alternatives are considered in this EA: 1) No action, continuing with the current monitoring and research of Devils Hole and 2) Preferred alternative, implementing the LTEMP.

Public Comment, Notes to Reviewers and Respondents

If you wish to comment on this EA, you may mail the comments to the name and address below. Our practice is to make comments, including names and addresses of respondents available for public review during regular business hours. Individual respondents may request that we withhold their home address from the record, which we would honor to the extent allowable by law. *If you want us to withhold your name and/or address, you must state this prominently at the beginning or your comment(s).* We will make all submissions from organizations or businesses, and from individuals identifying themselves as representatives or officials of organizations or businesses, available for public inspection in their entirety.

Written communication (hardcopy or electronic) is strongly preferred and will become a public record. However, you are free to call us if there are any questions we can answer, or if you need clarification.

Please Address Comments to:

Park Superintendent
Death Valley National Park
Attn: Devils Hole LTEMP EA Comments
PO Box 579
Death Valley, CA 92328

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Acronyms and Abbreviations

AMNWR	Ash Meadows National Wildlife Refuge
BLM	Bureau of Land Management
CEQ	Council on Environmental Quality
DVNP	Death Valley National Park
EA	Environmental Assessment
ESA	Endangered Species Act
LTEMP	Long-Term Ecosystem Monitoring Plan
NDOW	Nevada Department of Wildlife
NEPA	National Environmental Policy Act
NPS	National Park Service
SCUBA	Self-Contained Underwater Breathing Apparatus
SOP	Standard Operating Procedure
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service

1. Introduction

Purpose and Need for Action

Death Valley National Park (DVNP) proposes to implement a Long-Term Ecosystem Monitoring Plan (LTEMP) for Devils Hole. It is believed that a more holistic commitment to scientific understanding is necessary to effectively steward the Devils Hole ecosystem and the resident endangered Devils Hole pupfish (*Cyprinodon diabolis)*. Long-term monitoring would provide a more accurate and current understanding of complex ecological patterns and processes occurring in Devils Hole. The main purpose of the LTEMP is to increase the scientific rigor of ecosystem stewardship strategies and recovery recommendations of the Devils Hole pupfish while satisfying basic legal obligations.

Past management decisions have typically been driven by dramatic population declines of the Devils Hole pupfish. The first of these occurred in the late 1960's in response to a drawdown of the water table at Devils Hole by nearby groundwater production. This lead to the ruling of the United States Supreme Court in favor of the National Park Service (NPS) and in protection of their federally-reserved water right at Devils Hole (Cappaert v. United States 1976). In 1996 the population once again began a steady decline reaching as few as 38 individual adults by 2007. Unlike the population decline witnessed during the 1960s and 1970s the decline that started in the 1990s lacks a clear cause. Several hypotheses have been put forward as to the cause of this decline, but most of these hypotheses cannot be supported or refuted due to the lack of sufficient data.

The LTEMP is being developed in response to observed declines in abundance of the Devils Hole pupfish, as well as to the need for sufficient data to test ecosystem hypotheses. For over 30 years, records of adult pupfish abundance and water level have been kept. Recent efforts include preparation of a long-term monitoring plan for a suite of abiotic and biotic determinants (Blinn 2003) and a review of ecosystem monitoring approaches and priorities by a panel convened by the Pacific West Regional Directorate in March of 2007 (USGS 2007). Furthermore, a workshop was held at DVNP in September of 2007 to consider improved methods of data management for efforts at Devils Hole. These efforts have served to inform the LTEMP and are incorporated where appropriate.

The purpose of this project is to increase the scientific rigor of ecosystem stewardship strategies and recovery recommendations for the Devils Hole pupfish through the accurate collection of pertinent data. Collection of data would meet the following objectives:

1. Describe spatial and temporal patterns of variation in diverse ecological parameters thought to influence fundamental physical and biological processes
2. Describe spatial and temporal patterns of variation in the abundance of resident taxa
3. Connect sporadic and intensive ecological research with a more continuous and sustained record of ecosystem conditions
4. Provide preliminary data for the development or refinement of research hypotheses
5. Provide early warning of regional or global threats to resident taxa or ecosystem function

6. Maintain a current and accurate understanding of ecosystem conditions to share with the public
7. Provide scientifically defendable and credible information to managers

The proposed LTEMP is attached as Appendix A and is incorporated by reference throughout this EA.

Park Purpose and Significance

The purpose and significance of DVNP are defined in the *General Management Plan* (GMP) (NPS, 2002). According to this document, which is based on the park's enabling legislation and Presidential Proclamations, the purposes of DVNP include:

- To preserve the unrivaled scenic, geologic, and natural resources of these unique natural landscapes, while perpetuating significant and diverse ecosystems of the California desert in their natural state, and to ensure the maximum protection of wilderness values provided by law.
- To preserve the cultural resources of the California desert associated with prehistoric, historic and contemporary Native American culture, patterns of western exploration, settlement and mining endeavors.
- Provide opportunities for compatible public outdoor recreation and promote the public's understanding and appreciation of the California desert by interpreting the natural and cultural resources.
- Retain and enhance opportunities for scientific research in undisturbed ecosystems.

Some features of the park that contribute to its significance include the following:

- DVNP contains the lowest point in North America at 282' (86 m) below sea level. The valley floor receives the least precipitation in the United States (averaging 1.84" (5 cm) per year)) and has the nations highest recorded temperature (134° F; 57°C).
- The Park is world renowned for its exposed, complex and diverse geology and tectonics.
- Death Valley has been the continuous home of Native Americans, from prehistoric cultures to the present-day Timbisha Shoshone Tribe.
- Death Valley contains one of the nation's most diverse and significant fossil records and most continuous volcanic histories.
- Ninety-one percent of the Park is designated wilderness, providing unique opportunities for quiet, solitude, and primitive adventure in an extreme desert ecosystem.
- The Park's natural resources are extremely diverse. The area preserves large expanses of creosote bush valleys and other vegetation typical of the Mojave Desert. Extreme conditions and isolation provide habitat for an unusually high number of plant and animal species that are highly adapted to these conditions (of which the Devils Hole pupfish is a prime example).

Relationship to Previous Planning Efforts

Several plans, projects, and standards that the NPS and DVNP either have in place or have in progress may affect decisions regarding the LTEMP. In addition, the site's location adjacent to Ash Meadows National Wildlife Refuge (AMNWR) requires planning and coordination with U.S. Fish & Wildlife Service for any actions that could impact Refuge resources. The GMP established the guiding management philosophy for the Park and provides strategies for addressing issues and achieving management objectives. The emphasis of the GMP is protection and preservation of natural and cultural resources. This project conforms to the objectives of the GMP in the following

ways:

- The GMP established water resource objectives that include the goal of maintaining the water levels at Devils Hole (p. 12). This project conforms to the GMP by attempting to improve monitoring of the water level and conditions that impact the level.
- The GMP states that long-term status of the Devils Hole pupfish would be monitored and that a long-term monitoring program would be developed for the entire biological community at Devils Hole (pp.30-31). This project would implement the direction of the GMP.

The Recovery Plan for the Endangered and Threatened Species of Ash Meadows Neveda (USFWS, 1990) states recovery criteria for the Devils Hole pupfish which, when met, will enable the Devils Hole pupfish to be downlisted to threatened (a species with a single natural population cannot be delisted (Endangered Species Act 1973). These recovery criteria include a minimum water level of 1.4 feet below a copper washer installed along the cave cliff in 1976, a population of 300 individuals during winter and 700 during late fall, and two refugia populations established offsite from Devils Hole. Data obtained through this project would help to inform management decisions regarding the recovery actions.

An EA was recently completed for the Devils Hole Site Plan. A Finding of No Significant Impacts was signed by the Pacific West Regional Director on March 5, 2010 that selected the Preferred Alternative identified in the EA. The selected alternative consists of constructing a new fence around Devils Hole, enclosing a visitor platform, installation of a ships ladder to access the hole and creation of a sectional portable monitoring platform. At the time this EA is being written installation of the ships ladder is the only site plan activity that has been implemented. Funding is currently being sought to implement the remaining activities. Infrastructure necessary for current monitoring and visitor use of Devils Hole and impacts of such infrastructure was addressed in the Devils Hole Site Plan Implementation EA and therefore will not be addressed in this EA. None of the additional monitoring parameters proposed in this EA would alter the infrastructure needs already identified in the site plan.

2. Impact Topics

Impact Topics Analyzed is this Environmental Assessment

Impact topics to be analyzed within this EA were determined based on applicable laws, policies and regulations, internal scoping and the potential for impacts to those resources. Additionally, several comments were received on the Devils Hole Site Plan EA regarding monitoring at Devils Hole. Those comments were also used in selecting topics to be analyzed. The following impact topics will be analyzed in detail in this EA:

Water Quality
Aquatic Invertebrates
Devils Hole Pupfish

Impact Topics Dismissed From Further Consideration

The following impact topics were considered but determined not to have potentially significant impacts as defined under the National Environmental Policy Act (NEPA) (40 CFR 1500) and therefore were dismissed from further consideration in this EA.

Physical Resources

Air Quality and Climate Change

None of the monitoring methods proposed in the LTEMP would have a mechanism for an effect to air quality or climate change; therefore this topic is dismissed from further consideration.

Soils

The area that would be monitored under the LTEMP is a water filled cave with no soil present in the project area; therefore this topic is dismissed from further consideration.

Biological Resources

Vegetation: Special Status

There are no special status plants or their habitats in or surrounding Devils Hole; therefore this topic is dismissed from further consideration.

Birds: Special Status

There are no special status birds or their habitats located in or near Devils Hole; therefore this topic is dismissed from further consideration.

Mammals: Special Status

There are two bat species that are present at Devils Hole seasonally: western pipistrelle (*Pipistrellus hesperus*) and Townsend's big-eared bat (*Corynorhinus townsendii*). The Townsend's big-eared bat is listed as a sensitive species by the state of Nevada. Most monitoring activities would be conducted during daylight hours when the bats are not active. Therefore, implementation of the LTEMP is anticipated to have no impact on the species. Additionally, there would be no alteration of habitat for either species.

The NPS manages desert bighorn sheep (*Ovis canadensis nelsoni*) as a sensitive species. They have been sighted in AMNWR and are dependent on small, isolated springs for water. Since Devils Hole is fenced, access is not available to these larger mammals; therefore implementation of the LTEMP would have no impact.

There is no potential for impact to special status mammals; therefore this topic will not be carried forward for furt [(L-1(bi)c2 [(c)o(ens)0-2(i5(d(he)-2(n)-10os)1(t5-2(i5(on1(.)]TJ 0 Tc 0 T -12.

Archaeological evidence shows that the Devils Hole area has been occupied for at least 9,000 years and the surrounding area is still occupied by the Timbisha Shoshone and the Pahrump Piute. Devils Hole is considered a Traditional Cultural Property for both tribes and they are allowed access to the site under the American Indian Religious Freedom Act of 1978.

The Timbisha Shoshone, a federally recognized Tribe, have had a long relationship with Devils Hole, and have been active in the Ash Meadows area for thousands of years. One story about the Timbisha Shoshone relationship with Devils Hole is excerpted here:

> Evidence of the cultural significance of Devils Hole to these Native Americans was presented by Barbara Durham, an elder of the Timbisha Shoshone Tribe at the Devils Hole Workshop in Pahrump, Nevada on May 29-31, 2002. In her oral communication, she related the myth of Devils Hole "water babies" ready to swallow children (and perhaps even adults) that stayed at the pool too long. Smith (1993) refers to these water babies as well as to a giant, Tso'apittse, who lives near desert springs lying in wait for unsuspecting victims. In spite of those very powerful deterrents, Ms. Durham reported that she and her childhood friends frequently played at Devils Hole because they enjoyed having the pupfish "tickle their toes" (Riggs and Deacon 2002).

As well, conversations with elders of the Pahrump Paiute tribe have confirmed that Devils Hole was very important to the Paiutes in the past, and that "their ceremonial relationship with the area continue[s] today" (DVNP 2008). The Paiute have not been specific with the Park about their relationship with Devils Hole, but previous research suggests it owes much to the cultural significance of the water itself, as the following excerpt describes:

> But springs meant more than survival to Southern Paiute people. Springs and other water sources were also highly symbolic, sacred places, part of a living landscape, a storied place, peopled with animals, plants and other beings that brought it life and gave it meaning. Stories and songs that often include the names of springs and other places celebrate great hunts and other events that turn a desert into much more than simple geographic space. They create a landscape and a homeland that once gave, and in many ways still gives, people a strong sense of being and belonging – a sense of place. For Indian people, landscapes and homelands are often more important than events and time (Fowler 2002).

The two primary tangible resource conditions that sustain the cultural use and significance of Devils Hole for the affected tribes are site access and the water level in the cavepool itself. In addition, equipment additions into Devils Hole impact the intangible spiritual energy of the site. The Pahrump Paiute and Timbisha Shoshone tribes have strong historical and cultural ties to Devils Hole, and prefer that its resource conditions not be further degraded by actions that significantly increase physical disturbance or add to the potential for such due to increased visitation.

Although the Proposed Action would increase the number of biotic and abiotic parameters that are measured at Devils Hole, it is not anticipated to increase the presence of researchers or equipment in Devils Hole. No installation of new monitoring equipment is proposed and impacts to ethnographic resources from existing infrastructure were analyzed in the Devils Hole Site Plan EA. Access to the site for traditional cultural purposes would not be impacted by the Proposed Action. For these reasons, this topic has been dismissed from detailed analysis.

Historic and Pre-Historic Resources and Cultural Landscapes

No historic resources, prehistoric resources or cultural landscapes are present in the project area; therefore this topic has been dismissed from consideration.

Wilderness

The project area is not in designated, proposed or eligible wilderness; therefore this topic will not be considered further in this EA.

Socioeconomic Issues

Implementation of the LTEMP would be carried out by staff of the NPS, USFWS, NDOW their volunteers, and independent researchers. As such, this project would have a negligible impact on the local economy or creation of jobs in the area. This topic has been dismissed from further consideration.

Environmental Justice

Impacts associated with implementing the LTEMP would not disproportionately affect any minority or low-income populations. This impact topic is, therefore, dismissed from further consideration.

Public Health and Safety

Neither alternative would have an impact on public health and safety.

Prime and Unique Farmlands, Floodplains

There are no prime and unique farmlands or floodplains located within the project area. This impact topic, therefore, is dismissed from further consideration.

3. Alternatives

No Action Alternative

Under this alternative, DVNP would continue its stewardship responsibilities through the current monitoring program. This includes water quality, invertebrate, and Devils Hole pupfish sampling using the techniques and Standard Operating Procedures (SOPs) described below under Actions Common to Both Alternatives. In addition, current collaborative research projects would continue.

Under the No Action Alternative the monitoring program would remain the same and no new parameters would be measured to help answer possible changes to the Devils Hole ecosystem and possible causes of the decline in pupfish numbers.

Proposed Action Alternative

The Proposed Action would expand on the current monitoring program by increasing the number of abiotic and biotic parameters that would be measured. This holistic approach is intended to develop a better understanding of ecosystem function and community state(s) of Devils Hole.

SOPII: Water Temperature

Temperature is currently collected using the water quality data loggers as described under SOPI and from six small Hobo® temperature data loggers. The Hobo® data loggers are distributed equally over the shallow shelf at six locations. Temperature is collected at 15-minute intervals.

The No Action and Proposed Action alternatives would monitor temperature in the same manner as currently being conducted and described in SOPII.

SOP III: Water Level and Depth

Water level and depth have been collected over the past three decades and are currently overseen by DVNP hydrologists and the Water Resources Branch of the NPS. A large stilling well with a float connected to a chart recorder, and two smaller (35 mm ID) stilling wells each containing a transducer are used to monitor both water level and depth. Compliance for Devils Hole Site Plan was completed in March 2010, this allowed for the removal of the large stilling well and chart recorder. Removal of this equipment was completed between May 10 and May 15 2010. This has reduced the impact of water level and depth monitoring in Devils Hole.

The No Action and Proposed Action alternatives would monitor water level and depth using the small stilling wells that are currently being used and described in SOPIII.

SOP IV: Substrate Surveys

Substrate surveys are currently being conducted annually or following a major disturbance (e.g. earthquakes and/or floods). Annual surveys are conducted in winter when algal production is lowest reducing disturbance to the ecosystem.

The No Action and Proposed Action alternatives would use the same protocol that is currently being used. The shallow shelf is divided into 22 transects length-wise (south to north; Appendix A, Figure 1). Along each transect, 10 evenly spaced points are determined width-wise (east to west; Appendix A, Figure 1). At each of these points substrate size-class is determined and depth from substrate to water surface is noted. A total of 220 point measurements are taken. From this, percent composition of each size class is determined. Size classes include fine sand (< 1.0 mm), gravel (2-15 mm), pebble (16-60 mm), cobble (61-150 mm), and bedrock (>151 mm).

SOPVII: Devils Hole Pupfish

Current monitoring of pupfish life history traits consists of biannual adult surveys, and twice monthly surveys for early life stages (fish larvae (i.e. fry)). Adult surveys require the use of SCUBA and are conducted in the spring and autumn. Early life stage surveys are conducted on the shallow shelf and use trays composed of 4.5 cm inner diameter PVC piping cut in half length-wise into 30 cm pieces. Surveys are conducted at night using 27 trays. These trays cover only approximately 9% of the surface area of the shallow shelf

The No Action and Proposed Action alternatives would monitor pupfish in the same fashion as described above.

SOP VIII: Equipment Use and Decontamination

One of the most important mitigation measures for sampling in Devils Hole is following proper equipment use and decontamination protocols to remove any chance for the invasion of exotic species into Devils Hole. Currently, a thorough procedure is outlined in SOPVIII. This SOP contains two main steps. Step one is a Cleaning and Chemical disinfection process. This step requires the physical cleaning of equipment and disinfection with Quaternary Ammonium detergent disinfectant. Step two, physical disinfection contains three options. Option one is extended desiccation (drying) of equipment for a minimum of 14 days. Option two requires equipment to be frozen at or below -10°C (14°F). Equipment in the freezer must be maintained at or below -10°C overnight. If this can't be documented, this method should not be used. The third option is a superheated water bath (maintained at or above 50°C (120°F)). Equipment in the superheated water bath must be maintained at or above this temperature for a minimum of one hour.

The No Action and Proposed Action alternatives would continue to use SOP VIII as described above.

Agency and Environmentally Preferred Alternative

NPS policy (NPS, 2001) requires that an EA identify the environmentally preferred alternative. The environmentally preferred alternative is the alternative that would promote the national environmental policy expressed in NEPA (Sec. 101 (b)). This includes alternatives that:

1. Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations.
2. Ensure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings.
3. Attain the widest range of beneficial uses of the environment without degradation, risk of health or safety, or other undesirable and unintended consequences.
4. Preserve important historic, cultural, and natural aspects of our national heritage and maintain, wherever possible, an environment that supports diversity and variety of individual choice.
5. Achieve a balance between population and resource use that would permit high standards of living and a wide sharing of life's amenities.
6. Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources. (DO-12 Handbook, 2.7D; NPS 2001).

Based on the impact analysis, the Proposed Action is the environmentally preferred alternative. The No Action Alternative would realize a lower number of positive, long-term impacts because it provides less information for management decisions and ecosystem conditions. The Proposed Action Alternative would realize greater positive impacts over the long-term because it would provide a more holistic ecosystem approach to gaining information for stewardship of Devils Hole by providing greater information for management decisions. This would best fulfill the objectives of criterion one and two, above.

The Proposed Action Alternative is also the Agency Preferred Alternative because it would best implement the objectives of the GMP which states that long-term status of the Devils Hole pupfish

An impact would be less likely to constitute impairment if it is an unavoidable result of an action necessary to preserve or restore the integrity of park resources or values and it cannot be further mitigated (NPS 2006). The potential for impairment was estimated by qualitatively applying the three criteria listed above as required by NPS guidelines and policies (NPS 2001and 2006). Professional judgment and available information on the baseline conditions and features of the alternatives were relied on to determine whether there would be resource impairment to the parks cultural or natural resources. Public health and safety and visitor experience are not considered park resources and are therefore not analyzed for impairment.

Unacceptable Impacts

The impact threshold at which impairment occurs is not always readily apparent. Therefore, the NPS applies a standard that offers greater assurance that impairment will not occur. The NPS does this by avoiding impacts that it determines to be unacceptable. These are impacts that fall short of impairment, but are still not acceptable in a particular park's environment. Unlike impairment analysis, unacceptable impact determinations are made for all impact topics. For the purposes of these policies, unacceptable impacts are impacts that, individually or cumulatively, would:

- Be inconsistent with a park's purposes or values; or
- Impede the attainment of a park's desired future conditions for natural and cultural resources as identified through the park's planning process; or
- Create an unsafe or unhealthful environment for visitors or employees; or
- Diminish opportunities for current or future generations to enjoy, learn about, or be inspired by park resources or values; or
- Unreasonably interfere with park programs or activities; or
    - An appropriate use; or
    - The atmosphere of peace and tranquility, or the natural soundscape maintained in wilderness and natural, historic, or commemorative locations within the park; or
    - NPS concessioner or contractor operations or services.

Water Quality

Table 1: Intensity definition: water

Impact Intensity	Intensity Definition
Negligible	No change to ambient physicochemical parameters (water quality, nutrients)
Minor	Change of < 5% to a single physicochemical parameter
Moderate	Change of > 5% but <10% to one or more physicochemical parameters
Major	Change of > 10% to one or more physicochemical parameters

No Action Alternative

Parameters currently monitored include dissolved oxygen, pH, conductivity, and temperature. Two different YSI water quality data loggers collect data at continuously at 15-minute intervals. One is deployed over the southern portion of the shallow shelf, the second just above a shelf at 5 meters depth. Impacts are considered negligible. Six data logging temperature probes are deployed over the shallow shelf. Data are collected at 15-minute intervals.

Water level and depth have been collected over the past three decades and are currently overseen

Invertebrates

Impacts to Amargosa spring snail and Devils Hole warm springs beetle are used as the basis for determining impacts to invertebrates from sampling due to their status as Nevada at risk species. Impact thresholds were set for these species and it is assumed that impacts to all other invertebrates are the same or more minor.

Table 2: Intensity definition: invertebrates

Impact Intensity	Intensity Definition
Negligible	The direct take of < 1% of the estimated abundance of Amargosa spring snail or Devils Hole warm springs beetle
Minor	The direct take of > 1 and < 5% of the abundance of Amargosa spring snail or Devils Hole warm springs beetle
Moderate	The direct take of > 5 and < 50% of abundance of Amargosa spring snail and Devils Hole warm springs beetle
Major	The direct take of > 50% of abundance of Amargosa spring snail and Devils Hole warm springs beetle

No Action Alternative

Invertebrates are currently monitoring by sampling the benthic community on the shallow shelf Sixteen samples are collected every other month from randomly selected locations (SOP V). A 10 cm OD by 70 cm length of flexible stove pipe is used to take each sample. This amounts to 0.01% of the shelf being sampled for each collection date. For example, the mean number of snails picked from 112 benthic samples collected by NPS from June 2008 through June 2009 was 69 ± 68 (1 standard deviation). The estimated number of snails for the same number of samples was 8,787 snails/m^2 ± 8,754. Only 0.009% of Amargosa spring snails were sacrificed. A similar percentage was calculated for Devils Hole warm spring beetle. For 112 samples, 0.14 ± 0.5 beetles were picked from an estimated 18 ± 61 Devils Hole warm spring beetles/ m^2 equating to 0.008%. Short-term impacts to Amargosa spring snail and Devils Hole warm springs beetle from existing monitoring are direct and negligible.

There is a possibility of cumulative impacts to invertebrates from sampling six times annually. However, the community recovers quickly after sampling. There is typically no observable evidence of sampling after two days because invertebrates colonize the disturbed area (Wilson 2010). Therefore, long-term cumulative impacts are also considered negligible.

Since the No Action Alternative only samples the benthic community, several important habitats and types of invertebrates are being missed. This reduces the ability to evaluate ecosystem conditions across all trophic levels. For example, Protozoa, specifically ciliates, are not currently being monitored. This group of invertebrates may be an important food resource for other invertebrates and/or larval fish. Not sampling these trophic levels would not have long-term benefits to invertebrates because it would fail to collect adequate information to make informed decisions and monitor long-term trends.

Conclusion: The No Action Alternative would result in short-term, negligible impacts to invertebrates due to sampling. Long-term, adverse impacts may occur as a result of failing to monitor conditions across all trophic levels. Overall, there would be no unacceptable impacts and no impairment would occur.

Proposed Action Alternative

The Proposed Action would monitor invertebrates in a more holistic way by increasing habitat sampling. Methods used to monitor the benthic community would be the same as under the No Action Alternative. However, the Proposed Action would also monitor plankton, protozoa, meiofauna, neuston, and the flatworm *Dugesia* sp. (SOP V).

Protozoa, more specifically Ciliates, would be sampled from the interstitial spaces of the shallow shelf. A needle attached to a syringe would be slowly placed into the sediment to a depth of 5 cm. Water would slowly be drawn into the syringe and then placed into a sample bottle.

Meiofauna are invertebrates that range in size from 50 to 500 µm. A 5 X 5 cm template would be placed on the shallow shelf at nine randomly selected locations. A siphon (turkey baster) would be used to extract material to a depth of 5 cm. The total surface area of one sample is 0.06 m^2. Nine samples would cover < 0.01% of the shallow shelf.

Neuston is a habitat that is located at the water's surface. It consists of calcium carbonate ($CaCO_3$), algae, invertebrates, and detritus (terrestrial plant matter) that floats on the water surface. A 10 cm diameter screen would be used to collect eight neuston samples from over the shallow shelf. Each sample collects a surface area of 0.008 m^2, which would be < 0.01% of the water surface covering the shelf.

The nocturnal behavior of *Dugesia* requires monitoring to be conducted after dark. A 20 x 20 cm template would be randomly placed at 30 locations on the shallow shelf (Appendix A). The location and the number (abundance) of *Dugesia* would be recorded. This is a visual survey so impacts are considered negligible.

Sampling has been developed to collect invertebrates from different habitats which contain unique types of invertebrates. The sampling of additional species and habitats would increase the total number of invertebrates sampled, however the number of each species taken, and of the Amargosa spring snail and Devils Hole warm spring beetle in particular, would still only have short-term, negligible, direct impacts. Under the Proposed Action less than 1% of the shallow shelf would be disturbed when sampling the biological resources, thus long-term cumulative impact on invertebrates would also be negligible. No other projects have been identified that have potential for cumulative impacts to invertebrates in Devils Hole.

Increasing the number of habitats and types of invertebrates being sampled would provide a better understanding of ecosystem function and provide more information to managers to make better stewardship decisions. This would result in an overall long-term benefit to invertebrates within Devils Hole.

Conclusion: Short-term impacts to invertebrates from the Proposed Action would be negligible and direct. Long-term direct impacts would be negligible and there would also be a long-term benefit as a result of increased understanding of the ecosystem. No unacceptable impacts or impairment to invertebrates would occur under this alternative.

Devils Hole Pupfish

Table 3: Intensity definition: fish

Impact Intensity	Intensity Definition
Negligible	No detectable effect on any life-stage or behavior of the Devils Hole pupfish
Minor	An effect on fish behavior is detected (e.g. avoiding portions of the shallow shelf)
Moderate	Detectable effect on one life-stage (e.g. mortality) that is correlated to monitoring SOPs
Major	Multiple mortalities detected that are directly related to monitoring SOPs

No Action Alternative

Current monitoring of pupfish life history traits consists of biannual adult surveys, and twice monthly surveys for early life stages (fish larvae). Adult surveys require the use of SCUBA and are conducted in the spring and autumn. Disturbance to the shallow shelf is reduced by divers entering the water via a ladder. Anecdotal evidence suggests that diving may or may not affect adult pupfish; no conclusive evidence exists at this time. Fish have been observed avoiding divers during the day and swimming near divers at night.

Most diving equipment has been purchased for use in Devils Hole only (e.g. masks, fins, lights, regulators, buoyancy control devices, back plates and wet suit skins). This dedicated gear reduces the chances of invasive species entering Devils Hole and reduces the possibility of contaminates entering through new and different gear being used for each dive. Furthermore, strict decontamination protocols are followed for non dedicated gear (e.g. dive computers; SOPVIII).

Early life stage surveys are conducted on the shallow shelf and use trays composed of 4.5 cm inner diameter PVC piping cut in half length-wise into 30 cm pieces. Surveys are conducted at night using 27 trays. These trays cover only approximately 9% of the surface area of the shallow shelf. There is a possibility that deployment and retrieval of these trays may affect eggs and small fish (< 4 mm). This is mitigated through the slow deployment and gentle washing of the trays during retrieval.

There is no evidence that monitoring adult and early life-stage pupfish has a long-term cumulative effect on the fish. Surveys are typically conducted on different days. Furthermore, adult surveys are conducted during the day when larger fish are more active and the larval surveys are conducted at night when smaller fish are more active. The whole population is not being affected at any one time. There have been no observed negative effects during these surveys (Wilson 2010). At this time the direct impacts on adult and early life stage from all monitoring is considered to be minor for both the short and long-term.

The No Action Alternative does not provide a measure of error for adult fish since only one sample (count) is used as an index of population size.

Conclusion: Under the No Action, the direct adverse impact to Devils Hole pupfish as a result of disturbance during monitoring would be minor in both the short and long-term. However, this alternative would not monitor a sufficient number of parameters to improve understanding of

ecosystem function in the long-term. Overall, there would be no impairment or unacceptable impacts to Devils Hole pupfish.

Proposed Action Alternative

The Proposed Action would monitor pupfish in the same fashion as described in the No Action Alternative. Monitoring of pupfish life history traits consists of biannual adult surveys, and bimonthly surveys for early life stages (SOP VII) and impacts would be the same as those described under the No Action.

Monitoring of plankton, Protozoa, and meiofauna (SOP V) requires samples to be taken from Devils Hole. In order to mitigate impacts to the Devils Hole pupfish that may result from increased invertebrate sampling, several measures would be implemented. These measures include: close inspection of the net (plankton monitoring) for fish as it is being raised for placement of water into a sample bottle and close inspection of sample bottles (plankton, Protozoa, and meiofauna) for larval pupfish. With use of these measures, direct impacts to pupfish from invertebrate monitoring are considered negligible.

Under the Proposed Action, SOP VIII would be followed to decontaminate all equipment used in Devils Hole. Use of the decontamination procedure would mitigate impacts to water quality and reduce the risk of introducing exotic species that may impact the Devils Hole pupfish. With use of these procedures, impacts to the Devils Hole pupfish from monitoring are considered minor, the same as under the No Action Alternative.

Several projects were described under Cumulative Impacts (p. 18) that have potential to declining water levels at Devils Hole. These projects include solar development and changes in water diversion points in the Amargosa Valley. Declining water levels have been linked to drops in pupfish population in the past. It is possible that decreasing water levels and monitoring implemented under the Proposed Action may cumulatively impact Devils Hole pupfish. However, too little is known about what has caused recent declines in pupfish numbers to draw any conclusions about possible cumulative impacts from these projects. Gaining understanding of these factors is one of the goals of implementing the LTEMP.

The Devils Hole Site Plan EA is currently being implemented. As described in that EA, changes to monitoring equipment and infrastructure (such as installation of a collapsible walkway to access the shallow shelf) would decrease impacts to Devils Hole pupfish by reducing disturbance created by deploying the current access platform. Therefore, there are no anticipated cumulative adverse impacts from this ongoing project.

Conclusions: Under the Proposed Action, the direct adverse impact to Devils Hole pupfish in both the short and long-term as a result of disturbance during monitoring would be minor. However, there would also be long-term indirect benefits that result from increasing understanding of ecosystem functions; therefore, there would be no impairment or unacceptable impacts to Devils Hole pupfish as a result of this alternative.

Summary

This section summarizes the major findings. Impact types and intensities for the No Action and Proposed Action are summarized in Table 4. In the short-term, both alternatives would only have negligible to minor impacts on the Devils Hole ecosystem. Implementation of either alternative would not cause impairment to Park resources. However, the Proposed Action would have the long-term benefit of increasing the number of parameters measured in order to improve understanding of the ecosystem and provide better information to managers. Improved information and decision making will allow the Park to better steward the Devils Hole resource and preserve and protect it for future generations. Because the impact intensity definitions were only used to quantify adverse impacts, the less tangible long-term benefits of monitoring are not depicted in Table 4.

Table 4: A comparison of impacts for the No Action and Proposed Action alternatives in the short- and long-term.

	No Action Short-term	**No Action Long-term**	**Proposed Action Short-term**	**Proposed Action Long-term**
Water Quality	Direct Negligible	Direct Negligible	Direct Negligible	Direct Negligible
Invertebrates	Direct Negligible	Direct Negligible	Direct Negligible	Direct Negligible
Devils Hole Pupfish	Direct and Indirect Minor	Direct and Indirect Minor	Direct and Indirect Minor	Direct and Indirect Minor

6. Consultation and Coordination

Summary of Public Involvement

Development of a long-term monitoring plan for Devils Hole is one of the management actions identified in the Death Valley GMP. Extensive scoping was completed during the planning process for the GMP, which was signed on September 27, 2001. Several comments on monitoring procedures at Devils hole were received during the scoping period for the Devils Hole Site Plan EA in August 2009. The general nature of these comments expressed concern about the impacts of monitoring activities on the Devils Hole pupfish. These comments were used to inform the selection of impact topics and the analysis for this EA. Additionally, the public will be provided with 30-days to comment on this EA upon its release.

Contact and Consultation with Other Agencies

The following organizations and local, state, and federal agencies were consulted during the preparation of this document. Please see Appendix B for consultation letters.

U.S. Fish and Wildlife Service

Before any proposed federal action that may affect a federally listed Threatened or Endangered (T&E) species can be implemented, the agency that wishes to implement the action must first

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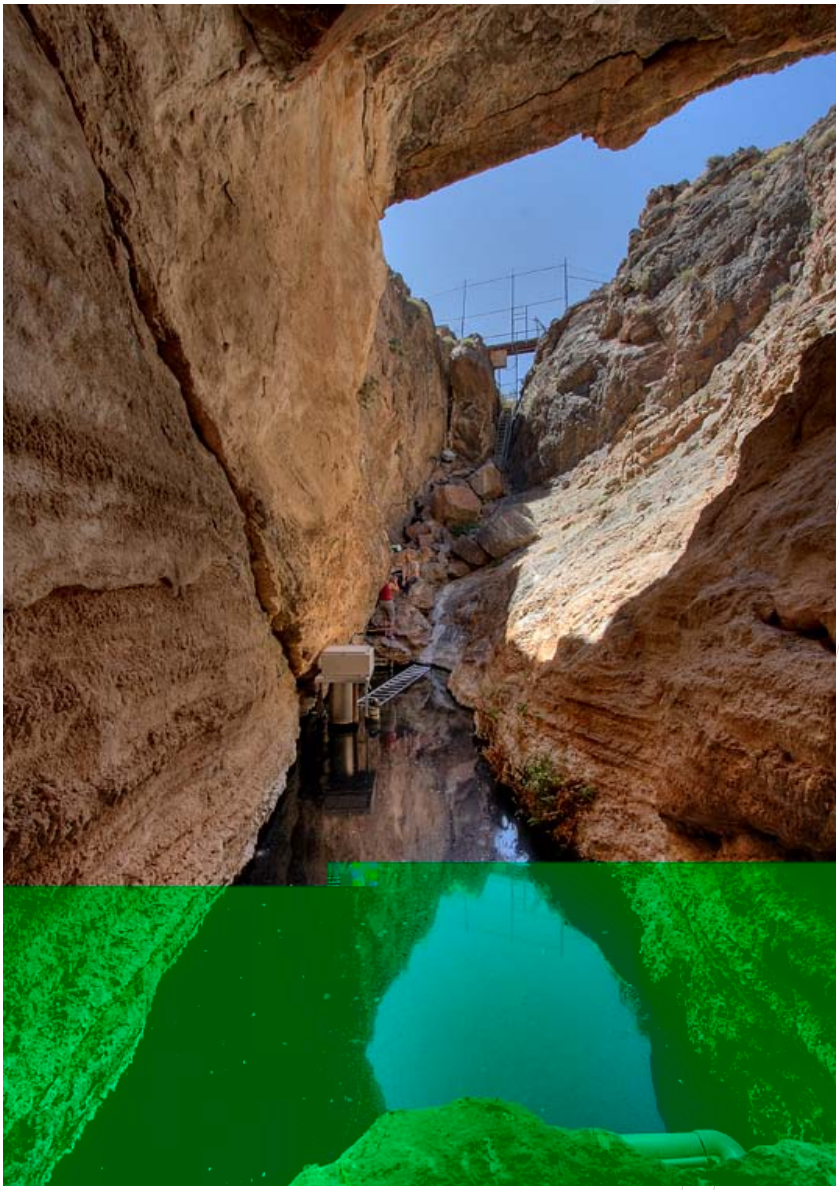
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Devils Hole Ecosystem Monitoring Plan *Death Valley National Park*

Natural Resource Report NPS/DEVA/NRR—2009/001



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ON THE COVER
Devils Hole, Death Valley National Park. View is towards the south. Note viewing platform at top of photo.
Photograph by: John Wullschleger, NPS

Devils Hole Ecosystem Monitoring Plan
Death Valley National Park

Natural Resource Report NPS/DEVA/NRR—2009/001

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Acronyms	
ADAPS	Automatic Data Acquisition and Processing System
AFDM	Ash-free dry mass
ANOVA	Analysis of variance
CFR	Code of Federal Regulations
DEVA	Death Valley National Park
DNA	Deoxyribonucleic acid
DO	Dissolved oxygen
DRI	Desert Research Institute
DVNP	Death Valley National Park
EPA	Environmental Protection Agency
FGDC	Federal government data compliance
FY	Fiscal year
GIS	Geographic information systems
LTEMP	Long term Ecosystem Monitoring Plan
MDE	Minimal detectable effect
NDOW	Nevada Department of Wildlife
NEPA	National Environmental Policy Act
NHS	National Historic Site
NIST	National Institute of Science and Technology
NM	National Monument
NP	National Park
NPres	National Preserve
NPS	National Park Service
NRA	National Recreation Area
NRDT	National Resource Database Template
NRR	National Resource Report
NTU	Nepholometric turbidity units
OMB	Office of management and budget
SCUBA	Self contained underwater breathing apparatus
SNPLMA	Southern Nevada Public Lands Management Act
SOP	Standard operating procedure
UCR	University California Riverside
UNLV	University of Nevada Las Vegas
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
UTC	Coordinated universal time
WRB	Water Research Branch
WRCC	Western Regional Climate Center

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Introduction and Background

Ecosystem description

The Devils Hole ecosystem is located within the Mohave Desert approximately 100 km west of Las Vegas, Nevada and 50 km east of Death Valley National Park headquarters at Furnace Creek, California (Figure 1). The landscape setting of Devils Hole is typical of the Basin and Range topography that dominates much of the Great Basin. Widespread normal block faulting has resulted in generally north-south oriented mountain ranges which are now separated by desert valleys (Fiero 1986). Devils Hole lies towards the eastern side of Amargosa Valley within a 16-ha parcel which is managed as a detached unit of Death Valley National Park. Bordering this parcel are the Ash Meadows National Wildlife Refuge and lands administered by the U.S. Bureau of Land Management.

Devils Hole itself lies near the base of a block thrust uplift along a northeast-striking fissure caused by expansion of the locally dominant marine carbonate rocks. This fissure intersects the water table at Devils Hole where a series of ceiling collapses has opened a small window into the regional groundwater aquifer, creating a water filled cave. This local aquifer is known as the Ash Meadows groundwater flow system (Riggs et al. 1994). The rectangular water surface encompasses an area of 3.5 m x 22 m in size. Of this, a shallow shelf area of 2.6 x 6.1 m, formed when a portion of the ceiling collapsed and lodged deeper into the fissure, is where the majority of biological production takes place (Figure 2). Depth of the shallow shelf ranges from 0.02 to 0.88 m and has a mean depth of 0.40 ± 0.16 m (SD, n=220). Extending further below the water surface, the Devils Hole cavern descends to a depth of at least 133 m, beyond which has not been explored (Figure 3).

The Ash Meadows groundwater flow system originates as precipitation on upland areas to the north and east, including the northern end of the Spring Mountains and mountain ranges from the eastern half of the Nevada Test Site to the Sheep Range, and as subsurface interbasin flow from the same general area (Belcher 2004). It has been estimated that it could take 1,500 – 2,900 years for water to arrive at Devils Hole from the aquifer recharge zone in the Spring Mountains (Thomas 1996). The water is supersaturated in calcium carbonate due to its long distance migration through carbonate geology (Figure 4 A). Calcium carbonate has precipitated at Devils Hole to form an array of interesting morphologies (Szabo et al. 1994; Figure 4 B) while preserving a 500,000-year calcite climate record (Winograd et al. 1992). Beyond Devils Hole, the aquifer discharges at numerous springs and seeps that form Ash Meadows, the largest oasis in the Mohave Desert, where it supports novel aquatic and riparian habitats with extraordinary endemism.

Ambient conditions in the Amargosa Valley can be characterized as generally hot and dry during the summer and more moderate during the remainder of the year. Air temperatures routinely reach 40°C during the summer months of June, July and August but can drop to as low as 0°C in the winter months of December and January. Precipitation in this portion of the Mohave Desert is restricted to an average of less than 10 cm annually (NOAA 2004).

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The fauna of Devils Hole share a complex hydrogeographic history and a unique set of selective pressures. Drying of an interconnected series of lakes and waterways within the Death Valley region over the last 20,000 years has resulted in a recent isolation and subsequent speciation of a

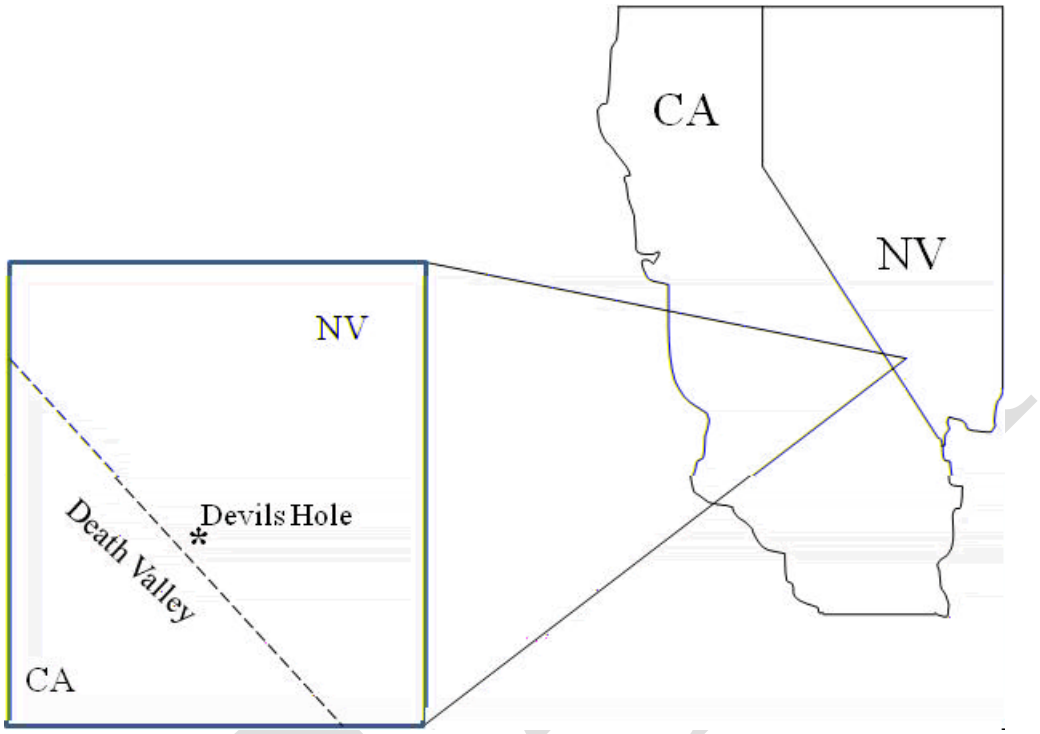

Figure 1. Vicinity map of Devils Hole in southern Nye County, Nevada (36°26”N, 116°17”W).

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Figure 2. View of the Devils Hole cavern facing northeast.

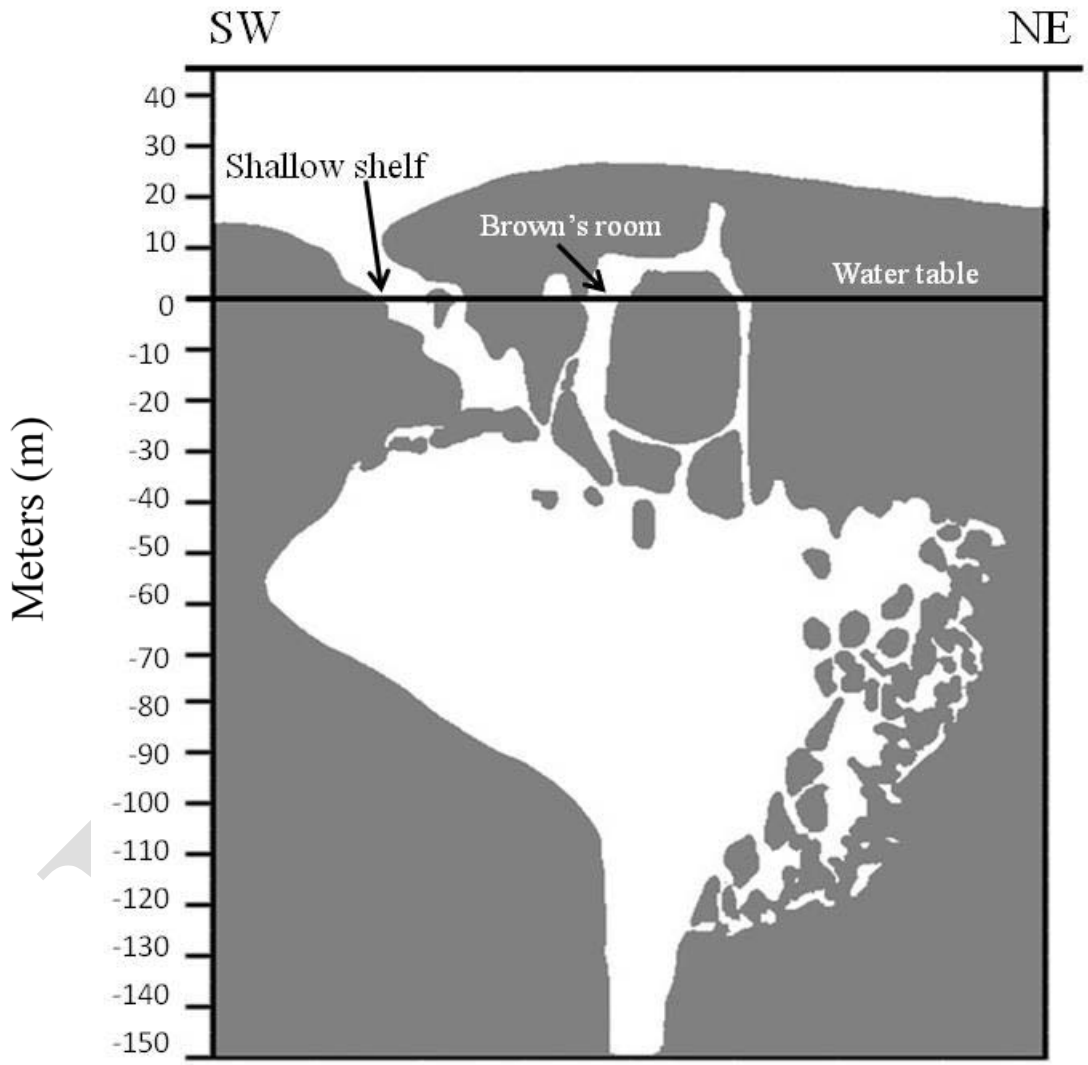

Figure 3. Cross-section of the Devils Hole (modified from Riggs and Deacon 2004). Horizontal scale equals vertical scale.

(A)

(B)

Figure 4. (A) View looking towards the surface as divers descend into Devils Hole (photo by R. Perotti) and (B) photograph of calcite formations in Brown's room (NPS photo). Field of view is approximately 1 m.

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unique endemic fauna within residual waters such as Devils Hole (Rehies et al. 2002; Martin and Wilcox 2004). In addition to founder effects and genetic drift, a unique suite of selective pressures has influenced the evolution of Devils Hole's flora and fauna. Within the deeper waters of Devils Hole, physicochemical conditions have been characterized as remarkably stable -750°C4(, 3(n a)pr)3(e)4(s-1(H)v)4(nc)oc2nd g5(of)luennsls-2(ut)-ureper

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Management history

Devils Hole has a rich human history beginning with Native American utilization of the area by ancestors of modern-day Timbisha Shoshone and Pahrump Paiute (Hunt and Hunt 1960; Wallace and Wallace 1979). Caucasians are thought to have first visited Devils Hole en route to their mining destinations during the gold rush of 1849, leaving references to the "Miner's Bathtub" in their journals (Halliday 1955). Beginning with the taxonomic description of the Devils Hole pupfish in 1930 by Joseph Wales, Devils Hole has since served an iconic role in the effort to preserve native aquatic biodiversity, most specifically, native desert fishes. Though the Devil Hole pupfish represents a fraction of the biological diversity of the Devils Hole ecosystem, the mandate for preservation of this unique fish has driven a good deal of the ecological research that has been conducted and has provided an impetus for pursuit of long-term ecosystem monitoring. For a timeline of studies see Table 1.

In 1952, Devils Hole was added to what was then Death Valley National Monument by proclamation of President Truman, citing that "…the said pool [Devils Hole] is of such outstanding scientific importance that it should be given special protection." Scientific inquiry began to expand during the early years of National Park Service management with multiple investigations and explorations of the Devils Hole cave system (Figures 3, and 4). Protections afforded the ecosystem were eventually tested when the Devils Hole pupfish population began a dramatic population decline in the late 1960's in response to a drawdown of the water table at Devils Hole by nearby groundwater production. A number of historically significant events followed including the listing of the Devils Hole pupfish as Endangered on the first such list in 1967, implementation of a suite of management actions intended to forestall extinction which continued through the early 1970's, and the ultimate ruling of the United States Supreme Court in favor of the National Park Service and in protection of their Federally-reserved water right at Devils Hole (Cappaert v. United States 1976).

Beginning soon after the cessation of groundwater withdrawal, the Devils Hole pupfish population began to rebound in conjunction with increasing water levels, continuing to grow for several years before entering a period of relative stability that lasted through the mid-1990's. In 1996 the population once again began a steady decline, reaching as few as 38 individual adults by 2007. Unlike the population decline witnessed during the 1960's and 1970's, this more recent decline lacks a clear cause. However, several hypotheses have been suggested to explain the observed decline. These include inbreeding depression (Wilcox 2001), declining solar radiation or allochthonous nutrients (Wilson and Blinn 2007), shifts in algal community state (Riggs and Deacon 2005), changes in sediment dynamics (Lyons 2005; Riggs and Deacon 2005), loss of a key prey species (i.e., an ostracode) from the primary feeding habitat (Herbst and Blinn 2003), continuing water level declines (Riggs and Deacon 2005; Deacon et al. 2007), and increasing water temperature due to global warming and/or declining water levels (Threloff and Manning 2003).

Partially in response to observed declines in abundance of the Devils Hole pupfish, significant progress has been made towards establishment of long-term ecological monitoring at Devils Hole. For over 30 years, records of pupfish abundance and water level have been kept. Recent efforts include preparation of a preliminary monitoring plan for a suite of abiotic and biotic

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determinants (Blinn 2003) and a review of ecosystem monitoring approaches and priorities by a panel convened by the Pacific West Regional Directorate in March of 2007 (USGS 2007). Furthermore, a workshop was held at Death Valley National Park (DVNP) in September of 2007 to consider improved methods of data management for efforts at Devils Hole. These efforts have served to inform the current plan and are incorporated by reference where appropriate.

Table 1. Summary of ecological research and monitoring conducted at Devils Hole, Nevada. USGS= United States Geologic Service, WRB= Water Rights Branch of the Water Resource Division of the National Park Service.

Year(s)	Activities	Reference(s)
1955 – present 1956 – present	Early cave exploration Water-stage monitoring USGS (1956-1990) WRB (1991-present)	Hoffman (1988) Deacon and Williams (1991)
1967 – 1968	Devils Hole pupfish life history and ecology	James (1969)
1972 – present	Adult pupfish census	Minckley and Deacon (1973) Minckley and Deacon (1975) Chernoff (1985) Baugh and Deacon (1983)
1984 – 1998	Algal diversity	Shepard et al. (2000)
1996	DO, pH, temp. measures, invertebrate abundance	Azad (1998)
1996 – 1997	Larval Devils Hole pupfish ecology	Gustafson and Deacon (1998)
1999 – 2001	Trophic ecology and energy flow	Blinn et al. (2000) Wilson and Blinn (2001) Wilson and Blinn (2007)
1999 – 2001	Macroinvertebrate ecology	Herbst and Blinn (2003)
2003 – 2004	Larval Devils Hole pupfish ecology	Lyons (2005)

Goals and objectives

It has become clear in retrospect that a more holistic commitment to scientific understanding is necessary to effectively steward the Devils Hole ecosystem. Ultimately, a combination of targeted field research, laboratory experimentation, and long-term ecological monitoring are needed to understand the complex ecological patterns and processes at Devils Hole in order to develop scientifically credible stewardship strategies. A critical first step in beginning on this logical path toward scientific understanding is to gain an accurate and current understanding of

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ecological conditions. From this understanding, realistic hypotheses can be formed and a strategy to test or refine these hypotheses can begin to emerge. In addition to this logical progression of scientific inquiry, long-term ecosystem monitoring serves a niche left vacant by sporadic though intensive research efforts. In a system where signals can be obscured by spatial autocorrelation given the system's limited extent, the acquisition of long-term correlative datasets is one of the primary ways in which ecological patterns and relationships can be described. It is also critical that an understanding of current conditions be maintained as a means to detect departures from typical conditions, in support of existing legal mandates (e.g., Supreme Court-mandated minimum water level), and as a measure of feedback from ongoing adaptive management efforts. Without a clear understanding of the ecosystem it is difficult to determine what is contributing to the population size and variability of the Devils Hole pupfish. This limits the ability for proper recovery actions.

It is the goal of this long-term ecosystem monitoring plan to increase the scientific rigor of ecosystem stewardship strategies and recovery recommendations for the Devils Hole pupfish while satisfying basic legal obligations. Specific objectives include:

1. Describe spatial and temporal patterns of variation in diverse ecological parameters thought to influence fundamental physical and biological processes
2. Describe spatial and temporal patterns of variation in the abundance of resident taxa
3. Connect sporadic and intensive ecological research with a more continuous and sustained record of ecosystem conditions
4. Provide preliminary data for the development or refinement of research hypotheses
5. Provide early warning by detecting trends of regional or global threats to resident taxa or ecosystem function
6. Maintain a current and accurate understanding of ecosystem conditions to share with the public
7. Provide scientifically defendable and credible information to managers

In subsequent sections this monitoring plan will detail a strategy for meeting these objectives using an adaptive monitoring scheme such as that promoted by Lindenmayer and Likens (2009). A series of hypotheses as conceptual models will be presented that represent the most current understanding of the Devils Hole ecosystem and form the rationale for monitoring the chosen parameters. Administrative and logistical considerations will be presented for project staffing, equipment use and decontamination, data management, sampling design, data analysis, reporting results, revision of the plan, and budgeting. Finally, following the guidance of Oakley et al. (2003), more detailed step-by-step protocols for monitoring specific parameters will be presented as a series of standard operating procedures (SOPs). A NEPA document has also been written outlining the possible impacts of the monitoring plan to the Devils Hole ecosystem and the endangered Devils Hole pupfish, *Cyprinodon diabolis*.

Conceptual Models and Monitoring Parameters

In an effort to maximize the efficiency of this ecosystem monitoring effort and ensure progress along a logical pathway of scientific understanding, two linked conceptual models are presented

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to document current understanding of the Devils Hole ecosystem and serve as *a priori* hypotheses that can be refined through the collection of long-term ecological datasets.

The first conceptual model hypothesizes major factors affecting the organization and function of the Devils Hole ecosystem. The second model hypothesizes how the main components of the first model might influence the Devils Hole pupfish population and life history.

A number of parameters are identified to monitor the indicated ecosystem features and assess linkages over time (Table 2).

Ecosystem model

Several abiotic and biotic processes and features are thought to drive the organization and function of the Devils Hole ecosystem.

Meteorological conditions (climate)

Background

Ambient conditions outside of Devils Hole interact with the ecosystem at the water surface to influence thermodynamics, and physicochemical conditions (Figure 5, Arrow 1).

Ambient air temperature is likely to influence water temperature, perhaps most significantly over the shallow shelf where radiative heating and cooling can occur most efficiently due to the shallow water depth (Figure 5, Arrow 2). In turn, changes in water temperature over the shallow shelf influence concentrations of dissolved oxygen (DO) (Figure 5, Arrow 3).

The amount of solar energy available to the aquatic ecosystem is also influenced by broad meteorological patterns and conditions. Seasonal changes in the amount of solar radiation reaching the surface of Devils Hole regulates the amount of biotic production, especially on the shallow shelf (Arrow 4). Solar radiation also influences temperature and DO on the shallow shelf (Arrow 3). Increased solar radiation during the summer increases temperatures and decreases DO along shallower portions of the shelf. Solar radiation also increases DO when sunlight directly hits the shallow shelf and then DO decreases to background concentrations during indirect light. Dissolved oxygen can also decrease and be lower than background concentrations found in the deep pool. The inverse occurs during the winter. The amount of solar radiation also controls the amount of evaporation occurring at the air-water interface. Changes in evaporation rates will influence the quantity of calcite rafts that form on the water surface (Arrows 5a and 5b). These rafts can limit the amount of light energy reaching benthic habitats, reducing primary production (Arrow 6).

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Table 2. Abiotic and biotic features chosen for long-term ecosystem monitoring at Devils Hole, Nevada.

Component	Monitoring approach	Standard operating procedure(s)
Abiotic components		
Water quality *temperature *dissolved oxygen *pH *specific conductivity *nitrogen, *phosphorus *hydrogen sulfide *alkalinity	Multi-parameter data-logging probes, nutrient analyses over the deep pool, shallow shelf, and sediment pore-water	SOP I
Water temperature	Data-logging thermistors over the shallow shelf	SOP II
Physical components		
Water level and depth	Data-logging sensors, survey of shallow shelf	SOP III
Substrate	Survey of the sediment distribution on shallow shelf	SOP IV
Biotic components		
Algae, protozoa, and invertebrates *plankton *ciliates *algae *macroinvertebrates *meiofauna *neuston **Dugesia* (flatworm)	Various sampling techniques on the shallow shelf, within the sediment-water interface, and the water column of the deep pool	SOP V
Allochthonous carbon	Funnel trap collections	SOP VI
Devils Hole pupfish *relative abundance (adults) *length-frequency *larvae surveys	Underwater visual survey, early-life-stage sampling, collection of natural mortalities	SOP VII

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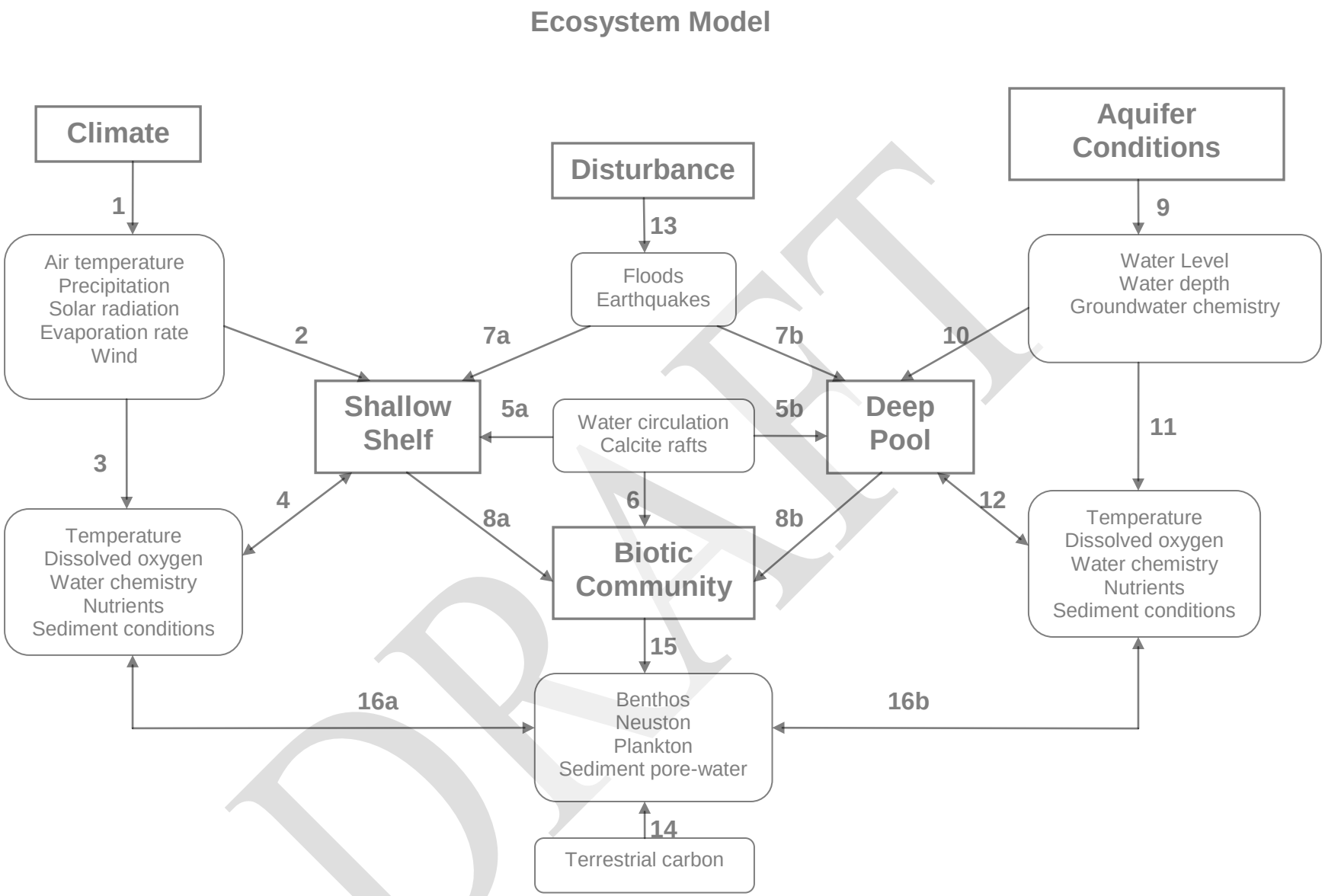

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Figure 5. Ecosystem model of Devils Hole showing major linkages between and among abiotic and biotic parameters.

Precipitation that causes flood events has a profound influence on the Devils Hole ecosystem by removing or adding debris to the shallow shelf and deep pool (Arrows 7a and 7b, respectively). Both flood and less intense events reduce the amount of solar radiation reaching the surface water, thus reducing the amount of biotic production (Arrows 8a and 8b).

The quantity of calcite rafts floating on the water surface and the amount of terrestrial carbon reaching the water surface are affected by wind (linkage not shown for clarity). This is highly dependent on the direction, duration, and intensity of wind in the vicinity of Devils Hole.

Monitoring

A continuous-recording weather station will be operated at Devils Hole by the Western Regional Climate Center (WRCC) at the Desert Research Institute (DRI) to monitor terrestrial solar radiation, air temperature, relative humidity, precipitation, barometric pressure, and wind speed. Responses of physicochemical conditions on the shallow shelf to changes in meteorological conditions will be continuously monitored by a multi-parameter water quality instrument (SOP I) and a series of continuous-recording thermistors (SOP II). Other physicochemical parameters will be measured on the shallow shelf and from pore-water at bimonthly intervals (e.g. nutrients) (SOP I).

Aquifer conditions (groundwater)

Background

Changes in water level or stage at Devils Hole have a rather direct influence on the shape and volume of the underwater ecosystem, given the limited aerial extent of the water surface. More specifically, changes in water level result in corresponding changes in water depth (Figure 5, Arrow 9) and volume over the shallow underwater shelf where the majority of biological production takes place. These changes in water depth and volume could affect the absorption of solar radiation (arrow not shown for clarity), leading to changes in water temperature. Water depth also influences water circulation between the deep pool (Arrow 10) and the shallow shelf (Arrow not shown for clarity).

Though water circulation patterns are presently poorly understood, mixing between the shallow shelf (Arrow 5a) and deep pool (Arrow 5b) could play a major role in regulating physicochemical conditions over the shallow shelf where the majority of biological production takes place. For example, Gustafson and Deacon (1998) reported gradients of dissolved oxygen concentrations across the shallow shelf habitat. These gradients were most notable during summer when algae production is at its peak creating pulses of increased DO when light reaches the shallow shelf. However, during winter, DO is relatively constant, presumably as a result of water circulation of an area of increased permeability underlying the shelf's East boundary. A reduction in organic biomass (e.g. algae) may increase permeability of the shelf, thus affecting circulation patterns. While isolation of the shallow shelf habitat acts to increase diel or seasonal variation in a number of physicochemical parameters, water mixing would act to attenuate such variation.

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The dynamics of calcite rafts and persistence at Devils Hole are presently poorly understood. Calcite rafts floating on the water surface may influence processes occurring on both the shallow shelf (Arrow 5a) and deep pool (Arrow 5b). Formation of calcite rafts results from CO_2 degassing and evaporation at the water surface. Further, increased primary production (photosynthesis and respiration) during the spring and summer increases the quantity of calcite rafts present on the water surface. These calcite rafts could act to reflect solar radiation, thereby reducing solar heating and decreasing the amount of solar energy available to benthic autotrophs.

Groundwater entering the Devils Hole ecosystem is remarkably stable and acts to buffer the ecosystem from sources of variation (Arrow 9). Groundwater chemistry, especially within the deep pool (to a depth of 40 m) shows relatively constant temperature, DO, nutrient concentrations, and other water chemistry parameters (Arrows 11 and 12). Greater variability in most water chemistry and nutrient parameters occurs on the shallow shelf. This is mainly attributed to seasonal changes in biological production that occur on the shallow shelf. Linkages between groundwater chemistry and shallow shelf parameters are not shown for clarity.

Groundwater physicochemical conditions will be monitored continuously by installing a multi-parameter water quality instrument at a depth of 5 m (SOP I). Synoptic sampling for additional analytes will be conducted by collecting a bimonthly water sample at the same depth (SOP I).

Monitoring

The interactions among water level, water depth, meteorological conditions, and physicochemical conditions over the shallow shelf are currently poorly understood but could be important features of ecosystem function. Continuous monitoring of water level will be performed to meet legal obligations and provide data necessary to determine linkages among other physical parameters (SOP III). Monitoring of water depth will be accomplished by surveying shelf morphometry following each disturbance event that has the potential to have added or removed sediment from the shallow shelf (SOP IV). The connectivity of the Devils Hole ecosystem to surrounding aquifer conditions, such as Devils Hole II, and local groundwater monitoring wells will be including in a yearly synthesis of the monitoring data?. These data should be available through the United States Geological Society (USGS).

Disturbance regime

Background

Though the Devils Hole ecosystem has at times been described as a remarkably stable environment, stochastic disturbances are prominent forces within the ecosystem. Precipitation within the small watershed surrounding Devils Hole can result in floods (Arrow 13) that transport water with high nutrient concentrations that have the ability to change water chemistry parameters (Arrows 4 and 12). Floods also carry sediment (Arrow 4 and 12), and organic matter onto the shallow shelf and into the deep pool of Devils Hole. These floods can aggrade the sediment bed over the shallow shelf with new material or redistribute existing sediments (Lyons 2005), while contributing a pulse of allochthonous nutrients (terrestrial carbon; Arrow 14)

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(Wilson and Blinn 2007). Additionally, earthquakes commonly generate waves in the ecosystem that have been known to sort, redistribute, and remove sediments from the shallow shelf and force sediments into the deep pool (Cutillo and Ge 2006). An anthropogenic source of disturbance occurs from ground water pumping in the vicinity of Devils Hole. As mentioned earlier pumping was directly responsible for the decline in the pupfish population in the late 1960 and early 1970's. Currently this threat has been reduced and continued pumping plays less of an immediate concern, but is a long-term concern (i.e. the slow decline of water level over many decades).

The interplay between sediment additions from floods and sediment sorting or removal from earthquake-induced waves acts to determine shelf morphometry, water depth, and the substrate size distribution. Given the shallow water column over the shelf, reductions in water depth may increase water temperatures by affecting the amount of solar heating. Changes in substrate size distribution may further affect the suitability of the shallow shelf for a variety of organisms such as amphipods (Herbst and Blinn 2003) or pupfish (Lyons 2005).

Both of these disturbances can also reset ecological succession by clearing the shallow shelf of invertebrates, algae,pfish (ometry,

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seasonal changes in available resources, resulting in restrained biological production (Wilson and Blinn 2007). For this reason, subtle changes in the amount of available solar radiation to drive primary production could be biologically significant. These changes may affect lower trophic levels such as Protozoa and meiofauna that may play an important role in food web dynamics of Devils Hole.

Within abiotic constraints, the unique flora and fauna of Devils Hole compete for available resources. The following biological processes and conditions are thought to strongly influence the outcome of interactions within the food web.

Microbes

To date, the microbial community of Devils Hole has received little attention. Microbial processes are responsible for the decomposition and energy transfer of organic matter. Recently, large white tufts present in various locations on the shallow shelf were determined to be a large species of bacteria (*Beggiatoa* sp., D. Moser, pers. comm.). This bacterium is found at the oxic/anoxic zone of the sediment-water interface producing hydrogen sulfide (H_2S) and became more abundant after large amounts of allochthonous material entered Devils Hole in September 2007. Fine sediment can also exacerbate the production of H_2S by creating a "seal" along the sediment-water interface. Excess production of H_2S may have negative impacts on the development of eggs and larvae of macroinvertebrates and pupfish. Seasonal shifts in solar radiation create conditions for different food resources for microbes (allochthonous versus autochthonous carbon) which may result in seasonally different microbial communities which may influence aerobic and anaerobic conditions at the sediment-water interface on the shallow shelf (Arrow 15). In turn, shifts in the community structure of microbes may influence other trophic levels such as ciliated Protozoa and meiofauna that are present in the benthos. In order to address the role of aerobic and anaerobic conditions along the sediment-water interface monitoring of pertinent nutrients will be conducted (SOP I).

Benthos

A thorough assessment of the upper food web of the Devils Hole ecosystem was recently completed. In this study, Wilson and Blinn (2007) examined food web structure, measured primary production, algae and macroinvertebrate standing mass, allochthonous carbon input, and used multiple stable isotopes to identify key energetic pathways. The majority of this work was conducted between October 1999 and June 2001. During this time allochthonous energy (terrestrial plant and animal matter) was determined to be an important energy source to the Devils Hole ecosystem. Stable isotopes further corroborated this finding with *C. diabolis* shifting in a diet dominated by filamentous cyanobacteria in the summer to one dominated by the aquatic insect *Stenelmis calida* in the winter. *Stenelmis* tissue had high proportions of allocthonous carbon in its tissue in the winter. Filamentous cyanobacteria were the dominant algae in the summer, whereas the filamentous *Spirogyra* dominated in the spring (Wilson and Blinn 2007).

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The possibility of multiple alternative community states has been raised by a number of authors and observers. Several lines of evidence suggest the possibility that multiple community states have prevailed at Devils Hole. These may have included a state dominated by the green algae *Spirogyra*, a state dominated by the filamentous cyanobacteria *Oscillatoria/Plectonema*, or one dominated by diatoms (e.g. *Denticula elegans*). For example, Lyons (2005) described Devils Hole as being dominated by *Spirogyra* during her study from November 2003 through August 2004 and more recently (June 2008), NPS staff from Death Valley National Park in collaboration with Dean Blinn determined that the algal community was dominated by a mixture of diatoms and the unicellular cyanobacterium *Chroococcus* sp. Changes in the algal community overtime may be due to fluctuation in solar radiation (Arrows 16a and 16b), changes in nutrient concentrations (Arrows 16a and 16b), disturbance events (floods and/or earthquakes; arrows not shown for clarity), or from yet to be determined causes (e.g. competition).

Though we are interested in changes in the abundance or production of individual species (e.g., ostracods), we are also interested in broad shifts in community state that could fundamentally restructure trophic linkages and energy pathways. Two such pathways that have received little attention are Protozoa (specifically ciliates) and meiofauna (part of the benthos, Arrow 15). These two groups may be important food sources for macroinvertbrates and larval pupfish. Changes in the amount of solar radiation can also change the quantity of allochthonous (terrestrial carbon) material entering Devils Hole, which is known to be an important carbon source for macroinvertebrates during the winter (Arrow 14). Algal production creates a positive feedback to higher trophic levels by increasing DO levels on a diel and seasonal basis (Arrows 16a and 16b).

Neuston

Neuston is a layer or habitat that forms on the water surface and consists of a complex mixture of inorganic and organic material. The amount of neuston present follows a similar seasonal pattern to that of benthic algae: increased solar radiation increases neuston biomass. Much of the neuston is composed of inorganic calcite crystals which can provide areas for the colonization of diatoms and micro- and macroinvertabrates. Calcite crystals form rafts that are predominantly regulated by photosynthesis, through the removal of CO_2 and production of O_2, and by the amount of CO_2 that is released during respiration of algae, animals, and microorganisms. However, calcite rafts can also form by degassing of CO_2 from the water to the atmosphere (Riggs et al. 1994). The dense neuston layer also creates a negative feedback by reducing light penetration to the benthic algal community (Arrows 16a and 16b). Blinn et al. (2000) reported a 50% reduction in light energy under thick neuston layers floating in Devils Hole. However, thick neuston layers may reduce water temperatures on the shallow shelf by shading, thus reducing solar heating (a positive feedback).

Plankton

Plankton of Devils Hole has been described as being low in abundance and seasonally variable (Wilson and Blinn 2001). However, shifts in density or community structure may have important linkages to other trophic levels. For example, phytoplankton densities were lowest in winter and highest in summer, most likely following solar energy patterns (Arrow 16a and 16b),

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whereas the dominant zooplankton (*Hyalella* sp. and copepods) showed variable seasonal and diurnal patterns. *Hyalella* sp. had higher densities in summer (June), whereas copepods had higher densities in winter and spring (February and April), and both groups had higher densities at night as compared to other sampling times (Wilson and Blinn 2001). Monitoring plankton seasonally and over a 24 h period may provide important information on food web dynamics and predator-prey interactions.

Monitoring

Each component of the biotic community will be monitored using SOP V. Sampling frequency for each variable was based on previous studies within Devils Hole and from methods literature. Frequencies were also developed to reduce impacts to the ecosystem. Allochthonous (terrestrial) carbon will be monitored using SOP VI. Sampling frequency for this protocol is seasonal. Funnel traps will be deployed in the winter and summer for one month each. This is based on the seasonal dynamics of terrestrial carbon.

Devils Hole pupfish influence model

This conceptual model will integrate the results of several studies of Devils Hole pupfish ecology with the most plausible hypotheses that have been promoted to explain the current and former declines in Devils Hole pupfish abundance (Figure 6). The first main response of this model will monitor the abundance of Devils Hole pupfish by underwater visual survey and the second main response will be monitored by implementing early-life-stage sampling over the shallow shelf (SOP VII).

The thermal environment of Devils Hole has been investigated on several occasions (reviewed in Threloff and Manning 2003). In combination with experimental temperature trials using closely related species (Shrode 1975; Shrode and Gerking 1977), these investigations suggest that Devils Hole pupfish currently live very near or at their thermal limits for successful oogenesis and egg incubation (Riggs and Deacon 2005). Measurements taken during 1999 and 2000 suggested that water temperatures may have increased over the previous decade, possibly by as much as 2°C

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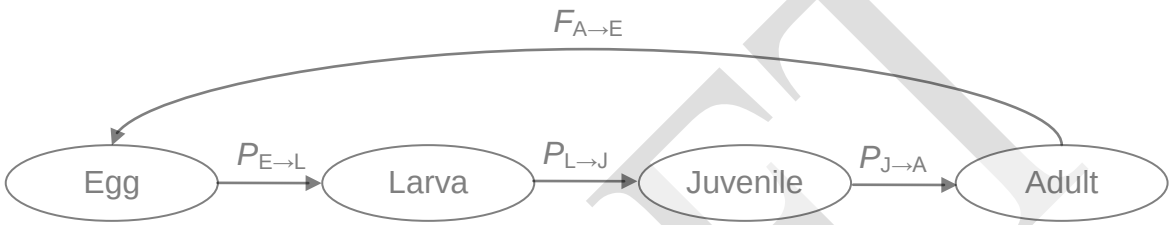
Devils Hole Pupfish Influence Model



	$P_{E\rightarrow L}$	$P_{L\rightarrow J}$	$P_{J\rightarrow A}$	$F_{A\rightarrow E}$
Water temperature	---	-		--
[Dissolved oxygen]	+++	+		
[H_2S and NH_3]	--	-		
Proportion of fine sediments	-	-		
Food availability		++	++	++
Inbreeding depression	-	-	-	-
Disease	-	-	-	-

Figure 6. Stage-specific model of the Devils Hole pupfish population and conceptual influence diagram. Survival probabilities among stages are given by *P* and egg production by adults is given by *F*. The direction (+ or -) and magnitude (number of symbols) of hypothesized influences are presented.

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(Threloff and Manning 2003). Small increases in maximum or mean water temperatures could result in a reduction in average fecundity, hatching success, or larval recruitment. Water temperatures over the shallow shelf and in the deep pool will continued to be monitored to detect patterns and trends in the thermal environment that may affect Devils Hole pupfish egg hatching success, larval recruitment, or oogenesis (Table 2; SOPs I and II).

In addition to water temperature, a variety of physicochemical conditions are thought to be of importance to Devils Hole pupfish reproduction and survival. The availability of suitable DO conditions over the shallow shelf in Devils Hole has been related to the prevalence of larval Devils Hole pupfish by several authors (Gustafson and Deacon 1998; Lyons 2005; Riggs and Deacon 2005). The background DO concentration in Devils Hole is rather low, at roughly 2.8 mg/L, though DO concentrations can vary significantly over the shallow shelf. From this low background DO concentration, it is plausible that community respiration could further reduce DO concentrations below the lethal limit for either eggs or larvae, particularly when a large organic load is present.

Sediment dynamics over the shallow shelf could further influence egg hatching success or larval survival. The embeddedness of sediments could affect larval survival by influencing the availability of hiding cover (Lyons 2005). Additionally, the presence of fine sediments could seal the sediment/water interface, reducing water circulation and oxygenation of pore-water, resulting in an increased probability of anaerobic metabolism and production of related and potentially toxic byproducts such as hydrogen sulfide or ammonia that may affect egg hatching rates or larval survival.

A combination of water column and pore-water sampling for physicochemical parameters including DO, hydrogen sulfide, and ammonia concentrations will be used to monitor physicochemical conditions encountered by various life stages of Devils Hole pupfish (Table 2; SOP I).

In the 1970s and well into the 1990s Devils Hole pupfish population size could be correlated with water level (Deacon and Deacon 1979; Anderson and Deacon 2001). In the recent decline, a direct correlation between declining water levels and pupfish numbers is less apparent. However, the potential influence of declining water levels on a suite of physicochemical parameters that may influence the suitability of habitats for Devils Hole pupfish such as water temperature, dissolved oxygen concentration, and habitat area warrant a careful evaluation of potential affects. For example, as water depth decreases with declining water level, solar heating of the shallow shelf may lead to greater water temperatures.

Water level will be monitored continuously to meet legal obligations and to correlate patterns and trends with ecological responses (Table 2; SOP III). Research is being initiated to model thermodynamic and hydrodynamic patterns and processes at Devils Hole in order to better understand how changes in the physical environment may affect habitat suitability for the Devils Hole pupfish.

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Another viable hypothesis is that food availability for Devils Hole pupfish may have declined, resulting in reduced fitness or fecundity of adults, survival of eggs and/or larvae, or recruitment of juveniles (Riggs and Deacon 2005). The morphology and life history of Devils Hole pupfish suggest annual food limitations, particularly in the late fall and winter when primary productivity is minimal. James (1969) found that mortality of 15-19 mm fish increased dramatically during the late fall and suggests it was in response to reduced food availability leading to starvation rather than old age. If food availability acts to regulate the size of the Devils Hole pupfish population on an annual basis under natural conditions, small changes in the productivity of the system would likely immediately result in fewer Devils Hole pupfish.

At least two efforts suggest that shifts in the algal community may have occurred, resulting in reduced secondary production (i.e., aquatic invertebrates) of items preferred by Devils Hole pupfish. Diet analyses conducted prior to the observed decline in the pupfish population from fish collected during 1967 – 1969 found that stomach contents were dominated by items associated with the green alga *Spirogyra* (Minckley and Deacon 1975). Subsequent to the observed decline, additional diet analyses were completed from fish collected during 1999 and 2000 as one component of a bioenergetics study and found a nearly complete absence of *Spirogyra* in the gut contents, being replaced by cyanobacteria (Wilson and Blinn 2001). Cyanobacteria are thought to decrease the efficiency of energy transfer through the food web, ultimately resulting in reduced biomass at the higher levels of the trophic structure (Stockner and Porter 1988). In their study of energy flow through the Devils Hole ecosystem, Wilson and Blinn (2007) determined that cyanobacteria represented the highest proportion as a food source in the tissues of Devils Hole pupfish in summer, but was minimal in winter.

Several potential mechanisms could explain such a shift in community state. Cyanobacteria tend to gain a competitive advantage under conditions of elevated water temperature, reduced solar radiation, or declining N:P nutrient ratios (Scheffer et al. 1997). As previously mentioned, trend information relative to water temperatures above the shallow shelf in Devils Hole is lacking, but declining water levels and increasing air temperatures could both result in increasing water temperatures, though the magnitude of change is difficult to predict. Historic trends in the amount of solar radiation at Devils Hole are currently poorly understood, though increasing airborne particulate concentrations in the Amargosa Desert warrant further investigation. A pilot study has been initiated by the Desert research Institute (DRI) to examine historic and current nutrient concentrations in Devils Hole. Preliminary findings suggest nutrient changes (K. Acharya, pers. comm.) that could have resulted in shifts in community state.

Additional responses of either primary or secondary production as described under the ecosystem conceptual model to a suite of abiotic or physical changes could also be responsible for a reduction in food availability for the Devils Hole pupfish. For example, Wilson and Blinn (2007) determined that allochthonous energy plays an important role in the Devils Hole food web, being especially important for the pupfish when autochthonous production is low during winter. Changes in the amount of allochthonous nutrients resulting from reduced growth by terrestrial vegetation could also, ultimately, reduce system productivity and the availability of invertebrate food items.

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To better understand the potential linkages between Devils Hole pupfish abundance and food availability, a variety of parameters will be monitored on a regular basis. These include benthic algae and invertebrate community composition and biomass as well as the abundance and species composition of the mieofauna (Table 2; SOP V). Additional laboratory research is being designed to investigate patterns of primary and secondary production in Devils Hole, with particular emphasis on the role of nutrients, solar energy, and water temperature in determining the algal community state.

Two additional hypotheses have been proposed to explain population-level declines in Devils Hole pupfish abundance. First, population genetics theory suggests that small populations are vulnerable to decreases in fitness or extinction through the accumulation of deleterious alleles. Given the small size of the Devils Hole pupfish population and known population bottlenecks, this theory has been frequently applied to the observed decline. Wilcox (2001), using microsatellite and mitochondrial DNA markers found evidence of non-neutral mutations in small pupfish populations though their effects were apparently repressed to some extent by strong selective pressures against these novel mutations. Next, though extensive disease screening has not occurred, it has been proposed that an unidentified disease could be affecting the population. Given the very small size of the Devils Hole pupfish population, lethal sampling is not generally advisable. Natural mortalities will be collected when encountered and processed for genetic and pathology testing (Table 2; SOP VII).

Administrative and Logistical Considerations

Equipment use and decontamination

The spread of exotic species into new habitats has been firmly established as a leading threat to native biodiversity (e.g., Richter et al. 1997; Wilcove et al. 1998). Introduction of exotic species have often been attributed to recreational boaters, fishermen, and other water enthusiasts, but have almost certainly also resulted from the improper decontamination of equipment by professional resource managers and scientists working among many ecosystems. It is critical that resource professionals begin to embrace the motto “First, do no harm” as has been commonplace in the medical profession for over a century. Under this philosophy, the first step in disrupting vectors of invasive species dispersal is to ensure that resource professionals are not, themselves, transporting non-native organisms into novel habitats.

Historic and more recent invasions in the direct vicinity of Devils Hole underscore the importance of a precautionary approach. The red-rim melania (*Melanoides tuberculatus*), a snail native to Asia, has been present in many of the springs in the Ash Meadows area for several decades, presumably having been introduced as a consequence of the aquarium pet trade (Williams et al. 1985). This species is known to act as a vector for fish diseases including a gill trematode that has caused serious losses in fish populations (Mitchell et al. 2005). The quagga mussel (*Dreissena rostriformis bugensis*), native to the Ukraine, has recently invaded Lake Mead and has started to disperse to other areas within and outside of the Colorado River Basin. As a filter feeder, this species has a large potential to disrupt the flow of nutrients and energy through the aquatic food web. If these species were to become established in the Devils Hole ecosystem,

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eradication would be impractical and control may dominate available funding. In implementing ecosystem monitoring at Devils Hole, stringent protocols will be followed to ensure that the ecosystem stays free of anthropogenic sources of contamination (SOP VIII).

Where practical, gear will be dedicated to the Devils Hole ecosystem and not used elsewhere. Where it is deemed absolutely necessary for gear to be used at Devils Hole and elsewhere, that gear will be subjected to a thorough decontamination procedure prior to use in Devils Hole. Specific steps will include primary and secondary treatments such as a combination of thorough cleaning with a detergent disinfectant and exposure to a physical disinfection treatment such as a hot water bath, a freeze treatment, or extended desiccation (SOP VIII). As disinfection techniques improve and expand on treating invasive species, disinfection protocols will be frequently revised.

Entering Devils Hole and personal items

It is mandatory that individuals entering Devils Hole sign into the "Devils Hole Entrance Log Book" located at the bottom of the entrance ladder. This log book may also be used to make observational comments, which is highly encouraged.

All personal items that are stored in clothing pockets must be left in a vehicle or in a backpack that is stored away from the shallow shelf. Such items may include cell phones, keys, coins, wallets, and/or other similar items.

Specimen collection and curation

The need to collect and preserve biological specimens from the Devils Hole ecosystem arises from two primary objectives. First, individual species vouchers (all flora and fauna) are needed to document identifications and provide a record of species presence at a particular point in time. Second, there is a recurring need to take advantage of natural pupfish mortalities for measuring and monitoring genetic diversity, fish health, and to validate length-at-age estimates. At a minimum the following seasonal vouchers should be collected and retained 1) benthic algae, 2) neuston and plankton material, and 3) newly encountered taxon. The following annual vouchers should be retained 1) macroinvertebrates, 2) meiofauna, and 3) Protozoa.

Specimen collection on NPS units is guided by 36 CFR 2.5(g) which directs each Park Unit to adhere to a process by which collection of cultural and natural specimens is authorized and information is managed. Before specimen collecting begins, a park accession number will be assigned by the park's curator. When specimen collecting is finished, the curator will be contacted to obtain a block of park catalog numbers for the specimens that will be permanently retained. Specimens that are consumed in the course of analysis or research need not be cataloged. The following information will be provided to the curator:

1. Park accession number
2. Collection date(s)
3. Number of specimens collected (estimates are acceptable for large collections)
4. Species or taxon and habitat

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The curator will either provide NPS specimen labels or will approve the electronic scanning or writing of NPS specimen labels. The curator will provide instructions for label completion. The labels must be completed in permanent, archival ink and appropriately affixed to specimens or their containers, even if the collector had previously applied their own labels. If the size of the specimen or the container preclude completion of another label, the collector's label must at minimum include the park accession and catalog number, in permanent ink, in the following format:

DEVA-1234 (for the accession number, must include a hyphen)
DEVA 99999 (for the catalog number, do not include a hyphen)

Voucher specimens will primarily be retained in the Death Valley National Park natural history collection. When alternative curation facilities are needed to meet program objectives, procedures for designation of non-NPS repositories are available by contacting the park curator. Procedures for loan of park collections are also available through the park curator.

Sampling design

Two primary spatial designs will be employed: stratified random sampling and repeated measures. Where *a priori* evidence indicates that a parameter (e.g., the abundance of an animal) is not distributed randomly and this distribution is likely to change in a predictable fashion, establishing meaningful strata and randomly allocating samples within these strata can help to control noise in the dataset, preserving the signal from the target parameter. Herbst et al. (2003) describes an example from Devils Hole where stratified random sampling would be most efficient. During their study, the distribution of various invertebrates was patchy, largely as a consequence of the distribution of preferred sediment sizes. Every time that the distribution of sediments in Devils Hole changes, such as following floods and earthquake-induced waves, substrate-based strata should be reestablished and randomized sample allocation should be repeated (SOP IV).

Examples of situations where a repeated measures approach would be most likely to detect important trends in ecological parameters include monitoring of physicochemical conditions such as water temperature. Water temperature does vary seasonally over the shallow shelf and between the shallow shelf and deep pool (Threloff and Manning 2003). The deep pool is remarkably stable with temperatures being 33.4 to 33.5°C year round. Therefore, to detect temporal trends in water temperature, the same monitoring locations would be maintained over time to limit noise from spatial variation.

Primary temporal design considerations include the seasonality of air temperature, solar energy, and primary production and the life cycle of resident taxa. For each monitoring parameter, the sampling frequency and schedule will be set to minimize noise originating from temporal variation in order to maximize the power of our design to detect important patterns or trends.

In all sampling conducted at Devils Hole, particular care must be taken to avoid disruption of the habitat or resident taxa given the extremely restricted habitat area. Sampling effort and methods

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will at times be constrained by this reality, limiting the number of methods available for use, the sample size, or the number of replicates.

All sampling locations need to be documented according to the Devils Hole coordinate system (Wilson and Blinn 2007; modified from Gustafson and Deacon 1998). Establish a transect (meter tape) along a south- north orientation of the east wall over the 5.75 m shallow shelf with point zero located 1.43 m from the USGS brass cap labeled RM 1. To verify correct orientation of the tape measure from point zero, the short pole in the middle of the shelf is located at 3.38 m and the last pole is at 5.60 m along the north-south transect. Three values are needed when recording a coordinate location, 1) south to north, 2) east to west, and 3) depth (substrate to top of water surface). Note depth is not always required.

Data management

In the end, the value of a long-term monitoring effort can be lost to ineffective or inefficient data handling, analysis, and reporting methods. It is often these methods that receive the least attention in the protocol development process, but without due consideration the value of the monitoring effort is severely diminished.

Standard systems will be utilized to the maximum extent possible to store, organize, and secure program data. Major bibliographical tools include NatureBib, a bibliographical index for references that pertain to Park resources, and NPSpecies, a repository for taxonomic and observational information relating to species found in Parks. Dataset Catalog is another NPS tool that can be utilized to document dataset holdings. NPStoret is a water quality database that serves to standardize water quality data reporting for inclusion in the Environmental Protection Agency's STORET database. The Natural Resource Database Template (NRDT) is a set of relational database tables that can ease the process of database development for individual monitoring programs while improving comparability among efforts. Finally, the NPS Metadata Tools and Editor is a custom software application that can be used to document program data.

A system of quality assurance and quality control will be instituted to ensure the accuracy and utility of program information. Specifically, standard approaches for data verification and validation, based largely on NPS (2008) national guidance, will be followed.

Database design and implementation

A relational database will be developed to house information from this monitoring effort based on the Natural Resources Database Template (NRDT) (http://science.nature.nps.gov/im/apps/template/index.cfm). The database will include the ability to interface with other natural resource data systems such as NPStoret, enabling the upload of water quality information to the Environmental Protection Agency's STORET water quality database following review by the NPS Water Resources Division.

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Data acquisition and entry

Data will be acquired in both analog and digital form. Paper datasheets will be used to record field data in the majority of cases, though electronic instruments with internal memory will be used to collect unattended measurements of certain parameters. Laboratory datasheets will be used for processing of physicochemical, flora and fauna samples. Original datasheets will be filed in a central location. Scanned copies of original datasheets will be archived on the program server. Raw data files from instruments will also be stored to the server. All original data will be retained in compliance with federal records management regulations.

For all electronic data formats, file names will be derived by tagging the date of data creation to a description of the data using the following convention:

FileDescription_DD-MON-YYYY

For example, a file containing invertebrate survey data that was conducted on June 01, 2008 might be named "InvertebrateSurvey_01Jun2008". Multiple versions from the same date should be versioned by lettering sequentially (e.g., InvertebrateSurvey_01Jun2008a and InvertebrateSurvey_01Jun2008b).

Quality assurance and quality control

Database records will be verified to ensure that raw data have been accurately transcribed. Data will be processed to remove missing values and other flaws; and data will be validated through visual inspection and queries to capture missing data, out-of-range values, logical errors, and violations of pre-defined data rules. Further, electronic instrumentation will be calibrated to National Institute of Science and Technology (NIST)-traceable standards per manufacturer instructions. Calibration and required maintenance will be performed at manufacturer-recommended frequencies, at a minimum, or more frequently when necessary to ensure data accuracy. Calibration and maintenance records will be generated for each service event and will include pre- and post-calibration readings for all parameters, required maintenance performed, and observations of instrument condition and performance. The following post-collection protocols will be followed to assure data quality:

- Use of database programming will be maximized to control data entry. This will be achieved via the use of lookup tables and/or field-type design in a database (e.g., yes/no field types, input masks), and constraints such as valid ranges, uniqueness, referential integrity, and nullity
- All database records (100%) will be verified against original source data (i.e., datasheets or raw data files) following data entry
- A subset of randomly selected database records (10%) will be reviewed after initial verification by the project manager or his/her designate. If errors are found, the entire data set will be verified again

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- Use of automated routines and/or data summary and visualization (e.g., histograms, line plots, and basic statistics) will be maximized to identify possible logic and range errors
- Corrections or deletions as a result of the data validation process will require notations in the original paper field records about how and why the data were changed, with the editor's initials
- Modifications of the field data will be clear and concise while preserving the original data entries or notes (i.e., no erasing)
- A record of the verification and validation process for each data set, including number of iterations and results, will be prepared as part of formal metadata generation

Data certification and maintenance

Following the process of data verification and validation, metadata records will be generated for each dataset using the NPS Metadata Tools and Editor. This step will be used to certify that the data have passed all quality assurance requirements, are complete, have been documented, and are ready for use and distribution. This step will be accomplished once per year in conjunction with the annual monitoring report. All subsequent changes to the dataset will be tracked in an accompanying edit log.

Individual standard operating procedures

Additional data management procedures are provided in each SOP except for SOP VIII Decontamination. Each SOP assembles different types of data (e.g. datalogging, abundance, coordinate positions, visual surveys) which requires slightly different management verifications and validations.

Data analysis

The extensive set of long-term datasets generated by this monitoring effort will be well-suited to a variety of analytical approaches. Initially, a variety of descriptive statistics and basic visualizations of datasets will be useful to identify patterns of particular interest and define the range of variation. Of primary importance will be a variety of basic and more advanced modeling approaches used to describe linkages among ecological parameters. Additionally, differences in time and space among samples will often be assessed using traditional hypothesis testing approaches such as t-tests for paired differences or ANOVA to assess differences among multiple samples.

One objective of the LTEMP is to determine the status and trends of parameters designated in the conceptual models that are thought to structure the Devils Hole ecosystem and that might influence the population dynamics of the pupfish. Status is defined as the condition or state of a population, or parameter of interest. It is a point in time measurement and is typically related to spatial conditions (McDonald 2003). Trends are related to directional change over time and consist of multiple points. A second objective is to synthesize ecosystem data to evaluate ecological relationships in a non-experimental context.

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In order to examine long-term trends the following summaries and statistical analyses will be conducted:

1. Measures of central tendency: means and median
2. Measures of variation: range, standard error, and standard deviation
3. Evaluating data for missing values and outliers: queries, quality control/assurance
4. Graphical summaries and visual inspection of data
5. Statistical analyses: repeated measures, time series using mixed linear models, and correlations and regressions

Rationale for selected statistical analyses:

1. Repeated measures: will be used to examine differences among sampling dates. This type of analysis was selected because some correlation is assumed among sampling dates (not truly independent samples; Sokal and Rohlf 1995). This type of analyses is typically applied to experimental designs where multiple samples are taken from the same experimental unit (Quinn and Keough 2002), but the LTEMP is designed to sample the same habitats over time in a non-experimental design. Correlation is assumed to exist when sampling habitat from the same ecosystem over time.

2. Time series general linear mixed model: will be used to address variance-covariance matrices that arise from missing data and repeated observations that are unequally spaced (Littell et al. 1996). These regression types of analyses are also referred to as random effects models (Scheiner and Gurevitch 2001). This type of approach uses curve fitting of data which can provide greater power then repeated-measures ANOVA.

3. Correlations and regressions: will be used to examine other factors that might be influencing a specific trend.

Synthesis of long-term ecosystem monitoring data will be addressed through multivariate statistical analyses. This approach will again examine ecological relationships over time in a non-experimental context. These types of analyses allow for comparisons of multiple factors. Two types of multivariate analyses will be used. Ordination and multiple regression approaches will be used to examine the influence of environmental variables on a particular population (e.g. pupfish, beetles). Essentially, these analyses reduce the unexplained error variance of a variable (Sokal and Rohlf 1995).

Once the Long Term Ecosystem Monitoring Plan (LTEMP) is implemented and data can be analyzed and an examination of β (power) and α (level of statistical significance or the probability of committing a Type I error) can occur. It is important that data sets have high power, which increases the ability to detect differences or trends while still allowing an acceptable level of false change (α).

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Further, a Minimum Detectable Effect (MDE) or the minimum change one wishes to detect, should be discussed and determined by resource managers (Green and Kauffman 1989, MacDonald et al. 1991). The Park staff will need to spend a significant amount of time discussing the MDE for each variable. It is recommended that Park staff refer to information provided by previous investigators on the Devils Hole ecosystem including Gustafson and Deacon (1998) and Wilson and Blinn (2001) for all determinations. For example, it is recommended that the MDE for substrate composition not exceed 20%., that a one-way ANOVA between years be conducted to determine significant change in substrate composition, and that a Tukey multiple-comparison test be conducted to determine which years are significantly different from one another (Zar 1984). It is recommended that this analysis be conducted on sand/gravel since this substrate category has the greatest spawning activity for *Cyprinodon diabolis*. Data can be compared with fish and larval counts to determine relationships between substrate composition and annual fish recruitment.

Reporting and protocol revision

Annual reports of the monitoring program will be completed by DVNP staff. Reports will be developed in standard scientific format (i.e., Introduction, Methods, Results, and Discussion sections). Reports will include program accomplishments, setbacks, and major conclusions from the resultant information. Reports will be reviewed internally and by program partners for accuracy and appropriateness of findings. When appropriate monitoring results will go through the peer review process. Proposed minor revisions to either the monitoring protocol or specific standard operating procedures will be included as a section of the annual report where necessary.

A formal assessment of the ecosystem monitoring program will be conducted every five years. This will include a thorough analysis and presentation of ecological data collected to date, assessment of monitoring protocol performance, identification of efficiencies that could be gained by restructuring sampling designs, identification of additional parameters to be monitored, and ultimately, measurement of attainment or departure from the stated goals and objectives of the monitoring protocol. As the primary mechanism for publishing the results of the ecosystem monitoring effort, a formal report will be developed following the format of the Natural Resources Technical Report series (http://www.nature.nps.gov/publications/NRPM/) and circulated for peer review. The peer review panel will include, at a minimum, the following academic disciplines:

- groundwater hydrology,
- atmospheric science,
- phycology,
- microbiology,
- limnology,
- aquatic invertebrate ecology,
- population ecology,
- fish biology, and
- biostatistics.

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Following independent review of the monitoring report, the peer-review panel will be convened at DVNP for a workshop where a more thorough evaluation of the monitoring program will be completed. In addition to written comments on the monitoring report, the panel will submit a report of findings from the workshop to DVNP for consideration during a major revision of the ecosystem monitoring protocol and standard operating procedures (SOPs) to span the next five year period.

Versions of this monitoring protocol, accompanying Standard Operating Procedures (SOPs), and data storage systems (e.g., databases) will be named using the NPS Inventory and Monitoring Network convention (see NPS 2008):

FileDescription_MajorRevision#.MinorRevision#

Version numbers will be incremented by a whole number (e.g., FileDescription_1.3 to FileDescription_2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., FileDescription_1.6 to FileDescription_1.7) when there are minor modifications that do not affect requirements or procedures included in the plan.

Roles and responsibilities

The Devils Hole ecosystem has a long history of collaborative research and management efforts. In the spirit of this collaborative legacy, the implementation of long-term ecosystem monitoring at Devils Hole is envisioned as a partnership among diverse agencies, institutions, and individuals, each of whom harbors a unique ability to help increase our collective understanding of the Devils Hole ecosystem. Jurisdiction for management of the Devils Hole pupfish is shared among three agencies: the National Park Service (NPS), the U.S. Fish and Wildlife Service (USFWS), and the Nevada Department of Wildlife (NDOW) with each agency adding resources to the recovery effort. Recovery strategies and management approaches for this species are developed in an interagency setting. Implementation of recovery actions has often been carried out in an interagency manner, though separation of duties has at times been necessary to maximize productivity. Monitoring of the Devils Hole ecosystem will continue to be pursued in collaboration and consultation with partner agencies.

Staff from the Resources Division of DVNP will ensure that a holistic research, monitoring, and stewardship program continues for the Devils Hole ecosystem. This includes a fish biologist and an aquatic ecologist serving as subject matter experts by designing and coordinating monitoring activities and managing field and laboratory operations, a biological science technician that leads the collection and maintenance of diverse ecological data, and a hydrologic science technician that leads the collection and maintenance of data pertaining to the physical environment and regional groundwater aquifer. Direct oversight of the Devils Hole ecosystem monitoring program will be provided by the Resources Management Division and Superintendent's office of Death Valley National Park.

A number of agreements are also in place to aid in monitoring the Devils Hole ecosystem. The measurement of water level at Devils Hole has been implemented as a collaboration between

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DVNP and the NPS Water Rights Branch. The Desert Research Institute (DRI) currently manages the collection and maintenance of meteorological data at Devils Hole as a part of the Western Regional Climate Center's weather station network.

A number of volunteers also make valuable contributions to the research and management of Devils Hole. For example, volunteer SCUBA divers assist Park biologists with research and monitoring of submerged resources.

Budget

Long-term monitoring, by definition, requires a long-term commitment of funds in order to ensure sustainability. Resource monitoring has often been viewed as a one-time, project-related expense that can be cut in times of budget shortfalls. This approach, though common, can result in a reactive, crisis-driven management approach that strains rather than encourages partnerships, is fiscally inefficient, and can hinder the identification of scientifically robust management strategies. A more proactive approach that institutionalizes a commitment to long-term ecological monitoring at Devils Hole is needed.

A five-year budget for the Devils Hole program, including ecosystem monitoring, applied research, and other stewardship responsibilities such as pupfish recovery efforts has been developed for fiscal years 2008 through 2012 (Appendix A). In addition to the implementation of this ecosystem monitoring plan, the budget recognizes the necessity of short-term applied research to advance understanding of key processes. In several instances, the program budget identifies opportunities for collaborations that act to increase the flexibility of existing funds as well as support development of lasting partnerships with academic institutions. Costs have been projected across five fiscal years as a means to anticipate the effects of inflation and logically organize program expenditures. This budget will be used to inform the development of an annual work plan for the Devils Hole program within the Resources Management Division's annual budget.

Acknowledgements

We wish to thank a panel of talented individuals initially convened at Death Valley National Park in March of 2007 to consider approaches to monitoring the Devils Hole ecosystem. The resulting summary report helped form the foundation from which the current plan was built.

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Standard Operating Procedures

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Devils Hole Ecosystem Monitoring Protocol

SOP I – Water Quality

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Version 1.0 (XX/XX/XXXX)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

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Introduction

This SOP describes methods for 1) continuous monitoring of a variety of water quality parameters at two fixed locations, one over the shallow shelf and a second at a depth of 5 m in the deep pool as well as 2) supplemental synoptic water sampling for nutrients will be collected from the water column over the shallow shelf, the deep pool, and sediment pore-water space.

Continuous monitoring

Measurement frequency

Record readings every 15 min. This is necessary to remove biofilm that covers the optical sensors. Further, the incised nature of Devils Hole regulates direct sunlight on the shallow shelf which creates quick changes in dissolved oxygen concentrations.

Field methods

Install YSI 6600 V2-M series multiparameter water quality sondes at two locations. Deploy one sonde over the southern end of the shallow shelf by suspending the instrument slightly off of the substrate to ensure a proper vertical orientation. Suspend a second sonde in the water column of the deep pool at an elevation 5 m below the copper washer. Record the specific location (X, Y, and Z) of each sonde using the local coordinate system. At both locations, measure the following parameters with the indicated sensors:

- dissolved oxygen concentration (mg/L) and % oxygen saturation [YSI 6155]
- pH [YSI 6561]
- conductivity and temperature (µS/cm, °C) [YSI 6560]
- depth (m)

- date/time (UTC)

Instrument calibration and maintenance

A protocol for water-quality sonde exchange, as described by Wagner et al. (2006), will be followed due to the harsh environmental conditions frequently encountered at the Devils Hole site (e.g., air temperature routinely exceeds 45°C) which could interfere with calibration accuracy. This includes an annual temperature validation. This is accomplished by placing all three Sondes into a water bath simultaneously. Temperatures from the Sondes are validated against an NIST thermometer. Sonde temperatures need to be within 0.2 °C of the validation thermometer. If temperatures exceed this value return the failing Sonde(s) to YSI for maintenance. Specific instructions include:

- Use a rotation of three sondes with two sondes deployed at Devils Hole and one retained in the laboratory for service at any given time.
- To the extent possible, limit disturbance of sondes to periods between field measurements (i.e., move sondes between readings),
- Replace each sonde on a biweekly basis with a fully serviced sonde from the laboratory so that no one sonde is deployed for a period longer than 14 straight days without being fully serviced and/or calibrated.
- Perform a calibration check in the laboratory within 24 hours prior to the sonde being deployed in the field.
- Follow manufacturer directions for calibration methods.
- Deploy the sondes in tandem for a minimum of 60 min to conduct a fouling check of the previously-deployed sonde.
- Use attached datasheets, structured after Wagner et al. (2006), to record instrument deployment details, the fouling and calibration checks, routine station and instrument maintenance, and repair history of each sonde (http://pubs.usgs.gov/tm/2006/tm1D3/).
- File datasheets in a log book for each sonde along with any pertinent records or notes.

Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to follow the procedures listed below.

Sonde and calibration datasheets:

- All datasheets need to be scanned upon return from the field and placed in the appropriate folder on the Pahrump server. Make sure to include all records in the log book for each Sonde.
- Annually photocopy and store copies in the Resource Management building in Death Valley to secure duplicates at a separate location.

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Downloading Sonde data (calibration, verification, and validation):

- Download raw data files from each instruments and archive in original form (EcoWatch software that is supplied with the YSI Sondes).
- In this original format select viewable parameters as follows: DateTime, Temp, SpCond, pH, ODO%, ODO Conc, and Depth. All at once copy and paste these parameters into Microsoft Excel data validation file for initial assessment.
- Next, plot raw data and review the results of for both the fouling and calibration checks.
- Apply corrections when needed to account for observed sensor fouling, calibration drift, and other errors following the methods of Wagner et al. (2006).
- If visual inspections of plotted data indicates fouling or drift that cannot be corrected then those portions of the dataset will not be validated and data will be retained only as raw data in its original form.
- Upload corrected and validated data and associated metadata into the Devils Hole data management database.
- Annually, the project manager needs to randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.

Sonde metadata and archiving:

- Archive validation methods and output of data corrections along with metadata records for each dataset on the Pahrump server (within the Abiotic data folder).
- Annually upload Sonde data to NPStoret as described in the monitoring plan.

Supplemental synoptic sampling

Sampling frequency

Bimonthly (February, April, June, August, October, and December) and following disturbance events. Alkalinity will be measured in winter and summer, and following disturbance events.

Field methods

Water samples for each nutrient parameter will be collected from the following habitats, 1) at the edge of the shallow shelf over the deep pool, 2) from the middle of the shallow shelf, and 3) from randomly selected sediment-pore water locations. Water samples may also be analyzed following research dives.

- Deep pool

    1. Collect water from the deep pool by reaching out from the end of the sampling walkway.
    2. Take triplicate samples using pre-labeled 1 l acid-washed bottles that have been rinsed in the lab with distilled water.

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3. Make sure no air bubbles are in the sample bottle. This is best accomplished by submerging the sample bottle.
4. Immediately place samples on ice in a cooler located at the parking lot for analyses back at the DEVA laboratory.

- Shallow shelf

1. Collect water from the shallow shelf by reaching off the sampling walkway.
2. Take triplicate samples using pre-labeled 1 l acid-washed bottles that have been rinsed in the lab with distilled water. Make sure there are no air bubbles in the sample bottle.
3. Immediately place samples on ice in a cooler located at the parking lot and bring back to the DEVA laboratory for analyses.

- Sediment pore-water

1. Randomly collect nutrient samples from three locations. At each location take three samples.
2. Use a Luer-Lok™ stainless steel hypodermic needle (9 cm length) attached to a 60 ml capacity syringe to collect pore-water. Place the needle perpendicular to the substrate and insert into the interstices to a depth of 5 cm. Slowly extract a 55 ml volume sample.
3. Pre-label syringes before going out into the field.
4. Remove air from syringe by inverting and gently pushing in the plunger. It is important not to agitate water samples because this can change certain nutrient concentrations.
5. Use a square piece of Parafilm™ to cover the tip of the syringe. Store syringes horizontally in a tray and place on ice in a cooler located at the parking lot.
6. Hypodermic needles and syringes should be acid-washed and rinsed with distilled water in the lab prior to use.

- Special note: water for total phosphorus needs to be filtered in the field. Separate sampling bottles and field filtering equipment need to be included for nutrient sampling.

1. Filter water through a filter manifold using GF/C filters (0.45 µm).
2. A syringe is placed into the water sample filled with water and injected through the manifold into an acid-washed and rinsed sample bottle. Each sample bottle needs to be filled completely (no air) and sealed.
3. Used filters should be placed into a small bag to be disposed of back in the lab.

Laboratory methods

The following analytes will be measured for each collection date using a Hach DR5000™ spectrophotometer:

- Nitrate (NO_3-N)

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- Nitrite (NO_2^--N)
- Ammonia (NH_3-N)
- Total Phosphorus (P as PO_4^{3-}-P)
- Hydrogen sulfide (H_2S as S^{2-})
- Sulfate (SO_4^{2-})
- Alkalinity ($CaCO_3$)

Each analyte requires a specific protocol to be followed. Hach Company (2008) will serve as the standard reference for each method.

- Nitrate (NO_3-N)

  1. Use Hach method #8192, range of 0.01-0.50 mg/l.
  2. Prior to analysis filter water through GF/C Whatman filters (0.45 µm) or other brand as long as pore size of filter is equal to 0.45 µm.
  3. Make sure samples are at room temperature before analysis.

- Nitrite (NO_2^--N)

  1. Use Hach method #8507, range of 0.002-0.300 mg/l.
  2. Prior to analysis filter water through GF/C Whatman filters (0.45 µm) or other brand as long as pore size of filter is equal to 0.45 µm.
  3. Make sure samples are at room temperature before analysis.

- Ammonia (NH_3-N)

  1. Use Hach method #10205, range 0.015-2.000 mg/l.
  2. Prior to analysis filter water through GF/C Whatman filters (0.45 µm) or other brand as long as pore size of filter is equal to 0.45 µm.
  3. Make sure sample is at room temperature before analysis.

- Total Phosphorus (P as PO_4^{3-}-P)

  1. Use Hach method #8190, range 0-3.5 mg/l.
  2. Water for total phosphorus should be filtered in the field through GF/C Whatman filters (0.45 µm) or other brand as long as pore size of filter is equal to 0.45 µm.
  3. Make sure samples are at room temperature before analysis.

- Hydrogen sulfide (H_2S as S_2^-)

  1. Use Hach method #8131, range 0.005-0.800 mg/l.
  2. DO NOT filter water. This will change the concentration of sulfide.
  3. Do not agitate sample. This will also change concentrations.
  4. Warm to room temperature only.

- Sulfate (SO_4^{2-})

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1. Use Hach method #10227, range 40-150 mg/l.
2. DO NOT filter sample. This will change the concentration of sulfide.
3. Do not agitate sample. This will also change concentrations.
4. Warm to room temperature only.

- Alkalinity ($CaCO_3$)

    1. Use the potentiometric titration method as outlined in Clesceri et al. (1998)
    2. DO NOT filter sample. It is best to measure alkalinity in the field.
    3. Do not agitate sample.

Standard solutions should be run routinely for each analysis for accuracy. Clean sampling bottles according to method protocols. See SOP VIII for decontamination protocols for cleaning of sampling gear.

Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to also follow the procedures listed below.

Field and laboratory datasheets:

- Each field datasheet needs to be quality controlled for completeness by two crew members prior to leaving Devils Hole. Double check coordinates for each sampling location, depth of pore-water samples, and type of benthic cover is mentioned on the comments section of the field data sheet.
- Upon return to the office each datasheet needs to scanned and placed into the appropriate folder on the Pahrump server. Originals need to be filed in the designated Devils Hole filing cabinet.
- After laboratory processing is complete follow the same procedure as described above for field datasheets.
- After completing a sampling event, all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data entry:

- Use the MS Access database developed for the monitoring plan to enter data (this database is still under design).
- To reduce data entry errors database programming will be maximized to control data entry. This will be achieved via the use of lookup tables, and/or field-type design in the database (e.g. yes/no field types, input masks), and constraints such as valid ranges, uniqueness, referential integrity, and nullity.

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Data verification:

- Each data point entered into the database needs to be checked against the original field and laboratory datasheets. If errors are found corrections need to be made to all pertinent database forms.
    - Procedure:
        - Print dataset and compare each point with datasheets.
        - Correct any errors.
        - If an error or errors are found recheck 100% of records for the specific sampling period for accuracy.

Data validation:

- Each data set needs be visually inspected by plotting each data point as a scatter plot and by running queries to capture missing data, out-of-range values, logical data, and violations of pre-defined data rules.
- Data entry may be correct, but not logical. An example would be having a higher concentration of ammonia compared to nitrate in the water column, which is not biologically possible. Data was most likely entered into the wrong place on the laboratory datasheets.
- If errors are found the entire data set needs to be verified again.
- Annually the project manager will randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.

Metadata procedures

- Generate metadata records using the NPS Metadata Tools and Editor Metadata then follow the Federal Geographic Data Committee (FGDC) standards and include biological profile elements that allow integration of the metadata record with the NPS I&M NPSpecies and NatureBib online databases.
- A detailed procedure will be included in the next version.

Data archiving:

- After water chemistry and other physicochemical data sets have been validated each data set needs to be uploaded to NPStoret as described in the monitoring plan.

References

Clesceri, L.S., Greenberg, A.E., and Eaton, A.D. 1998. Standard methods for the examination of water and wastewater. 20th Ed. American Public Health Association, Washington D.C.

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Hach Company. 2008. Hach Water Analysis Handbook Procedures, 5th Edition. (http://www.hach.com/hc/browse.product.documentation/FILCAT_PROC_WAH_MAIN/NewLinkLabel=Hach+Water+Analysis+Handbook+Procedures,+5th+Edition/). Accessed 16 December 2008.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments. (http://pubs.usgs.gov/tm/2006/tm1D3/). Accessed 19 June 2008.

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DEVILS HOLE
CONTINUOUS WATER-QUALITY MONITOR CALIBRATION FORM

Date: _____ Time:_____ Name:_____

Previous Sonde Deployment Location: _____

Previous Sonde Deployment Date: _____

Monitor Make/Model _____ Monitor Serial No. _____

Sonde Make/Model _____ Sonde Serial No. _____

Comments:

CALIBRATION DRIFT CHECKS

TIME	Initial time check: _____	Calibrated to: _____
Comments:		

SPECIFIC CONDUCTANCE Calibration Criteria: the greater of 5 uS/cm or 3% of measured value				Calibration Check		Recalibration	
STD VALUE	STD LOT NO.	STD TYPE KCl; NaCl	Exp. Date	STD TEMP	SC READING	STD TEMP	SC READING
Reading in air = (should be zero)	Comments:						

TEMPERATURE Calibration Criteria: ±0.2 °C for Thermisters	YSI Reading	NIST Certified Thermister Reading

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pH Calibration Criteria: ± 0.2 pH Units			Calibration Check		Recalibration	
pH BUFFER	BUFFER LOT NO.	BUFFER EXP DATE	TEMP	pH READING	TEMP	pH READING
pH 7						
pH ____						
pH ____						
Comments:						

DISSOLVED OXYGEN

Calibration Check

Calibration Criteria: ± 0.3 mg/L

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DEVILS HOLE
CONTINUOUS WATER-QUALITY MONITOR FOULING CHECK FORM

Date: _____ Time:_____ Name:_____

Sonde Deployment Location: _____

Monitor Make/Model _____ Monitor Serial No. _____

Sonde Make/Model _____ Sonde Serial No. _____

Comments:

Parameter	Before Cleaning Time _____		After Cleaning Time _____	
	Recorded/ Live Value	Field Meter	Recorded/ Live Value	Field Meter
Temp (°C)				
pH (units)				
DO (mg/L)				
SC (µS/cm)				
Other _____				

Comments:

Pictures Taken: Yes No

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Devils Hole Nutrient Field Data Sheet

Collection date:_____ Time of collection:_____

Investigator(s):_____

Sample Location	Check Off When Complete	Coordinate (S-N, E-W)
Shallow shelf	Sample 1_____ Sample 2_____ Sample 3_____	N/A
Deep Pool	Sample 1_____ Sample 2_____ Sample 3_____	N/A
Sediment pore-water location #1	Syringe 1_____ Syringe 2_____	
Sediment pore-water Location #2	Syringe 1_____ Syringe 2_____	
Sediment pore-water Location #3	Syringe 1_____ Syringe 2_____	

Comments:_____
_____
_____
_____

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Devils Hole Nutrient Laboratory Data Sheet

Date collected:_____ Time of collection:_____

Date processed: _____Time processed:_____

Investigator(s):_____

Nutrient	Replicate #	Shallow Shelf	Deep Pool	Sediment Pore-Water	Sediment Pore-Water Location*
Nitrate	1				
	2				
	3				
Nitrite	1				
	2				
	3				
Ammonia	1				
	2				
	3				
Total phosphorus	1				
	2				
	3				
Hydrogen sulfide	1				
	2				
	3				
Sulfate	1				
	2				
	3				

*Sediment pore-water location refers to the sampling point randomly collected from the shallow shelf.

Comments:_____
_____
_____
_____

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Devils Hole Ecosystem Monitoring Protocol

SOP II – Water Temperature

Michael R. Bower[1], Kevin P. Wilson[1], and Dean W. Blinn[2]

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Version 1.0 (XX/XX/XXXX)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

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Introduction

This SOP describes procedures for monitoring water temperature on the shallow shelf.

Sampling frequency

Record readings at 15-min intervals.

Field methods

Place data logging thermistors (HOBO® U22 Water Temp Pro v2) at the following six coordinate locations on the shallow shelf (see SOP IV for coordinate protocol):

1) 5.10 m north, 1.40 m west
2) 4.85 m north, 0.30 m west,
3) 3.40 m north, 1.45 m west
4) 3.60 m north, 0.32 m west
5) 2.30 m north, 1.25 m west
6) 2.45 m north, 0.30 m west.

Make sure each data logger rests on the bottom substrate securely attached to leads above the water surface to avoid loss in the event of a flood or earthquake. If thermistors are disturbed by a flood or earthquake, record their ending location and retrieve them to perform a calibration check.

Instrument calibration and maintenance

Conduct accuracy checks on each field thermistor prior to its initial deployment and annually thereafter following the methods of Wilde (2006) to ensure measurement accuracy over the range of anticipated temperatures:

- Maintain a log book containing the calibration and certification history for each calibration and field thermometer used at Devils Hole,
- Use a NIST-certified or NIST-traceable calibration thermometer that has a certification of no more than two years old to perform accuracy checks.
- Accuracy checks are accomplished by placing all six Hobo thermistors into a water bath simultaneously.
- Thermistors found to be out of calibration by more than 0.2°C must be returned to the manufacturer for repair or replacement.

Data logging thermistors have a finite battery life, and should be replaced or serviced before the have the potential to fail due to expired batteries. Data loggers should be downloaded on a two week interval to ensure that vandalism, earthquakes, and floods do not destroy or eliminate irreplaceable data.

Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to follow the procedures listed below.

Calibration and certification datasheets:

- All datasheets need to be scanned monthly and placed in the appropriate folder on the Pahrump server. Make sure to include all records in the thermistor log book.
- Annually photocopy and store copies in the Resource Management building in Death Valley to secure duplicates at a separate location.

Downloading thermistor data (calibration, verification, and validation):

- Download raw data files from each instruments and archive in original form (HOBOwares software that is supplied with the thermistors).
- Initial assessment of data will be performed by reviewing the results of accuracy checks as explained above.
- Corrections will be applied to measurements made with a thermometer that is within ±1 percent of full scale or ±0.5°C of the calibration thermometer.
- Upload corrected and validated data and associated metadata into the Devils Hole data management database.
- Annually, the project manager needs to randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.
- Corrections should be applied by using the calibration curve or table located in the thermistor log book. Be sure to keep track of the correct serial number.

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Thermistor metadata and archiving:

- Archive validation methods and output of data corrections along with metadata records for each dataset on the Pahrump server (within the Abiotic data folder).
- Annually upload data to NPStoret as described in the monitoring plan.

References

Wilde, F.D. 2006. Temperature (version 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.1. (http://water.usgs.gov/owq/FieldManual/Chapter6/6.1_ver2.pdf) Accessed 23 June 2008.

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Devils Hole Shallow Shelf Water Temperature Field Data Sheet

Date Deployed:_____

Date of Data Retrieval:_____ Investigator(s):_____

Data Logger #	Time Deployed	Coordinate Location Deployment	Time Data Retrieved	Coordinate Location Data Retrieval
1		5.10 m north, 1.40 m west		
2		4.85 m north, 0.30 m west,		
3		3.40 m north, 1.45 m west		
4		3.60 m north, 0.32 m west		
5		2.30 m north, 1.25 m west		
6		2.45 m north, 0.30 m west.		

Comments:_____
_____
_____
_____
_____

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Devils Hole Ecosystem Monitoring Protocol

SOP III – Water Level

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Version 1.0 (XX/XX/XXXX)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

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Introduction

The National Park Service (NPS) holds a Federal reserved water right for a water level at Devils Hole (Cappaert v. United States, 426 U.S. 128, 1976). The United States Geological Survey (USGS) began recording intermittent water levels at Devils Hole in 1956. A copper washer was installed on the cavern wall in 1962 as a reference for water levels and was established as the measurement datum. Due to corrosion and erosion two subsequent reference points have been installed at the same datum, (brass screw 1989 and steel bolt 1992). The steel bolt is the current datum or base gage.

The USGS monitored the water level until 1990. From 1990 until present NPS's Water Rights Branch (WRB) of the Water Resources Division has provided water level monitoring assistance to Death Valley National Park (DEVA). This SOP describes the methodology used to collect and process water-level data in Devils Hole.

Sampling frequency

Electronic 15-minute data and a continuous chart recorder.

Equipment

Two monitoring systems are used in Devils Hole to measure water level. The primary monitoring system is two submersible pressure transducers attached to a Campbell Scientific CR10 data logger. The two 0-5 PSIG (pounds per square inch) submersible pressure sensors (Druck 1830 and / or Instrumentation Northwest, Inc. PS9105) record water levels every 15-minutes. Both pressure sensors are reported to 0.1% of full-scale accuracy. The submersible pressure sensors are installed in separate, 2-inch-diameter stilling wells attached to an aluminum frame, anchored to the cavern wall at the junction of the shallow shelf and main pool. Other instruments include a Setra NIST Traceable barometric pressure sensor which records data every 15-minutes and a thermistor installed outside the enclosure of the data logger, that records air temperature in degrees centigrade every 4-hours.

A second redundant monitoring system is composed of a float and pulley system that drives a Stevens GS-98 electronic data logger and Stevens Type A Model 71 (A/71) strip chart recorder. The Stevens GS-98 data logger records water-level every 15-minutes. The Stevens A/71 chart recorder provides a continuous strip chart record that can be used to interpret extraordinary events and periods of time finer than 15-minutes. The float is located inside a 12-inch-diameter aluminum stilling well, attached to the same aluminum frame as the pressure sensors.

The Campbell Scientific monitoring instrument and the battery power supply for both instrument systems are located in a NEMA 4 enclosure at the upper west end of Devils Hole. The Stevens monitoring equipment is located in a NEMA 4 enclosure located over the 12-inch stilling well. To access the Stevens equipment a special onsite ladder is installed above the shallow shelf to minimize impacts to the pupfish habitat.

There are currently three standard USGS type A staff gages in Devils Hole. Stage in feet is read from an inverted vertical staff gage attached to the southwest side of the 12-inch-diameter stilling well. The staff gage was installed by the USGS in 1976 and referenced to the copper-washer datum. Two additional staff gages, installed by the USGS in 1964 and 1970, are mounted on the west and northwest sides of the stilling well. The west staff gage (1964) is used during datum surveys. The northwest staff gage (1970) can only be viewed by standing on the opposite end of the pool and is not used.

Data Collection and Instrument Calibration and Maintenance

Water-level data are collected and processed for Devils Hole on a monthly basis. Monthly Field Forms are used to record observations at the start and end of a monthly monitoring cycle.

Stevens Ending Field Forms

- The names of the party and current weather conditions are recorded at the top of the Field Form.
- Time is recorded from the site watch and data logger. The recording interval is recorded.
- Evidence of vandalism is recorded in the Comments section with photo-documentation.
- Digital photos are taken from fixed photo points and the time for each photo is recorded.
- The monitoring equipment batteries are checked with a voltmeter and voltage is recorded. (The batteries should maintain a charge from solar panels).
- Temperature of the data logger enclosure is measured by a mercury maximum/minimum thermometer and is recorded.
- Stage is measured at the staff gage and at the base gage (top of the steel bolt to the water surface using a dedicated steel tape). Chart recorder and data logger readings are also recorded.
- An In-Situ Rugged Reader® Pocket PC is used to download the data from the Stevens GS-98 data logger and the file is named for the date of download. The time of download is recorded, dated and signed by the field personnel.

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- The endpoint on the Stevens A-71 chart is circled. Date, time, gage height from the staff gage, base gage, chart recorder and data logger are all recorded on the top of the chart paper and the field personnel sign their names. The completed chart paper is removed and paper is then placed in position for a new record. Pens and paper are checked to see if they are adequate for continuous recording.

Campbell Scientific Instrumentation Ending Field Form

- The names of the party and current weather conditions are recorded at the top of the Field Form.
- Time is recorded from the site watch and the data logger.
- Battery voltage is checked and recorded.
- The Campbell Scientific's LoggerNet software is used to extract the water-level data from the Campbell Scientific CR10 instrument. All data collected since the last data download is comma separated in ASCII format and saved to a file named for the date of download. The time of download is recorded, dated and signed by the field personnel. An external data storage module (Campbell Scientific SM4M) is installed on the Campbell Scientific CR10 data logger. The SM4M data storage module is replaced with another SM4M at the time of the data download and taken back to the office. If any problems are found in the downloaded data, the redundant data is then available.
- A handheld Control Company NIST Traceable barometer is also kept in the enclosure and barometric pressure is recorded for comparison with the continuous recording on-site barometer. Barometric pressure is corrected for site elevation.
- Water temperature is measured at the 12 [(i)-2(s)-1(a)4(l)-2(s6(s)1(t 2(el)-2(o)-14(i(e i)-163(I)]TJ /GS1(

egge62 0r 0 Td [(s)1(iT*c 0)-15(e i)-16(s)-5(r). .0048c6(em)-ch-14(d s 0 -5r)-15(()-1(at)-6(u)-15(e i)-16(s)-5(r) Tw [0 -5r)-1

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Campbell Instrumentation Starting Field Form

- The names of the party and current weather conditions are recorded at the top of the Field Form.
- Time is recorded from the site watch and data logger.
- A staff gage reading and data logger time are recorded before a new log is started on the Campbell Scientific CR10 instrument. The real-time values from the data logger for date, time, pressure sensor stage values and barometric pressure and recording interval are recorded. If the stage for either of the 0-5 PSIG submersible pressure sensors varies more than ± .015 ft from the staff stage, the data logger stage(s) is reset to the staff gage value. Recalibrated values are recorded. The new log will continue from the point the data was downloaded.
- Battery voltage is checked and recorded.
- Barometric pressure is measured using the handheld Control Company barometric pressure sensor and used as a check for with the continuous recording Serta barometer. Both are recorded.
- Campbell Scientific's LoggerNet software is used to start water-level data collection.
- Desiccant for the pressure sensors is checked and replaced if necessary.

Campbell and Stevens Instrumentation Mid-month/Random Field Forms

A mid-month or as-needed random inspection of the monitoring instrumentation is conducted. Procedures are the same as previously documented for Starting and Ending Forms.

- The names of the party and current weather conditions are recorded at the top of the Field Form (All).
- Evidence of vandalism is recorded in the Comments section and photo-documented (Stevens).
- Digital photos are taken from fixed photo points and the time for each photo is recorded (Stevens).
- Battery voltage is checked and recorded (All).
- Temperature within the monitoring box is measured by a mercury maximum/minimum thermometer and recorded on the Midmonth form (Stevens).
- The site watch date and time, staff gage and base gage values are read and recorded. The real-time values from the data logger for date, time, pressure sensor stage values and barometric pressure are recorded. If any of the pressure sensor stage values need to be reset, they are corrected and documented (Campbell).
- The portable sensors barometric pressure is measured and recorded with the correction for site elevation (Campbell).
- Water temperature is measured and recorded (Campbell).

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- The site watch date and time, staff gage, base gage, are read and recorded on the chart and form. The real-time values from the Stevens GS-98 data logger for date, time and stage value are recorded. The Stevens A-71 chart record is documented accordingly. If any of the recorders need to be reset, they are corrected and documented. The chart paper is checked so that an adequate supply remains until the end of the month. Chart pens are replaced as needed (Stevens).

Death Valley National Park Processing and Archiving of Data

Data verification and validation

Electronic data collected at Devils Hole is formatted by DEVA field personnel and sent via e-mail to the WRB for data processing and evaluation. Hard copies of the original chart and forms are sent through the United States Postal Service to WRB. Copies of all forms and charts are maintained in the DEVA Hydrology Department. Copies of electronic data are maintained on the DEVA Resources share drive. Photographs are electronically archived by date and time to a Devils Hole share drive at DEVA.

Electronic data recovered from the Stevens GS-98 data logger in ”txt” format is transferred from the In-Situ Rugged Reader® Pocket PC to a DEVA system computer via Microsoft ActiveSync software. The data is converted to the appropriate column format using Stevens Axread30 utility software with a “raw” extension. The “raw” output file is viewed with Windows Notebook or imported into an Windows Excel spreadsheet for completeness.

Electronic data from the Campbell Scientific data logger is saved as a “dat” file. The file is reviewed for the complete download record using the Campbell Scientific LoggerNet software. If data is missing, duplicate data from the SM4M storage module can be downloaded and used to secure a complete data record. All the electronic data is forwarded to WRB by email.

DEVA Hydrology personnel import the Stevens .raw file into an Excel spreadsheet. A chart is created showing the water levels during the month. The average water level is calculated for the month. That value is added to an ongoing Mean Gage Height spreadsheet. This data is available through the DEVA Hydrology Department.

Water Rights Branch Processing of Data and Archiving of Data

Levels

The various instruments at a Devils Hole are set to register the altitude of a water surface at a selected level reference surface called the gage datum. The gage’s supporting structures, such as stilling wells or backings, tend to settle or rise as a result of earth movement, static or dynamic loads, vibration, or floodwaters and flood-borne debris. Vertical movement of a structure makes the attached gages read too high or too low and, if the errors go undetected, may lead to increased uncertainties in water level records. Leveling, a procedure by which surveying instruments are used to determine the differences in altitude between points, is used to set the gages and to check them from time to time for vertical movement (Kennedy, 1990, p. 1). Levels

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are run periodically to all benchmarks, reference marks, reference points, and gages to determine if any datum changes have occurred (Rantz and others, 1982, p. 545).

Errors in gage-height data caused by vertical changes in the gage or gage-supporting structure can be measured by running levels. Gages can be reset or gage readings can be adjusted by applying corrections based on levels (Kennedy, 1983, p. 6).

Procedures for computing records for each station include adjusting gage-height values based on current level data. Level field notes are checked, which includes insuring the front sheets of the field notes are complete and correct, the information has been listed in the level-summary file, and the station description and gage-height data have been updated accordingly. Appropriate adjustments to the gage-height record are made by applying datum corrections.

Datum corrections are applied to gage-height record in terms of magnitude (in feet) and in terms of when the datum change occurred. In the absence of any evidence indicating exactly when the change occurred, the change is assumed to have occurred gradually from the time the previous levels were run, and the correction is prorated with time (Rantz and others, 1982, p. 545). Datum corrections are applied when the magnitude of the vertical change is greater than 0.015 feet.

Records and Gage Height Corrections

The gage-height record is assembled for the period of analysis in as complete a manner as possible. Periods of inaccurate gage-height data are identified and corrected as appropriate. Items included in the assembly of gage-height record and procedures for processing the data are discussed in Kennedy (1983, p. 6), and Rantz and others (1982, p. 560 and p. 587). All data are entered into the USGS program ADAPS. Raw data are maintained unaltered for future reference on a file on the WRD WRB personal computer (PC) and in ADAPS, a USGS server. Stage data are used for computing water level records and are compared closely with field observations, including observer readings.

Records computation includes examination of gage-height record to determine if the record accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, an inaccurate gage-height record is corrected. All missing gage-height records are documented. Specifically, the period and the reason for the missing record should be listed in the station analysis.

A correction applied to gage-height readings to compensate for differences between the recording gage and the base gage is called a “gage-height correction” (Rantz and others, 1982, p. 563). These corrections are applied in the same manner as datum corrections and use ADAPS. Gage-height corrections are applied so the recorded data are made to agree with base-gage data. These corrections are applied when the difference between the recording gage and the base gage is equal to or greater than 0.015 foot.

Datum corrections and gage-height corrections are entered into ADAPS and are stored as finalized data once reviewed by NPS WRD reviewing processes. Datum corrections and gage-height corrections are documented in the station analysis, and associated graphs and computer

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printouts are included in Devils Hole, Water Year folder as part of the permanent record. This documentation is maintained indefinitely for future reference.

Station Analysis

A complete analysis of data collected, procedures used in processing the data, and the logic upon which the computations were based is documented for each year of record for each station to provide a basis for review and to serve as a reference in case questions arise about the records at some future date (Rantz and others, 1982, p. 580). Topics discussed in detail in the station analysis include, but are not limited to, equipment, hydrologic conditions, gage-height record (including when and why record is missing), datum corrections, rating, discharge, special computations, hydrographic comparison, a listing of ice-affected periods, and remarks concerning the quality of the records

A hard copy of the station analysis is kept in the Water Year folder currently being computed. Included with the hard copy of the station analysis are all graphs, printouts of site inspections, primary computations, computer generated year-end summary, and printouts of the datum and data corrections. The hard copy of the analysis, signed and dated by reviewers, is considered the permanent document for the Water Year folder; the electronic file stored in the word processor is considered the temporary working file.

Daily-Values Table

The daily-values table generated by use of ADAPS represents what discharge values are stored for each day of the water year. The finalized daily values are stored in the standard USGS computer database, ADAPS, for future retrieval and analyses.

Manuscript and DataStore

When records computation for the water year has been completed and finalized, the daily mean water-level data (manuscript) for that water year are posted by personnel on NPS DataStore. Information presented on NPS DataStore are daily discharge values during the year, extremes for the year and period of record, various statistics, station analysis, station description, water year hydrograph and cumulative yearly hydrograph.

Station Descriptions

A station description is prepared and becomes part of the permanent record. Station descriptions are updated once every three years, or more often if any changes in the equipment or gage structure occur. Any updates needed in the station description are made while working the water year record.

Station descriptions are written to include specific types of information in a consistent format (Kennedy, 1983, p. 2). Types of information included in the station description are location, access routes, drainage area, establishment history, cooperator identification, descriptions of equipment and gage structure, information on extremes of stage, datum of gage, elevations of reference marks, and a photocopy of an area map. Also included is other helpful information about observers, and anything that will assist in collection of data under various conditions.

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References

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Wagner, Richard J., H.C. Mattraw, G.F. Fritz, and B.A. Smith. 2000. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting, Techniques and Methods 1-D3, U. S. Geological Survey, Reston, VA.

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Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form – Stevens – Monthly Starting

Names: _____, _____

Weather: _____

Site Watch	**Date (yymmdd):** _____	**Time:** _____(UTC)
Data Logger	**Date (yymmdd):** _____	**Time:** _____(UTC)
Battery	**ID:** _____	**Voltage:** _____(V)

USGS Staff Gage **Stage:** _____ (ft) **Time:** _____ (UTC)

NPS Steel Bolt – Tape Down from Top of Bolt to Water Surface: _____ (ft)

Measuring Device: _____(ex. Steel Tape – Leitz)

Data Logger Stage: _____ (ft)

Chart Recorder Stage: _____ (ft)

Comments: Note discrepancies in time, stage levels, or instrument problems. Include potential / actual problems, actions taken, site conditions, then sign and date.

Measuring Devices

Changes: Yes / No

Stevens Data Logger Serial #

Stevens (A-71) Chart Recorder Serial #

Stevens (A-76) Chart Encoder Serial #

Logger Reset: Yes ☐ No ☐

USGS Staff Gage Stage: (ft) Time: (UTC)

Data Logger Stage: (ft)

Chart Recorder Stage: (ft)

Revised 05/17/02 by Cable and Chatelson See DH Monthly and DH Mid-Month SOPs

Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form – Stevens – Monthly Ending

Names: _____, _____

Weather: _____

Previous Download Date (yymmdd): _____ **Recording Interval:** _____ (min)

Site Watch	**Date** (yymmdd): _____	**Time:** _____(UTC)
Data Logger	**Date** (yymmdd): _____	**Time:** _____(UTC)
Photo Times	**Far:** _____(UTC)	**Near:** _____(UTC)
Battery	**ID:** _____	**Voltage:** _____(V)
Battery Box Temp	**Min:** _____(°F)	**Max:** _____ (°F)

USGS Staff Gage **Stage:** _____ (ft) **Time:** _____ (UTC)

Measuring Device _____ (ex. Steel Tape – Leitz)

Data Logger Stage: _____ (ft)

Chart Recorder Stage: _____ (ft)

Comments: Note discrepancies in time, stage levels, or instrument problems. Include potential / actual problems, actions taken, site conditions, then sign and date.

_____

_____

_____

Measuring Devices

Changes: Yes / No

Stevens CS-98 Data Logger: Serial # _____ / _____

Stevens (A/71) Chart Recorder: Serial # _____ / _____

Stevens (A/71) Chart Encoder: Serial # _____ / _____

Log Start Date: _____ / _____

Data File: **Download Time:** _____ (UTC)

Raw: _____ **Edited:** _____

I certify that the above data files were downloaded from the Data Logger on this date, and that the raw data file is exactly as downloaded.

Signature: _____ **Date:** _____

Revised 03/17/09 C. Gable and G. Nelson See "DH Monthly and DH Mid Month SOPs"

Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form – Stevens – Mid Month

Names: _____, _____

Weather: _____

Site Watch	**Date** (yymmdd): _____	**Time:** _____(UTC)
Data Logger	**Date** (yymmdd): _____	**Time:** _____(UTC)
Photo Times	**Far:** _____(UTC)	**Near:** _____(UTC)
Battery	**ID:** _____	**Voltage:** _____(V)
Battery Box Temp	**Min:** _____(ºF)	**Max:** _____(ºF)

USGS Staff Gage **Stage:** _____ (ft) **Time:** _____ (UTC)

NPS Steel Bolt – Tape Down from Top of Bolt to Water Surface: _____ (ft)

Measuring Device: _____(ex. Steel Tape – Leitz)

Data Logger Stage: _____ (ft)

Chart Recorder Stage: _____ (ft)

Comments: Note discrepancies in time, stage levels, or instrument problems. Include potential / actual problems, actions taken, site conditions, then sign and date.

_____

_____

_____

Measuring Devices

Changes: Yes / No

Stevens GS-98 Data Logger : Serial #_____ ____ / ____

(A/71) Chart Recorder: Serial #_____ ____ / ____

(A/71) Chart Encoder: Serial #_____ ____ / ____

Reset **Yes** ☐ **No** ☐

taff Gage **Stage:** _____ (ft) **Time:** _____ (UTC)

gger Stage: _____ (ft)

ecorder Stage: _____ (ft)

/17/09 C. Gable and G. Nelson See "DH Monthly and DH Mid Month SOPs" Revised 03

Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form - Campbell – Monthly Starting

Names: _____, _____

Weather: _____

Site Watch **Date** (yymmdd): _____ **Julian Date**_____ **Time:** _____(UTC)

Data Logger **Date** (yymmdd): _____ **Time:** _____(UTC)

Battery **ID:** _____ **Voltage:** _____(V)

Water Temperature **Location:** SE stilling well **Depth:** 0.2 ft **Temp:** _____(ºC)

Location: SE stilling well **Depth:** 2.0 ft **Temp:** _____(ºC)

Handheld Barometer (ATM) _____(hPa) – **Offset @ 2360 ft (site elevation) 83.48** hPa =

Corrected (ATM – Offset) _____(hPa)

USGS Staff Gage **Stage:** _____(ft) **Time:** _____(UTC)

USGS Staff Gage (Calibration Reading) Stage: _____(ft) **Time:** _____(UTC)

Campbell Data Logger (LoggerNet Software)

Initial Time:	_____*(UTC)*	***Calibration Time:***	_____*(UTC)*
ISTAGE-EP Stage:	_____(ft)	**ISTAGE-EP Stage:**	_____(ft)
DRK10 Stage:	_____(ft)	**EP_OFFSET:**	_____(ft)
EP_OFFSET:	_____(ft)	**DRK10_Stage:**	_____(ft)
EP_SLOPE:	_____(ft)	**DRK10_OFS:**	_____(ft)
DRK10_OFS:	_____(ft)		
DRK10_SLP:	_____(ft)	**ISTAGE-EP Reset?**	Yes / No (circle)
CR10_VOLT:	_____(V)	**DRK10 Reset?**	Yes / No (circle)
LOGR_TEMP:	_____(ºC)		
P_hPa:	_____(hPa- Barometer)		

[redacted]

Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form - Campbell – Monthly Ending

Names: _____, _____

Weather: _____

Data Logger: Date (yyyymmdd): Time: (UTC)

Battery: ID: Voltage: (V)

Water Temperature: Location: SE Stilling well Depth: 0.2 ft Temp: (°C)

Location: SE Stilling well Depth: 2.0 ft Temp: (°C)

Handheld Barometer (ATM) (hPa) Offset @ 2360 ft (site elevation) 83.48 hPa:

Corrected (ATM – Offset) (hPa)

USGS Staff Gage: Stage: (ft) Time: (UTC)

Campbell Data Logger (LoggerNet Software)

Initial Time: (UTC) CR10_VOLT: (V)

ISTAGE_EP Stage: (ft) LOGR_TEMP: (°C)

DRK10 Stage: (ft) P_hPa: (hPa Barometer)

EP_OFFSET: (ft)

EP_SLOPE: (ft)

DRK10_OFS: (ft)

DRK10_SLP: (ft)

Measuring Devices Changes: Yes / No

Campbell Scientific CR10 Logger: Serial #:

Campbell Scientific CS105 Barometer: Serial #:

Pressure Sensors: Druck PTX630: Serial #:

Instrumentation Northwest BS910b: Serial #:

Thomas Scientific Handheld Barometer: Serial #:

Fisher Scientific Digital Thermometer: Serial #:

Comments: Note discrepancies in time, stage levels, or instrument problems. Include potential causes, problems, actions taken, site conditions, then sign and date.

Log Start Date: /

Download: Download Time: (UTC)

RAW: Edited:

I certify that the above data files were downloaded from the Data logger on this date, and that the raw data file is readily undownloadable.

Signature: Date:

Key entry date: Calc and Check: See initials and DYYYYMMDD stamp

Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form - Campbell – Mid-Month

Names: _____, _____

Weather: _____

Site Watch **Date** (yymmdd): _____ **Julian Date** _____ **Time:** _____(UTC)

Data Logger **Date** (yymmdd): _____ **Time:** _____(UTC)

Battery **ID:** _____ **Voltage:** _____(V)

Water Temperature **Location:** SE stilling well **Depth:** 0.2 ft **Temp:** _____(ºC)

Location: SE stilling well **Depth:** 2.0 ft **Temp:** _____(ºC)

Handheld Barometer (ATM) _____(hPa) – **Offset** @ 2360 ft (site elevation) **83.48** hPa =

Corrected (ATM – Offset) _____(hPa)

USGS Staff Gage **Stage:** _____(ft) **Time:** _____(UTC)

USGS Staff Gage (Calibration Reading) Stage: _____(ft) **Time:** _____(UTC)

Campbell Data Logger (LoggerNet Software)

Initial Time: _____*(UTC)*	***Calibration Time:*** _____*(UTC)*
ISTAGE-EP Stage: _____(ft)	**ISTAGE-EP Stage:** _____(ft)
DRK10 Stage: _____(ft)	**EP_OFFSET:** _____(ft)
EP_OFFSET: _____(ft)	**DRK10_Stage:** _____(ft)
EP_SLOPE: _____(ft)	**DRK10_OFS:** _____(ft)
DRK10_OFS: _____(ft)	
DRK10_SLP: _____(ft)	**ISTAGE-EP Reset?** Yes / No (circle)
CR10_VOLT: _____(V)	**DRK10 Reset?** Yes / No (circle)

LOGR_TEMP: _____(ºC)

Desiccant changed? Change if purple or pink (Circle)

ISTAGE-EP Yes / No **DRK10** Yes / No **Logger Box** Yes / No

Measuring Devices Changes: Yes / No

Campbell Scientific CR10 Logger: Serial #

Campbell Scientific CS105 Barometer: Serial #

Pressure Sensors: Druck 1830 – Serial #

Instrumentation Northwest PS9105 Serial #

Thomas Scientific Handheld Barometer: Serial #

Fisher Scientific Digital Thermometer: Serial #

Comments: Note discrepancies in time, stage levels, or instrument problems. Include potential / actual problems, actions taken, site conditions, then sign and date.

SOPs: Revised 01/17/09 C Gable and G Nelson See DH Monthly and DH Mid Month

Death Valley National Park –Devils Hole **Site ID 3625232116172701**

Site Visitation Form - Campbell – Random

Names: _____, _____

Weather: _____

Site Watch **Date** (yymmdd): _____ **Julian Date** _____ **Time:** _____(UTC

Data Logger **Date** (yymmdd): _____ **Time:** _____(UTC)

Battery **ID:** _____ **Voltage:** _____(V)

Water Temperature **Location:** SE stilling well **Depth:** 0.2 ft **Temp:** _____(ºC)

Location: SE stilling well **Depth:** 2.0 ft **Temp:** _____(ºC)

Handheld Barometer (ATM) _____(hPa) – **Offset** @ 2360 ft (site elevation) **83.48** hPa =

Corrected (ATM – Offset) _____(hPa)

USGS Staff Gage **Stage:** _____(ft) **Time:** _____(UTC)

USGS Staff Gage (Calibration Reading) Stage: _____(ft) **Time:** _____(UTC)

Campbell Data Logger (LoggerNet Software)

Initial Time: _____*(UTC)*

ISTAGE-EP Stage: _____(ft)

Calibration Time: _____*(UTC)*

ISTAGE-EP Stage: _____(ft)

DRK10 Stage: _____(ft)

EP_OFFSET: _____(ft)

EP_SLOPE: _____(ft)

DRK10_OFS: _____(ft)

EP_OFFSET: _____(ft)

DRK10_Stage: _____(ft)

DRK10_OFS: _____(ft)

Reset? Yes / No (circle)

Reset? Yes / No (circle)

DRK10_SLP: _____(ft)

CR10_VOLT: _____(V)

LOGR_TEMP: _____(ºC)

P_hPa: _____(hPa- Barometer)

ISTAGE-EP R

DRK10 R

Yes / No

Changes: Yes / No

/

/

/

/

/

/

potential / actual

Desiccant changed? Change if purple or pink (Circle)

ISTAGE-EP: **Yes / No** **DRK10 Yes / No** **Logger Box**

Measuring Devices

Campbell Scientific CR10 Logger: Serial #

Campbell Scientific CS105 Barometer: Serial #

Pressure Sensors: Druck 1830 – Serial #

Instrumentation Northwest PS9105 – Serial #

Thomas Scientific Handheld Barometer: Serial #

Fisher Scientific Digital Thermometer: – Serial #

Comments: Note discrepancies in time, stage levels, or instrument problems. Include problems, actions taken, site conditions, then sign and date.

Monthly and DH Mid Month SOPs

Revised 03/17/09 C. Gable and G. Nelson

See DH M

Death Valley National Park –Devils Hole	**Site ID 3625232116172701**

[redacted]

Devils Hole Ecosystem Monitoring Protocol

SOP IV – Substrate

Kevin P. Wilson[1] and Dean W. Blinn[2]

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2 – Regent's Professor Emeritus Northern Arizona University: deandiacad@comcast.net

Version 1.0 (XX/XX/XXXX)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

DRAFT

Introduction

This SOP describes the protocol to monitor substrate composition. The shallow shelf of Devils Hole is susceptible to disturbance from two main sources, precipitation leading to flooding and earthquakes creating earthquake-induced waves. These two types of disturbance may add or remove sediment to/from the shallow shelf. Sediment composition also changes by the continuous input of rocks falling onto the shelf through gravity. Substrate size can influence the abundance and composition of macroinvertebrates (Herbst and Blinn 2003) and spawning behavior of pupfish (Gustafson and Deacon 1998).

Survey frequency

Annual (December/January) and following a major storm and/or tectonic disturbance.

Field methods

1. If the transect tape is in place along the east wall skip to step number three. If it is not proceed to number two.

2. Establish a transect (meter tape) along a south- north orientation of the east wall over the 5.75 m shallow shelf with the USGS brass cap labeled RM1 being point zero. Point zero needs to be along the east wall which is located 1.43 m east of the brass cap.

3. Along the south-north transect, establish 22 east-west transects at 25 cm intervals with the first transect starting at 0.50 m (northing) from the brass cap.

4. A measurement should also be taken to indicate the east endpoint of each transect located at the water's surface keeping in mind that this point can be either positive, negative, or

zero depending on whether the east endpoint of the transect is east of the tape (negative), west of the tape (positive) or directly under the tape (zero).

5. Next, record the total wetted width at the water's surface of the transect, i.e. east water's edge to west water's edge remembering that at times the rocks/walls are undercut and that the measurement is to be made at the water's surface.

6. Divide each east-west transect into 10 evenly spaced points. Therefore, a point coordinate location for any collection will consist of two readings. The first reading represents a location along the south- north transect (in meters) and the second represents a location along the east-west transect (in meters) either positive or negative in relation to the north-south meter tape.

7. Using a meter stick, at each coordinate location (n = 220), record water depth (cm), substrate type directly under the meter stick into one of the following size classes [fine sand (<1.0 mm), gravel (2-15 mm), pebble (16-60mm) cobble (61-150 mm), bedrock (>151 mm)], and presence or absence of filamentous cyanobacteria, filamentous green algae (*Spirogyra*), and/or mixture of diatoms/*Chroococcus*sp. If necessary use a plastic ruler to determine substrate size. The substrate classification is a modification of data collected by Gustafson and Deacon (1998) and Bain (1999).

Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to follow the procedures listed below.

Field and laboratory datasheets:

- Each field datasheet needs to be quality controlled for completeness by two crew members prior to leaving Devils Hole. Double check coordinates for each substrate location and that the presence or absence of benthic covering has been documented.
- Upon return to the office each datasheet needs to scanned and placed into the appropriate folder on the Pahrump server. Originals need to be filed in the designated Devils Hole filing cabinet.

Data entry:

- Use the MS Access database developed for the monitoring plan to enter data (this database is still under design).
- To reduce data entry errors database programming will be maximized to control data entry. This will be achieved via the use of constraints such as valid ranges for each coordinate direction and depth (area of shallow shelf and maximum possible depths are known).

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- After completing data entry all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data verification:

- Each data point entered into the database needs to be checked against the original field and laboratory datasheets. If errors are found corrections need to be made to all pertinent database forms.
    - Procedure:
        - Print dataset and compare each point with datasheets.
        - Correct any errors.
        - If an error or errors are found recheck 100% of records for the specific sampling period for accuracy.

Data validation:

- Once data has been verified percent substrate needs to be calculated.
    - Procedure
        - Sum the total number of points for each size class.
        - Divide the total number of each size class by the total number of points (n=220).
- Validate percent composition by adding each substrate size class. This should equal 100%.
- Annually the project manager will randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.

Metadata procedures

- Generate metadata records using the NPS Metadata Tools and Editor Metadata then follow the Federal Geographic Data Committee (FGDC) standards and include biological profile elements that allow integration of the metadata record with the NPS I&M NPSpecies and NatureBib online databases.
- A detailed procedure will be included in the next version.

Data archiving:

- After metadata has been generated upload data to the Pahrump server.

References

Bain, M.B. 1999. Substrate. Pages 95-104. *In* Common Habitat Assessment: Common Methods. M.B. Bain and N.J. Stevenson eds. American Fisheries Society, Bethesda, Maryland.

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Gustafson, E.S. and J.E. Deacon. 1998. Distribution of larval Devils Hole Pupfish, *Cyprinodon diabolis* Wales, in relation to dissolved oxygen concentration in Devils Hole. Final Report, Death Valley National Park, April 1, 1998.

Herbst, D.B. and D.W. Blinn. 2003. Devils Hole benthic invertebrate community dynamics: distribution, seasonality and production. Final Report provided to Death Valley National Park. Resource Management Office, Death Valley National Park, CA. 32 pp.

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Devils Hole Substrate Survey Field Data Sheet

DATE: _____ TIME: _____ INVESTIGATORS: _____ Page ____ of ____

Eastern most endpoint of E-W transect:_____ S-N coordinate:_____ Wetted width of transect:_____

Transect Number	Water Depth (cm)	Fine sand (<1 mm)	Gravel (2-15 mm)	Pebble (16-60 mm)	Cobble (61-150 mm)	Bedrock (>151 mm)

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Devils Hole Ecosystem Monitoring Protocol

SOP V – Algae, Protozoa and Invertebrates

Kevin P. Wilson[1] and Dean W. Blinn[2]

1 - Death Valley National Park: Kevin_Wilson@nps.gov
2 – Regent's Professor Emeritus Northern Arizona University: deandiacad@comcast.net

Version 1.0 (XX/XX/XXXX)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

DRAFT

Introduction

This SOP describes protocols to monitor algae, protozoa and invertebrates in Devils Hole. Monitoring protocols for the following habitats will be described: 1) benthic sampling on the shallow shelf, 2) Protozoa (ciliate) sampling within the interstitial pore-water space on the shallow shelf, 3) meiofauna sampling within the interstices of the shallow shelf 4) plankton sampling of the water column between the 5 m shelf and the shallow shelf, 5) neuston sampling over the shallow shelf, and 6) *Dugesia dorotocephala* (flatworm) sampling on the shallow shelf.

Sampling frequency

Protozoa sampling: seasonal (February, April, August, and October).
Meiofauna sampling: seasonal (February, April, August, and October).
Benthic sampling: bimonthly (February, April, June, August, October, and December).
Plankton sampling: seasonal (February, April, August, and October).
Neuston sampling: seasonal (February, April, August, and October).
Dugesia dorotocephala sampling: seasonal (February, April, August, and October).

Voucher samples

Make sure to prepare seasonal vouchers for benthic, neuston and phytoplankton and any newly encountered invertebrates. Annual vouchers must be retained for all macroinvertebrates and meiofauna.

Field methods

Protozoa (Ciliate) sampling

1. Randomly collect nine (9) pore-water samples from the interstices of the shallow shelf.

2. Use a Luer-Lok™ stainless steel hypodermic needle (9 cm length) attached to a 30 ml capacity syringe to collect pore-water. Place the needle perpendicular to the substrate and insert into the interstices to a depth of 5 cm (depth may change after initial sampling). Slowly extract a 25 ml volume (volume may also change depending on ciliate densities).

3. Gently dispense sample into a pre-labeled vial (30 ml minimum capacity) and preserve with mercuric chloride ($HgCl_2$) to a final concentration of 2.5% (Sime-Ngando & Groliere, 1991). Preservative must be added to each sample at the parking lot. DO NOT bring the preservative into Devils Hole. Typically this requires only 1-2 drops of $HgCl_2$ from an eye dropper.

4. Rinse syringe and needle between samples with distilled water.

5. Take a coordinate and water depth, and note substrate type and algae cover at each sampling site.

6. Store samples out of the sun and bring back to the laboratory for processing.

Meiofauna sampling

1. Randomly collect 9 meiofauna samples from the shallow shelf. If a sample falls on bedrock (>151 mm) select another random location.

2. Place a 5 X 5 cm template over each randomly selected collection point. Use a turkey-baster to siphon material from within the template area to a depth of 5 cm. Make a note on the field data sheet if the baster depth is different then 5 cm. The goal is to sample the surface area of a cube (5 x 5 x 5 cm).

3. Place material into a pre-labeled sample bottle and preserve with 95% ethanol.

.

4. Keep samples out of the sun and return to the laboratory for processing.

Benthic sampling

1. Systematically collect 16 benthic samples from coordinate points on the established transects based on the stratified substrate data (see SOP IV). Collections should be representative of the composition of the substrate on the shallow shelf.

2. Place a 10-cm diameter (0.0078 m^2 area), cylindrical stove pipe over each collection

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point. Two 30-cm sections of stove pipe may be employed, so the sampler can be extended to 60 cm for deeper collections. Note: the bottom edge of the first stove pipe needs to be covered with foam weather stripping. This will create a seal between the substrate and the stove pipe.

3. Use a stiff-bristled brush (plastic) to disturb and thoroughly clean the substrates contained within the stove pipe. Collect all suspended materials within the stovepipe, including suspended sediments, with a turkey baster and place all material into a metal pan. When the baster does not contain any material (water is clear), slowly remove the stove pipe to reduce disturbance.

5. Visually inspect sampling area to be sure all material from the substrate has been collected. It may be necessary to pour off excess water from the metal pan through a 243 µm mesh net so each sample will fit into a properly labeled bag.

6. Take a coordinate and water depth (cm) reading at each collection site.

7. Store samples on ice in the dark and transport to the DEVA Aquatic Ecology Laboratory for sorting.

Plankton sampling

1. Phytoplankton tows:

   a.) Collect triplicate phytoplankton tows with a 20 cm diameter net with a mesh size of 53 µm.

   b.) Lower the net to a depth of 4.5 m, slowly pull the net up making sure not to capture any pupfish. When the net reaches the water surface pull the opening just above the water surface, examine the net for fish keeping a close eye for small pupfish larvae. If fish present, release and start over. If no fish are present, gently rinse material down the net and into the collection bottle.

   c.) Remove the collection bottle from the net and examine for fish, if present empty sample and start over. If no fish are present, pour contents into sample bottle.

   d.) After three samples are collected immediately preserve in acid-Lugol's solution up at the parking lot. DO NOT bring acid into Devils Hole.

2. Zooplankton tows:

   a.) Collect triplicate zooplankton samples with a 30 cm diameter net with a mesh size of 243 µm.

   b.) Follow steps (b) through (d) under phytoplankton.

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Neuston sampling

1. Haphazardly collect 8 neuston samples that are floating over the shallow shelf. Collect samples using a 10 cm diameter, 3 cm high PVC pipe that has 53 µm mesh hose tied to one opening.

2. Gently place the sampling device under the neuston layer to be collected. Make sure not to create bubbles or waves from the device that would disturb the sample. With the mesh end down quickly lift the sampling device to capture the floating neuston within the area of the sampler. Place sample into a properly labeled bag.

4. Take a coordinate reading at each collection site.

3. Store samples on ice in the dark and transport to DEVA Aquatic Ecology Laboratory for processing.

Dugesia dorotocephala *sampling*

1. Due to the nocturnal behavior of *Dugesia*, estimates should be conducted 1-2 h after sunset as outlined by Wilson and Blinn (2001).

2. Divide the shallow shelf into three equal areas (area 1= 0 to 2 m, area 2= 2 to 4 m, and area 3= 4 to 6 m) along a south-north orientation. Haphazardly place a 20 x 20 cm template on the shallow shelf at ten coordinate locations in each of the three areas to estimate densities.

3. At each sampling site record location (coordinate), flatworm abundance, substrate type, and depth.

Sample sizes

- Sample sizes for benthic, neuston, plankton, and *Dugesia* collections are based on Wilson and Blinn (2001). Sample sizes for meiofauna and Protozoa are based on literature and are subject to change after monitoring has been initiated for one year.

Laboratory methods

Protozoa (Ciliate) processing

1. Determine ciliate densities from each collection using a Sedgwick-Rafter counting cell under a compound microscope (200X). If ciliate densities are low, samples may need to be processed using an inverted microscope at another facility (DRI Las Vegas). Larger sample volumes can be processed using an Utermöhl chamber (10 ml).

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2. Using the Sedgwick-Rafter counting cell: swirl the sample vial prior to taking a 1 ml sample using a Pasteur pipette. Dispense volume into counting cell that already has a cover slip placed diagonally over it.

3. A minimum of five replicate 1 ml samples should be processed. This will be dependent on total ciliate density. Typically with a count of 400 units, the error limits are about 10%. This is only if the distribution of organisms is random and the population fits a Poisson distribution; if this is the case, the counting error may be estimated (Standard Methods). However, these densities may not be reached in Devils Hole.

4. A digital photograph should be taken of each new species encountered during processing. Drawing of different ciliates should also be done on Laboratory data sheets.

Meiofauna processing

1. Pour the preserved sample through a 243 µm mesh net and rinse thoroughly with distilled water. Make sure all material has been washed down to the center of the net and then invert and rinse sample into a small beaker for sorting.

2. Use a modified Bogarov counting chamber to sort meiofauna samples. Sort samples into the following categories: Nematoda, Copepoda (Cyclopoida, Harpacticoida or Calanoida), Oligochaeta, Ostracoda, Diptera, and "other". Place each organism from a single sample into a labeled vial with 70% ethanol.

3. After each tray has been sorted pour material into a "sorted" beaker. When sample is finished, screen material through a 243 µm mesh and place material into a pre-weighed crucible. Oven-dry (60°C) crucibles to a constant weight and combust dried samples at 500º C for 1 h in a muffle furnace for ash-free dry mass determinations (AFDM; Clesceri et al. 1998).

Benthic and Neuston processing

1. Sorting should be completed within 72 h. Sort each sample under a dissecting microscope (10X) into the following categories: allochthonous plants (>0.2 cm), allochthonous animals, filamentous cyanobacteria (*Oscillatoria*, *Plectonema*), filamentous green algae (*Spirogyra*), diatoms/*Chroococcus*/fine detritus (particles <0.2 cm), snails (*Tryonia*), amphipods (*Hyalella*), adult and juvenile beetles (*Stenelmis* and *Neoclypeodytes*), and an "other" category that contains additional invertebrates (see data sheet#). Each invertebrate category also needs to be enumerated. Investigators should note and identify any species within the "other" category that exceeds 5% of the total invertebrate density. A sample of each "other category" should be stored in a reference vial in 70% ethanol.

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2. Place material from each category into a pre-weighed crucible for AFDM determinations as explained under meiofauna processing.

Phytoplankton processing

1. Determine composition and density of phytoplankton using a Sedgwick-Rafter counting cell at 400X.

2. Place a Sedgwick-rafter cover slip diagonally over the counting cell. This is done prior to dispensing of subsample in order for the counting cell to hold 1 ml.

3. Remove a 1 ml aliquot from a well mixed sample using a Pasteur pipette. Dispense the aliquot into the Sedgwick-Rafter counting cell. The cover slip should automatically move and cover the counting cell. Make sure there are no air bubbles. If present start over.

4. Due to the low abundance of phytoplankton, five replicate subsamples need to be processed for each sample. The entire area of the Sedgwick-Rafter needs to be scanned.

Zooplankton processing

1. Determine composition and density of zooplankton using a modified Bogarov counting chamber.

2. Prior to sorting samples need to be rinsed through a 243 µm mesh net to remove the acid-Lugol's preservative. When using a net make sure it is completely rinsed into a sorting beaker. This will reduce the chance of losing zooplankton.

3. Proper use of a mesh net. Gently pour entire sample into the net. Next, rinse the inside of the sample bottle with a squirt bottle filled with distilled water. Use the squirt bottle to rinse the sides of the net so all of the material reaches the bottom or center of the net. Carefully invert the net and rinse all material into a small beaker for sorting.

4. Proper use of a modified Bogarov counting chamber. Use a disposable plastic pipette to transfer sample material from the beaker to the counting chamber. Fill the chamber canals to just below the top. You are now ready to sort.

5. Completely sort each sample using a dissecting microscope at 10X into the following categories: *Hyalella* (amphipod), copepods (Cyclopoida, Harpacticoida, or Calanoida), and "others". Keep track of what the "other" category consists of. Sort each category into plastic vials containing 70% ethanol.

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Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to follow the procedures listed below.

Field and laboratory datasheets:

- Each field datasheet needs to be checked for completeness by two crew members prior to leaving Devils Hole. Double check coordinates for each substrate location and that the presence or absence of benthic covering has been documented.
- Upon return to the office each datasheet needs to scanned and placed into the appropriate folder on the Pahrump server. Originals need to be filed in the designated Devils Hole filing cabinet.
- After laboratory processing is complete follow the same procedure as described above for field datasheets.
- After completing a sampling event (each protocol described above), all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data entry:

- Use the MS Access database developed for the monitoring plan to enter data (this database is still under design).
- To reduce data entry errors database programming will be maximized to control data entry. This will be achieved via the use of lookup tables, and/or field-type design in the database (e.g. yes/no field types, input masks), and constraints such as valid ranges, uniqueness, referential integrity, and nullity.
- After completing data entry all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data verification:

- Each data point entered into the database needs to be checked against the original field and laboratory datasheets. If errors are found corrections need to be made to all pertinent database forms.
    - Procedure:
        - Print dataset and compare each point with datasheets.
        - Correct any errors.
        - If an error or errors are found recheck 100% of records for the specific sampling period for accuracy.

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Data validation:

- Each data set needs be visually inspected by plotting each data point as a scatter plot and by running queries to capture missing data, out-of-range values, logical data, and violations of pre-defined data rules.
- Datasets must be examined for "logical" data. Data entry may be correct, but not logical. An example would be having a high biomass of algae in winter, where it should be another category such as allochthonous plants. Data was entered into the wrong place during processing in the laboratory.
- If errors are found the entire data set needs to be verified again.
- Annually the project manager will randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.

Metadata procedures

- Generate metadata records using the NPS Metadata Tools and Editor Metadata then follow the Federal Geographic Data Committee (FGDC) standards and include biological profile elements that allow integration of the metadata record with the NPS I&M NPSpecies and NatureBib online databases.
- A detailed procedure will be included in the next version.

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Devils Hole Protozoa (Ciliate) Field Data Sheet

Collection date:_____

Time of collection:_____ Investigator(s):_____

Sample#	Coordinate (S-N, E-W)	Water Depth (cm)	Algae Cover[1]	Needle Depth[2] (cm)	Vol. Sample[3] (ml)
1					
2					
3					
4					
5					
6					
7					
8					
9					

[1]Algae cover consists of: FC (filamentous cyanobacteria), FS (filamentous *Spirogyra*), DC (diatom/*Chroococcus* matrix), or NC (no cover).
[2]Initial penetration depth of needle has been set at 5 cm.
[3]Initial volume of sample has been set at 25 ml.

Comments:_____
_____
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Devils Hole Meiofauna Field Data Sheet

Date collected:_____

Time of collection:_____ Investigator(s):_____

Sample#	Coordinate (S-N, E-W)	Water Depth (cm)	Algae Cover[1]	Depth of Sample[2] (cm)	Substrate[3]
1					
2					
3					
4					
5					
6					
7					
8					
9					

[1]Algae cover consists of: FC (filamentous cyanobacteria), FS (filamentous *Spirogyra*), DC (diatom/*Chroococcus* matrix), or NC (no cover).
[2]Initial penetration depth of the baster has been set at 5 cm, make a note if different.
[3]Substrate choices: fines (<1 mm), sand/gravel (1-60 mm), or cobble (60-150 mm). If random sample falls on bedrock (>160 mm) select another random location.

Comments:_____
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Devils Hole Benthic Field Data Sheet

Collection date:_____Investigators:_____

Substrate*	Sample #	Coordinate (m) (S-N, E-W)	Depth (cm)	Time	Stage

*Substrate composition as determined on 20 June 2008 stratifies the sampling as follows: FINES= 2, SAND/GRAVEL= 6, COBBLE= 4 and BEDROCK= 4 samples (n= 16 in total).

Comments:_____
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Devils Hole Neuston Field Data Sheet

Collection date:_____Investigators:_____

Sample #	Coordinate (m) (S-N, E-W)	Time	Stage
1			
2			
3			
4			
5			
6			
7			
8			

Comments:_____
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Devils Hole *Dugesia* Field Data Sheet

Date:_____ Time:_____

Investigator(s):_____

Area[1] 1, 2, or 3	Collection Number	Coordinates	Substrate	Depth (m)	Density of *Dugesia*
1	1				
1	2				
1	3				
1	4				
1	5				
1	6				
1	7				
1	8				
1	9				
1	10				
2	1				
2	2				
2	3				
2	4				
2	5				
2	6				
2	7				
2	8				
2	9				
2	10				
3	1				
3	2				
3	3				
3	4				
3	5				
3	6				
3	7				
3	8				
3	9				
3	10				

[1]The shallow shelf is divided into three equal regions: area 1= 0 to 2 m, area 2= 2 to 4 m, and area 3= 4 to 6 m. Ten samples are collected from each region.

Comments:_____

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Devils Hole Meiofauna Laboratory Data Sheet

Date collected:_____ Date processed:_____
NPS Accession#:_____

Time of collection:_____ Investigator(s):_____

Category	Density	Total Density	Drawing
Nematoda			
Oligochaeta			
Cyclopoida			
Harpacticoida			
Calanoida			
Ostracoda			
Chironomidae			
Ceratopogonidae			
Other*			
Benthic** Macroinvertebrates			

*Other category= unknown specimens, but meiofauna.
**Benthic macroinvertebrates consist of *Hyalella*, *Tryonia*, *Stenelmis*, *Neoclypeodytes*, and *Dugesia*.
Comments:_____
_____

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Devils Hole Benthic/Neuston Laboratory Data Sheet

Date collected:_____ Date processed:_____ NPS Accession#:_____

Investigator:_____ Sample #:_____ Substrate:_____

Category	Crucible #	Density	Dry wt.	AFDM
Cat #1 Alloch. Plants				
Cat #2 Alloch. Animals				
Cat #3 Cyanobacteria				
Cat #4 *Spirogyra*				
Cat #5 Diatom/detritus				
Cat #6 *Tryonia*		Full: _____ Empty:		
Cat #7 *Hyalella*		_____ #Pregnant:		
Cat #8 *Stenelmis* Adult				
Cat #9 *Stenelmis* Juvenile				
Cat #10 *Neoclypeodytes* Adult				
Cat #11 *Neoclypeodytes* Juvenile				
Cat #12 *Dugesia*				
Cat #13 Other inverts*				

*Other invertebrates may include: Oligocheata, Annelida, Ostracoda, Hemiptera (Veliidae), Diptera (Chironomidae or Ceratopogonidae) or undiscovered invertebrates.

Comments:_____

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Devils Hole Phytoplankton Laboratory Data Sheet

Date collected:_____ Date processed:_____ Page___ of___
Investigator:_____ Sample #:_____Replicate #:_____
NPS Accession#:_____

Taxon	Density	Drawing

Comments:_____

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Devils Hole Zooplankton Laboratory Data Sheet

Date collected:_____ Date Processed:_____

Time of collection:_____ Sample #:_____ Page____ of____

Taxon	Density*	Total Density	Drawing
Hyalella			
Cyclopoida			
Harpacticoida			
Calanoida			
Other**			

*Density of each taxa is sorted into a vial with 70% ethanol.
**Other taxa need to be listed in the comments section (animal only).

Comments:_____
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Devils Hole Ecosystem Monitoring Protocol

SOP VI – Allochthonous Carbon

Kevin P. Wilson[1] and Dean W. Blinn[2]

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Version 1.0 (XX/XX/XXXX)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

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Introduction

This SOP describes the protocol to monitor allochthonous material that enters Devils Hole near the water surface. Allochthonous (terrestrial) carbon has been shown to be an important energy source and a seasonal linkage in the food web of Devils Hole (Wilson and Blinn 2007).

Sampling frequency

Biannual sampling of allocthonous material will be collected for the entire month of June and December.

Field methods

Deployment of funnels:

1. Deploy rope across the water surface by attaching a pulley to the pieces of metal exposed on the top of the large rocks on the north and south end of the waters surface. A rope should be placed through the north pulley first and then brought back to the southern end. Attach the rope so that it moves freely through the pulleys. This will allow each funnel to be deployed and retrieved at the end of the sampling period.

2. Use vinyl tape to secure Whirl-Pak® bags (16 oz) to the narrow opening at the base of each funnel (four in total). Suspend each funnel (31.5-cm diameter opening) over the water surface at the following locations (See Fig 5):

   Trap 1: centered over the shallow shelf
   Trap 2: centered over the shallow shelf 2 m from the drop-off into the deep pool
   Trap 3: centered over the shallow shelf and the deep pool
   Trap 4: centered over the deep pool

Retrieval of funnels:

1. At the end of each collection, gently pull the rope until you reach the first funnel.

2. Examine the interior of the funnel. If any material is stuck to the sides of the funnel gently push the material down through the tip and into the collection bag.

3. Gently remove bag from funnel by removing the vinyl tape. Be sure not to rip the bag, place sample bag into a new 16 oz Whirl-Pak®, and then place in a cooler to be brought back to the DEVA Aquatic Ecology Laboratory for processing.

Laboratory methods

1. Use a dissecting microscope at 10X to sort each sample into the following categories: sand/gravel, detritus including a mixture of terrestrial plants and animals <0.2 cm, allochthonous plants (terrestrial plants >0.2 cm) and the terrestrial insect categories of bees, moths and butterflies, dipterans, beetles, and miscellaneous insects (see data sheet#).

2. Place material from each category into pre-weighed crucibles and oven-dry at 60ºC to a constant weight.

3. Combust material at 500ºC for one hour in order to determine ash-free dry mass (AFDM). Report rate of allochthonous input as (g AFDM/m^2/day).

4. It is strongly recommended that bags be collected and changed immediately after a rainfall event.

Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to follow the procedures listed below.

Field and laboratory datasheets:

- Each field datasheet needs to be quality controlled for completeness by two crew members prior to leaving Devils Hole. Double check coordinates for each substrate location and that the presence or absence of benthic covering has been documented.
- Upon return to the office each datasheet needs to scanned and placed into the appropriate folder on the Pahrump server. Originals need to be filed in the designated Devils Hole filing cabinet.

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- After laboratory processing is complete follow the same procedure as described above for field datasheets.
- After completing a sampling event (each protocol described above), all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data entry:

- Use the MS Access database developed for the monitoring plan to enter data (this database is still under design).
- To reduce data entry errors database programming will be maximized to control data entry. This will be achieved via the use of lookup tables, and/or field-type design in the database (e.g. yes/no field types, input masks), and constraints such as valid ranges, uniqueness, referential integrity, and nullity.
- After completing data entry all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data verification:

- Each data point entered into the database needs to be checked against the original field and laboratory datasheets. If errors are found corrections need to be made to all pertinent database forms.
    - Procedure:
        - Print dataset and compare each point with datasheets.
        - Correct any errors.
        - If an error or errors are found recheck 100% of records for the specific sampling period for accuracy.

Data validation:

- Each data set needs be visually inspected by plotting each data point as a scatter plot and by running queries to capture missing data, out-of-range values, logical data, and violations of pre-defined data rules.
- Datasets must be examined for “logical” data. Data entry may be correct, but not logical. Data was just entered into the wrong place during processing in the laboratory. An example would be an macroinvertebrate category was greater than the terrestrial plant category.
- If errors are found the entire data set needs to be verified again.
- Annually the project manager will randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.

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Metadata procedures

- Generate metadata records using the NPS Metadata Tools and Editor Metadata then follow the Federal Geographic Data Committee (FGDC) standards and include biological profile elements that allow integration of the metadata record with the NPS I&M NPSpecies and NatureBib online databases.
- A detailed procedure will be included in the next version.

Data archiving:

- After metadata has been generated upload data to the Pahrump server.

References

Wilson, K.P. and D.W. Blinn. 2007. Food web structure, energetics, and importance of allochthonous carbon in a desert cavernous limnocrene: Devils Hole, Nevada. Western North American Naturalist 67:185-198.

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Devils Hole Allochthonous (Funnel Trap) Laboratory Data Sheet

DATE DEPLOYED_____ DATE COLLECTED_____

TIME INTERVAL _____

INVESTIGATORS_____Page _____ of _____

Category	Crucible #	Density	Dry Weight	AFDM[1]
Sand/Gravel				
Detritus (<2 mm)				
Allochthonous Plants (>2 mm)				
Bees				
Moths and Butterflies				
Beetles				
Misc. Insects				
Unidentified Material				

[1]ash-free dry mass (AFDM)

COMMENTS:_____
_____
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Devils Hole Ecosystem Monitoring Protocol

SOP VII – Devils Hole Pupfish

Stanley D. Hillyard[1], Zane L. Marshall[2], and Michael R. Bower[3]

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Version 7.1 (December 17, 2008)

Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

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Introduction

To understand the ecology of the single wild population of Devils Hole pupfish, robust methods for monitoring both ecosystem conditions and population responses are needed. Three separate methods are currently being used or are being developed to monitor the responses of the Devils Hole pupfish population to ecosystem conditions. The first method entails an underwater visual survey that has been conducted at least twice per year for over 30 years. The method uses a modified census approach where research divers count fish along a standardized route as a measure of abundance. As a secondary feature of this method, fish length (in 5-mm increments) is estimated on a separate dive to develop a length-frequency distribution for the population. The second method, which is currently being developed and refined, is a visual count of early-life-

methodological issues that may bias results or limit effectiveness. Describe within-estimate variation or uncertainty and statistical power to detect important trends or responses from management actions and environmental change.

2. Recommend alternative methods that alleviate limitations identified in Objective 1 to improve performance and statistical power. Alternative methods for the underwater visual census will focus on adding a measure of uncertainty to estimates of abundance while preserving the existing dive census approach (i.e., continue to follow established route) to maximize comparability. Alternative methods of early-life-stage survey will not be constrained by current methods. Following approval of alternative protocols by the project team, existing and alternative protocols will be implemented concurrently. A comparative analysis will be completed to assess statistical power and performance of existing versus alternative methods.

3. Develop and assess a method for monitoring the length-frequency distribution of the pupfish population using underwater stereo-video.

4. Using refined length-frequency information, develop a stage-specific model of pupfish population dynamics and an associated sensitivity analysis to identify potential recruitment bottlenecks.

5. Recommend final monitoring methods based on findings from previous objectives for 1) an underwater visual survey of pupfish abundance, 2) determination of the population length-frequency distribution, and 3) early-life-stage abundance and length-frequency sampling over the shallow shelf.

6. Following approval of final methods by the project team, combine all methods into an holistic long-term monitoring protocol for tracking population abundance and vital rates over time, following the guidance of Oakley et al. (2003).

In the absence of additional or alternative methods that may result from this project, the underwater visual census will continue to be implemented, as described in the following method, at a minimum of twice per year to provide needed feedback from ongoing management while preserving the existing long-term record of pupfish abundance. A method for collection and preservation of natural pupfish mortalities will also be described. Methods for monitoring early-life-stage Devils Hole pupfish will continue to be developed though a written SOP will not be developed until alternative approaches can be tested.

Underwater visual survey

Introduction

Since the early 1970's, researchers and resource managers have conducted an underwater visual survey of the Devils Hole pupfish population using SCUBA. These surveys have remained relatively standardized as methods were passed down from the original research teams. Due to the physical complexity of Devils Hole, it is certainly impossible to count every fish in the

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population. Therefore, the population survey in Devils Hole is thought to underestimate abundance. Survey methods are standardized and redundant so that population numbers and length frequencies can be compared among survey events.

Given the overhead environment of Devils Hole, its remote location, and the generally rugged environment, diving in Devils Hole requires many unique considerations in order to ensure safe and effective operations. Specific regulations and requirements of the National Park Service dive program can be found in NPS Reference Manual #4: Diving Management. Specific requirements for diving within the Devils Hole environment including organization of the Devils Hole Dive Team, equipment configuration and maintenance, diver certification, and emergency procedures can be found in the Death Valley National Park Dive Safety Manual. The highest priority for all dive operations at Devils Hole is to ensure the safety of both researchers and pupfish.

Sampling frequency

Surveys will be conducted twice per year, once in the spring (during the last week of March or fist week of April) and once during the fall (during the last week of September or first week of October).

Two to three dives will be conducted, with two dives being replicate counts and the third dive being used to estimate the population's length frequency distribution. The first dive is generally started by 0800 and the last dive is generally completed by 1500.

Survey methods

Entering Devils Hole

A critical aspect of the dive is that the divers approach and enter the pool carefully so as not to disturb the shallow shelf or the algal mats on the west wall. This is done by laying a ladder to the gauge frame, clamping on a metal support beam, and placing aluminum bleacher seats on the ladder.. Divers must use a rope to climb down a steep and slippery rock face about 2 m long and then balance on the plank to reach the drop-off where the divers enter via a ladder. The entry is made by carefully climbing down the ladder and easing into the pool to limit surface disturbance. Once in the pool and the fins are on, divers should move to the east wall and limit fin movement to avoid disturbing the algal mats on the west wall. Before descent, Dive Team members should make sure that: a) all equipment is functioning (bubble and light check); and, b) that there are no further questions about the dive plan.

Descent to Anvil Rock

The first step in the survey is to descend to Anvil Rock, which is about 75 feet below the surface (see Figure 1). It is important that an experienced member of the team lead the descent for several reasons. First, it is necessary to descend near the center of the ceiling, so as to avoid disturbing the floor and walls of Devils Hole and the fish that occur there. Second, an experienced diver will know where Anvil Rock is and will instruct the others to follow him/her

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and avoid the above concerns. Finally if any of the divers have problems that can not be solved during the descent, the dive must be cancelled.

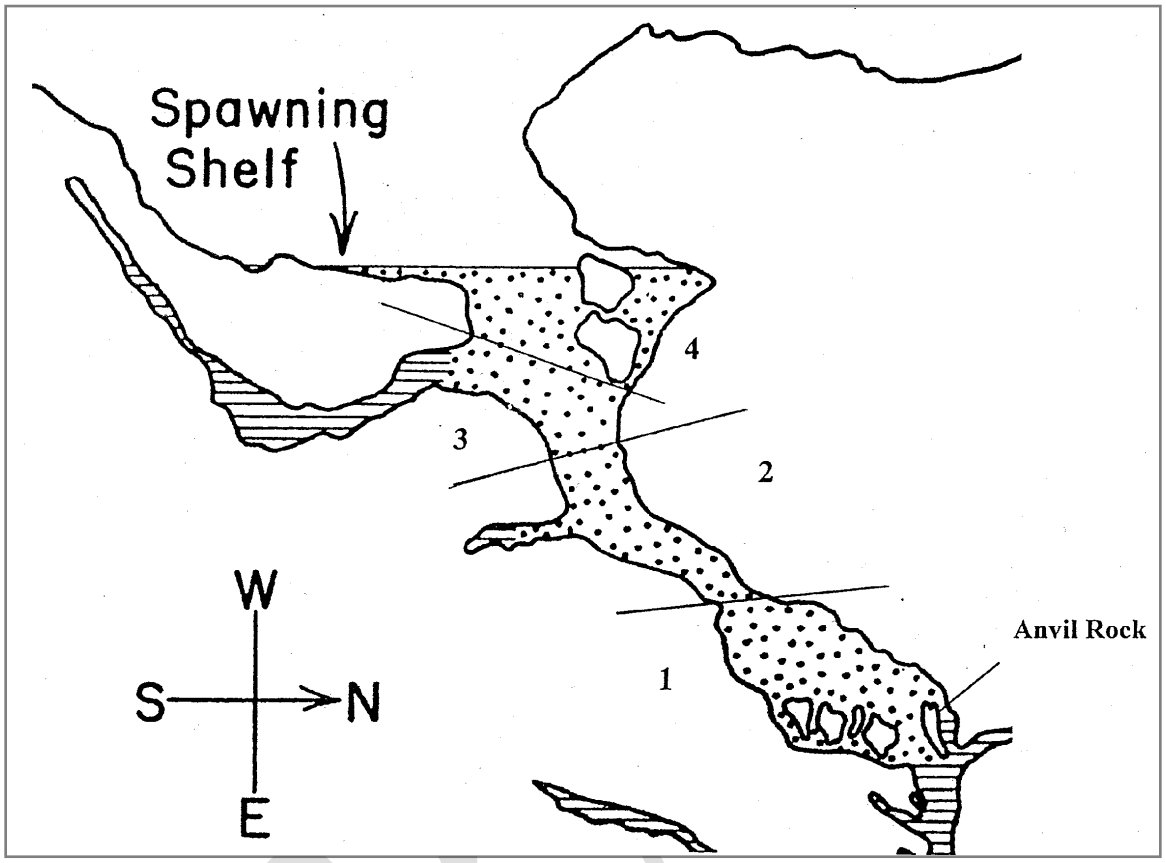

Figure 1. Cross section of Devils Hole showing pupfish survey Levels 1, 2, 3, and 4 plus the position of Anvil Rock

Beginning the Count (Counting Level 1)

Once the Dive Team meets at Anvil Rock, they level off, give an OK signal (indicated by a circular motion with a dive light) and the Lead indicates that he/she is continuing to the next phase of the dive plan. Initially the team will, in single file, drop just below Anvil Rock and turn right towards Flat Room. After right turn proceed for about 75 feet, at depths of 100-106 feet into passage leading to Flat Room. One of the safety divers remains just below Anvil Rock to guide return after egress from the passage. Turn around point is a vertical line at the opening that leads upward to Level 1. Look for fish and turn around, egress and ascend to Anvil Rock under supervision of safety diver. Last diver out of the passage is also responsible for ensuring that the other two exit properly. Although fish rarely occur in this location, it is thought that leaving the main cavern for a few minutes may allow spooked fish to return to their natural behavior. In addition, exhaust bubbles from divers in Flat Room may move fish out of the substrate and into the main cavern where they will be counted during later stages of the dive. After a few minutes, the team will then return to Anvil Rock.

At Anvil Rock, the Dive Team will split into a lead team and a secondary team, and the secondary team will ascend to the ceiling immediately above Anvil Rock (approximately 50 feet deep). The lead team will then begin to count the crevices around Anvil Rock and slowly move up and along the floor (See Figure 2). It is important that the safety diver not start behind the research diver until he/she is about one to two body lengths away from Anvil Rock. The research diver looks in crevices and on rock surfaces for the fish. Approximately 20 feet from Anvil Rock is a passage leading downward into Flat Room. The research diver will briefly penetrate approximately 5 feet into the passage looking for fish not observed during the excursion into Flat Room from below Anvil Rock. The safety diver should remain outside, but watch the research diver.

Once the research diver exits Flat Room passage, he/she will continue up and along the cavern floor to a rock face about 8-10 feet high. Once the research diver arrives at the vertical face, he/she counts fish along the vertical face, below the ledge that begins Level 2. At this point the counter turns around (facing north) and counts along the rock face to the west as he/she moves back towards Anvil Rock. Fish will be seen on the diver's left side swimming along the face. The research diver then turns back to the top of the ledge leading to the next level. The safety diver should remain at least two to three body lengths behind the research diver at all times. Before progressing to Level 2, the research diver records the number of fish counted in Level 1 on a slate.

Once the lead team exits Level 1, the secondary team will descend to Anvil Rock and repeat everything the lead team carried out. As the census continues, the secondary team will only begin counting a level after the lead team has finished that level.

Figure 2. Counting Level 1. The shaded line indicates the approximate path of the counter.

Continuing the Count (Counting Level 2)

At the top of the rock face, there is a gently sloping shelf (see Figure 3) that is covered with rocks and sometimes these are overlaid with algal mats. It is important that the counter keeps in neutral buoyancy above this ledge and slowly (with minimum fin movement) moves up the ledge and counts the fish. Historically, there have been groups of as many as 10-20 fish in this area. The research diver should attempt to count these groups more than once to get an accurate number. The research diver then moves to the opening of a small cave and counts fish in the bottom of that cave while going in and counts fish on the walls on the way out. Next, the research diver moves north along the west wall and counts fish on the wall. Finally, the research diver moves back over the safety diver to the top of the ledge above the cave opening. The number of fish counted in Level 2 is then recorded on a slate.

The safety divers should let the research diver get at least half way to the opening of the cave before moving to Level 2. It is extremely important that they not disturb the bottom since the debris disturbs the fish and compromises visibility on second and third dives. The safety diver should remain outside of the cave opening as the research diver exits and makes the loop back to count fish along the wall.

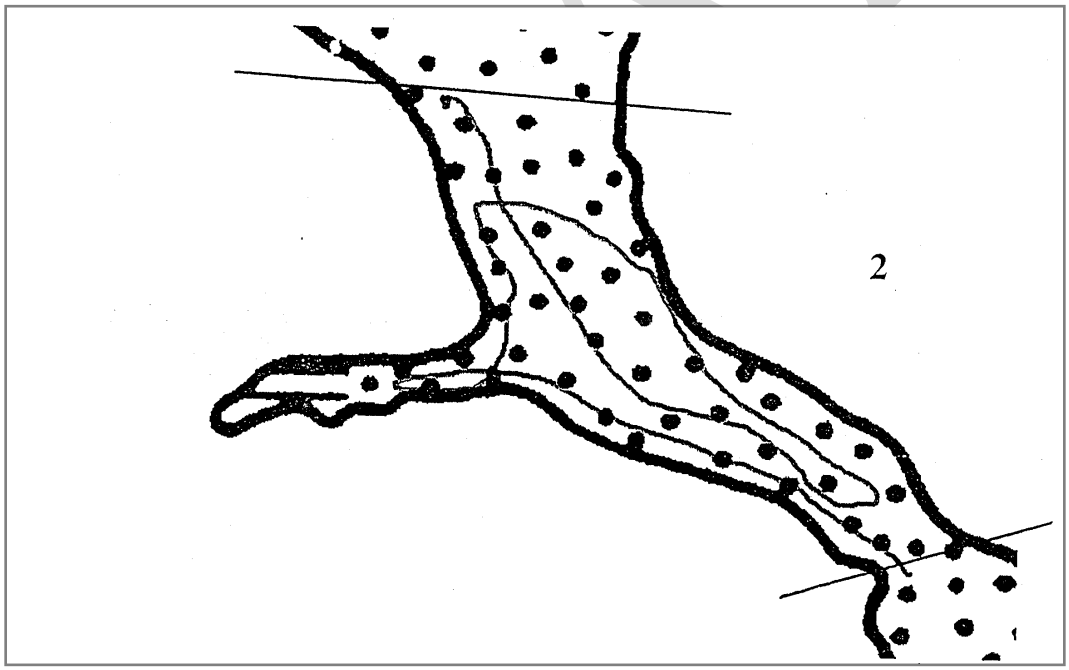

Figure 3. Counting Level 2. The shaded line indicates the approximate path of the counter.

Continuing the Count (Counting Level 3)

Above the cave opening in Level 2 is a gradually sloping floor (see figure 4) that is the beginning of Level 3. Like the floor in Level 2, Level 3 has rocks and algal mats in which the fish may be seen. It is useful to just watch the floor of Level 3 for a while before proceeding to count the fish, so as to get a search image for fish, especially smaller fish, on the background of the floor. The research diver then moves above the floor toward a cave that is deeper than that of Level 2. At the entrance of the cave, the floor is covered in silty sand and schools with many fish are often seen swimming around. As above, multiple counts should be taken to verify numbers of fish counted. The research diver then penetrates to the back of the cave, moving very slowly and carefully so as not to disturb the silty floor. There are a variety of crevices where fish might be seen. Counting continues as the research diver moves out to the opening of the cave and along the wall above the cave opening. The number of fish counted in Level 3 is then recorded.

The safety diver should stay below the ledge leading to Level 3 until the research diver is at least half way to the cave opening, and the safety diver should stay outside of the cave in Level 3 due to the silty floor.

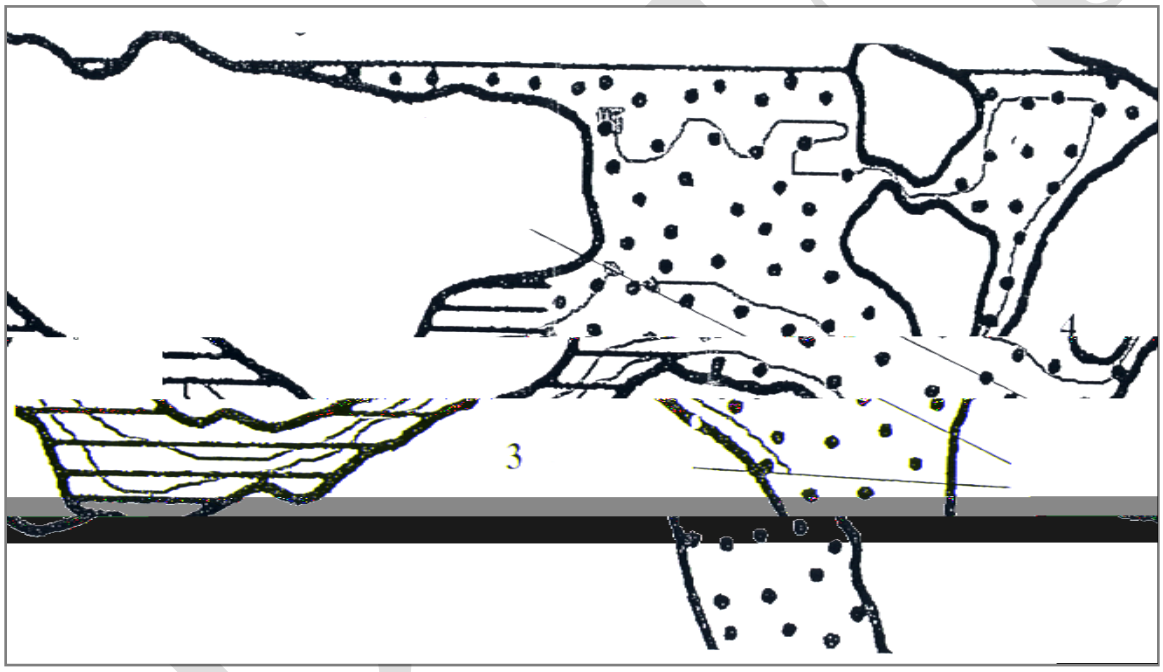

Figure 4. Counting Levels 3 and 4. The approximate path of the counter is shown for both Levels.

Finishing the Count (Counting Level 4)

The research diver moves along the western wall, which is often covered by algae, and counts fish on his/her left. The research diver proceeds along the lower half of the west wall and continues below a large rock formation and ascends into a chamber that opens behind the large rock at the north end of the pool (See Figure 4). The counter then moves into the main body of water via a gap between two large rocks and counts fish along the upper half of the west wall. There is a small ledge at the north end of the main pool that should be checked as smaller fish

The organization of the surface count team is coordinated by the Agencies. Prospective counters should be familiar with counting fish, have adequate vision and should be able to balance on their knees on a narrow platform. No more than three counters will count at a time and the same counters will be used during replicate counts.

The counters should carefully proceed onto the platform set out for the divers after the divers have begun their dive and their exhaust has disappeared. When ready, the team should establish boundaries between each other, which will delineate the area that each member will count fish in. Where the boundaries are is not as important as maximizing the ability of each counter to count the fish in his/her area.

When all team members are familiar and comfortable with their areas and associated boundaries, the first count, a practice count, may proceed. The count begins when everyone has stated their readiness and the time has been noted. When counting, each member should be careful not to double count fish in their or their neighbor's area. It is imperative that counters communicate regarding fish that have or may move into a neighboring area. When the first count is completed, the time and the counts for each area are noted on the data sheet. After the counts are totaled, the next three counts may then proceed in the same fashion as the practice count. After each individual surface count, each counter will record the numbers from their area on the data sheet. Once all four counts are complete, the average of the last three counts is calculated and noted on the data sheet.

After the divers have returned to the water to gather length-frequency data, fish on the shelf are measured by one of the surface counters. To aid in this activity, a portion of a ruler mounted on a metal dowel can be used. As the fish are measured, they are recorded into 5 mm categories. As many fish as possible will be measured, taking care to limit harassment and to ensure that the same fish is not measured more than once.

Count "for the day"

The "count for the day" will be calculated by adding the result from the first count by the Lead to the average of three surface counts during the first dive. In the event that a significant reason to question the result of the first count by the Lead and/or surface team exists (e.g., an underwater equipment failure), the Agencies may consider a subsequent dive as the day's result with consensus support. The "official count" result (now with a measure of variation) will be calculated as the mean of the "count for the day" for the number of days that the standard count is conducted.

Data management

First refer to the monitoring plan for data management guide lines. It is also necessary to follow the procedures listed below.

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Field and laboratory datasheets:

- Each field datasheet needs to be quality controlled for completeness by two crew members prior to leaving Devils Hole. Double check counts for each level from each diver and surface counts for each section.
- Upon return to the office each datasheet needs to scanned and placed into the appropriate folder on the Pahrump server. Originals need to be filed in the designated Devils Hole filing cabinet.
- Send a copy of the scanned datasheets via email to NDOW and USFWS.
- After completing a sampling event (each protocol described above), all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data entry:

- Use the MS Access database developed for the monitoring plan to enter data (this database is still under design).
- To reduce data entry errors database programming will be maximized to control data entry. This will be achieved via the use of lookup tables, and/or field-type design in the database (e.g. yes/no field types, input masks), and constraints such as valid ranges, uniqueness, referential integrity, and nullity.
- After completing data entry all datasheets must be photocopied and brought to the resource Management building in Death Valley to secure duplicate copies at a separate location.

Data verification:

- Each data point entered into the database needs to be checked against the original field and laboratory datasheets. If errors are found corrections need to be made to all pertinent database forms.
    - Procedure:
        - Print dataset and compare each point with datasheets.
        - Correct any errors.
        - If an error or errors are found recheck 100% of records for the specific sampling period for accuracy.

Data validation:

- Each data set needs be visually inspected by plotting each data point as a scatter plot and by running queries to capture missing data, out-of-range values, logical data, and violations of pre-defined data rules.
- Datasets must be examined for “logical” data. Data entry may be correct, but not logical.
- If errors are found the entire data set needs to be verified again.
- Annually the project manager will randomly check 10% of the database records for final validation. If errors are found the entire data set needs to be verified again.

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Metadata procedures

- Generate metadata records using the NPS Metadata Tools and Editor Metadata then follow the Federal Geographic Data Committee (FGDC) standards and include biological profile elements that allow integration of the metadata record with the NPS I&M NPSpecies and NatureBib online databases.
- A detailed procedure will be included in the next version.

Data archiving:

- After metadata has been generated upload data to the Pahrump server.

Collection and preservation of natural mortalities

Given the rarity of the Devils Hole pupfish it will infrequently be advisable to remove large numbers of live specimens for destructive analyses. As such, the limited number of natural mortalities encountered will be utilized to best contribute to our long-term understanding of the Devils Hole pupfish population. Uses could include:

- development of a DNA bank for genetic investigations
- preservation of histological samples for disease screening and as a reference for future investigations
- preservation of gut contents as an historical benchmark for future ecological investigations
- collection of otoliths for aging individuals and validating length-at-age relationships over time

Following is a step-by-step procedure for collecting and preserving natural pupfish mortalities encountered at Devils Hole. There could be specific investigations which require an alternative procedure to be implemented to answer a specific research question. In this event, the research permitting process will be used to document the purpose of the investigation and to disclose methods to be implemented, along with any Park-imposed stipulations. For routine natural pupfish mortalities, the following standard operating procedure will be applied.

Field kit

Prepare a mortality collection kit to have on-site at Devils Hole at all times. Include in the kit the following:

- several mortality collection data sheets (attached), printed on waterproof paper
- forceps
- scissors
- white porcelain tiles (4” x 4”)
- disposable alcohol wipes

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- 95% ethyl alcohol
- sample vials (3-mm or greater)

Field Collection

1. Clean forceps and white porcelain tile with disposable alcohol wipes
2. Using forceps, collect the mortality from the water and transfer it to the white tile for processing
3. Photograph the specimen lying on the white tile oriented on its left side along with a small ruler for scale using the MACRO camera feature to capture sufficient detail.
4. Transfer the whole fish into a 2 ml or larger sample vial and fill with 95% ethyl alcohol.
5. Begin to fill out a "Devils Hole Pupfish Mortality Collection Record" (attached) by recording the date, time, length, weight, and collector.
6. Fill out the notes fields by describing the condition of the specimen (i.e., to what extend has the specimen decomposed) and any applicable observations of site conditions. Pay particular attention to any suspected causes of the pupfish mortality.
7. Use a pencil to fill out a label indicating the collection date, NPS Accession #, Park Catalog Number, species, sample type (natural mortality, whole fish). Cut out the label and enclose it WITHIN the sample vial along with the whole fish.
8. If the NPS Accession # or Park Catalog Numbers are unknown at the time of collection, contact the Park Curator at the earliest opportunity and add the number to the datasheet and sample label.

Specimen curation

Specimens will be retained and maintained in the Death Valley National Park natural history collection for future investigations and/or reference. When alternative curation facilities are needed to meet program objectives, procedures for outgoing loan of Park collections may be available by contacting the Park Curator.

References

Oakley, K.L, L.P. Thomas, and S.G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin **31**:1000-1003.

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DEVILS HOLE POPULATION COUNT DATA

Survey Date: __/__/

MORNING COUNT

Water Stage (USGS Staff Plate) _____ Time _____
Photos taken at photopoints? Yes/no
Additional photos taken? Yes/no
Photos taken by whom/agency/format _____

SCUBA Count

Counter 1 _____ Time down _____
Counter 2 _____ Time up _____
Buddy 1 _____ Total time down _____
Buddy 2 _____

Number of Pupfish

Counter 1

level 1 _____
level 2 _____
level 3 _____
level 4 _____

Total Counter 1 _____

Counter 2

level 1 _____
level 2 _____
level 3 _____
level 4 _____

Total Counter 2 _____

Surface count

Counter 1 _____ Shelf section _____
Counter 2 _____ Shelf section _____
Counter 3 _____ Shelf section _____

Time started _____ Light conditions on shelf_____
Time ended _____ Light conditions on shelf_____

Number of Pupfish

	Counter 1	Counter 2	Counter 3	Total
Practice Count	_____	_____	_____	_____
Count 1	_____	_____	_____	_____
Count 2	_____	_____	_____	_____
Count 3	_____	_____	_____	_____

mean number of surface fish:
(Count 1 + Count 2 + Count 3) / 3

Total number of fish (Total number of underwater fish (counter 1) + mean number of surface fish):

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AFTERNOON COUNT

SCUBA Count

Counter 1 _____
Counter 2 _____
Buddy 1 _____
Buddy 2 _____

Time down _____
Time up _____
Total time down _____

Number of Pupfish

Counter 1

level 1 _____
level 2 _____
level 3 _____
level 4 _____

Total Counter 1 _____

Counter 2

level 1 _____
level 2 _____
level 3 _____
level 4 _____

Total Counter 2 _____

Surface Count

Counter 1 _____
Counter 2 _____
Counter 3 _____

Shelf section _____
Shelf section _____
Shelf section _____

Time started _____
Time ended _____

Light conditions on shelf_ _____
Light conditions on shelf_____

Number of Pupfish

	Counter 1	Counter 2	Counter 3	Total
Practice Count	_____	_____	_____	_____
Count 1	_____	_____	_____	_____
Count 2	_____	_____	_____	_____
Count 3	_____	_____	_____	_____

mean number of surface fish:
(Count 1 + Count 2 + Count 3) / 3

Total number of fish (Total number of underwater fish (counter 1) + mean number of surface fish):

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MISCELLANEOUS INFORMATION

Earthquake activity (previous 6 months)

severe (disabled water level recorder) minor (some water level fluctuations) none

Current owl presence

some pellets present rodent carcasses present no sign

Other notes

_____
_____
_____
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_____
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_____
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_____

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DEVILS HOLE PUPFISH LENGTH/FREQUENCY

Survey Date: __/__/

Shelf

Measurers name_____
Measured with ruler attached to end of ~ 1 meter long metal rod.

Classes	Number of Fish	Total Fish in Class
0-5mm		
6-10mm		
11-15mm		
16-20mm		
21-25mm		
26-30mm		
31-35mm		
35+mm		

Scuba

Counter 1 _____
How measured

Classes	Level 1	Level 2	Level 3	Level 4	Total Fish in Class
0-5mm					
6-10mm					
11-15mm					
16-20mm					
21-25mm					
26-30mm					
31-35mm					
35+mm					

Counter 2 _____
How measured

Classes	Level 1	Level 2	Level 3	Level 4	Total Fish in Class
0-5mm					
6-10mm					
11-15mm					
16-20mm					
21-25mm					
26-30mm					
31-35mm					
35+mm					

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Devils Hole Pupfish Natural Mortality Collection Record

NPS Accession #:	Park Catalog #(s):
FWS/NDOW ID:	Date (local):
Length (mm):	Time (local):
Weight (g):	Collector:

Mortality condition (circle one):

highly decomposed minor decomposition recent mortality

Specimens collected:

Fin? Otolith? Stomach? Carcass? Other (list)_____

Preservation method(s):

_____
_____
_____
_____
_____

Additional observations:

_____
_____
_____
_____
_____

Specimen label (remove and include in sample vial):

NPS ACCESSION #:
PARKCATALOG#:
DATE:
TIME:
SPECIES:
SAMPLE TYPE:
PRESERVATION METHOD(S):

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Devils Hole Ecosystem Monitoring Protocol

SOP VIII – Equipment Use and Decontamination

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Revision History Log:

Previous version #	Revision date	Author	Changes made	Reason for change	New version #

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Introduction

Equipment or other items that enter the water at Devils Hole must be cleaned and disinfected in order to eliminate the potential of chemical and biological contamination. This includes new equipment which may harbor chemical residues from the manufacturing process, equipment being borrowed for temporary use at Devils Hole, and the instruments and equipment of collaborators. The unique novelty and fragility of the Devils Hole ecosystem requires that special attention be paid to the specific techniques used to accomplish this task.

Given the ever-growing list of potential aquatic invasive species threats, this protocol focuses on an approach that, if followed, is robust to the differential tolerances of individual organisms to chemical disinfectants. This is accomplished by focusing first on acquiring dedicated gear for routine tasks. For situations when dedication of gear is infeasible, a two-phase cleaning and disinfection procedure is described. This two-phase approach is intended to ensure adequate disinfection of highly tolerant organisms while avoiding the use of harsh chemicals that could be toxic to the Devils Hole ecosystem at residual concentrations. Several options are presented to accommodate the various needs of sensitive equipment.

As the golden rule, if there is any doubt about the potential contamination of a piece of equipment or its history of use in other aquatic ecosystems, avoid its use in Devils Hole until it can be properly decontaminated.

Use of dedicated gear

Though physical and chemical disinfectants continue to be widely used to prevent the accidental introduction of exotic organisms into aquatic ecosystems, rarely are these 100% effective in removing this threat. It is frequently impossible to document that all equipment surfaces receive the target treatment. In the case of chemical disinfectants, there is the additional possibility of traces of residual chemical being introduced to the ecosystem. For these reasons and others, the

most effective and efficient way to prevent the accidental introduction of undesirable organisms or chemical contaminants is to purchase and maintain dedicated gear for use at Devils Hole.

For new gear being used for the first time at Devils Hole, a thorough cleaning will be completed to remove any byproducts of the manufacturing process that may serve as chemical contaminants. A detergent will be used to dissolve insoluble chemicals and clean the equipment's surfaces. The equipment will then be thoroughly rinsed to remove all detergent.

Decontamination of field gear

When it is infeasible to acquire dedicated gear to accomplish critical tasks, gear may be decontaminated using the following procedure. There are two steps to this procedure, an initial cleaning and chemical disinfection followed by a physical disinfection treatment. It should be noted that this protocol is only effective when **BOTH** steps are followed. Step One below will not suffice to decontaminate equipment. Several known threats, such as the red-rim melania (*Melanoides tuberculatus*), an exotic operculated snail, are extremely tolerant of chemical disinfectants (e.g. Mitchell et al. 2007) and will require one of the physical disinfection treatments described in Step Two for eradication. Conversely, the physical disinfection treatment options described in Step Two below are not effective against many potential pathogens. Both steps, in combination, are necessary to ensure adequate decontamination of equipment.

Following completion of Steps One and Two, equipment should be stored in a cool and dry central location where there is no potential for cross-contamination by equipment used in other aquatic ecosystems.

STEP ONE: Cleaning and Chemical Disinfection

Option 1. Quaternary ammonium detergent disinfectant

This technique includes the dual benefits of cleaning equipment of chemical residues and killing many pathogens that are intolerant of quaternary ammonium. This chemical has also been shown to kill NZ mudsnails in 5 min (Hosea and Finlayson 2005).

1. Dilute quaternary ammonium detergent disinfectant per label directions.
2. Using detergent, thoroughly wash all equipment surfaces, internal and external, making sure to remove all organic matter and soil that could retain contaminants, invasive organisms, or residual moisture.
3. Thoroughly rinse all equipment surfaces in fresh water.

STEP TWO: Physical Disinfection

Option 1. Extended desiccation

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This option requires minimal effort and works equally well for sturdy field gear and sensitive electronic instruments. Thoroughly drying equipment after use outside of Devils Hole should kill most aquatic organisms, though desiccation-resistant invasive species are well established in the area. For this reason, it is imperative that a THOROUGH drying of equipment be extended for a minimum of 14 d after complete drying prior to use in Devils Hole.

1. Complete Step One.
2. Thoroughly rinse equipment and place in a well ventilated and secure area.
3. Drying racks or hangers can help to speed the drying process.
4. Occasionally check equipment to see if internal surfaces, fabrics, or pores are drying or if they continue to retain moisture.
5. Where necessary, utilize drying aids such as fans and boot dryers to initially dry equipment.
6. Continue the desiccation treatment for 14 d following the complete drying of ALL surfaces.
7. If personnel are unable to document the complete drying of ALL equipment surfaces, internal and external, prior to and during the treatment, this technique should not be used.

Option 2. Freezing

This is a convenient technique for gear that is easily cleaned and can be subjected to freezing conditions without sustaining damage. Most aquatic organisms, particularly those living in thermal springs, are not tolerant of freezing conditions.

1. Complete Step One.
2. Thoroughly rinse all equipment and let drip dry.
3. Adjust temperature within the freezer to -10°C (14°F) prior to placement of equipment.
4. Maintain equipment in the freezer at -10°C (14°F) overnight.
5. If personnel are unable to document that air temperature reaches and maintains -10°C (14°F) overnight, this technique should not be used.

Option 3. Superheated water bath

This technique can be used to easily disinfect equipment that can be subjected to intense heat without sustaining damage.

1. Complete Step One.
2. Establish and maintain a 50°C (120°F) hot water bath. This can be accomplished in several ways, including use of a home water heater and bathtub, use of a metal trough and propane blaster, or use of a laboratory autoclave.
3. After a sufficient heating period, check water temperature with a mercury thermometer.
4. Place equipment into hot water bath for a minimum of one hour.
5. If personnel are unable to document that water temperature reaches and maintains 50°C (120°F), the technique should not be used.

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Personal products and clothing

People entering Devils Hole during pupfish surveys or research activities should shower the morning prior to entering Devils Hole. They should also wear clean clothes to Devils Hole. Aftershaves, colognes, antiperspirant, suntan lotion, etc. should not be applied to the body, since these substances have the potential to contaminate the aquatic environment.

People that conduct field work and have mud or organic matter on their clothes and shoes have the potential to introduce exotic organisms to Devils Hole. Individuals entering the gate that surrounds Devils Hole should be prepared to have clean clothes and footwear that have not been exposed to other aquatic environments. If the footwear has been exposed to other wetlands, it must be decontaminated using one of the above-mentioned techniques.

Vehicle use

Vehicles being used to carry equipment and supplies for use at Devils Hole should be free of potential chemical and biological contaminants. This primarily requires that staff understand the usage history of vehicles being used to support work at Devils Hole. If a vehicle's usage history is unknown, avoid its use until it can be thoroughly cleaned.

References

Hosea, R.C., Finlayson, B. 2005. Controlling the spread of New Zealand mudsnails on wading gear. California Department of Fish and Game, Rancho Cordova, California.

Mitchell, A.J., M.S. Hobbs, and T.M. Brandt. 2007. The effect of chemical treatments on red-rim melania *Melanoides tuberculata*, an exotic aquatic snail that serves as a vector of trematodes to fish and other species in the USA. North American Journal of Fisheries Management **27**:1287-1293.

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Appendix A. Budget Projections for the Devils Hole Pupfish Recovery and Management Program – FY 2008 through FY 2012

Death Valley National Park
Resources Management Division

February 25, 2008

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Introduction

This budget has been prepared in anticipation of a base-funding (OFS) increase in the amount of $385,000 for Death Valley National Park (DEVA) to support recovery of the Devils Hole pupfish. From the NPS 2008 budget request (Green Book):

> *Funding is requested to preserve and protect threatened aquatic species in Death Valley NP and the Mo-jave Network of parks (Great Basin NP, Lake Mead NRA, Mojave NPres, Manzanar NHS, Grand Canyon-Parashant NM, and Joshua Tree NP). During the past nine years, Devils Hole pupfish have gone from 433 in October 1996 to 84 in November 2005, and continue to decline. The Devils Hole pupfish holds special significance in that it: 1) is one of the first species ever listed under the Endangered Species Act, 2) set precedent in the U.S. Supreme Court case that substantiated the authorities in the Act, and 3) is a bellwether for other aquatic threatened and endangered species in the southwestern deserts. Funding would be used to prevent extinction of the pupfish in its natural habitat. Funding would help to develop a coordinated research, monitoring, and management program to determine causative factors for the decline in pupfish population, identify actions and strategies to reverse the population decline, and remove the threat of imminent extinction. As the Devils Hole pupfish are stabilized, expanded attention would be given to other aspects of sensitive aquatic ecosystems in the Mojave Network of Parks and surrounding southwestern locations. Funding would protect resources and increase visitor satisfaction.*

As described in the Green Book budget justification, recovery of the single wild population of Devils Hole pupfish will require a holistic approach and sustained vision. This budget identifies specific needs that when considered cumulatively over a five year period, increase our capacity to investigate both basic and complex ecological processes at Devils Hole, identify trends in ecological parameters, and merge the results of short-term investigations with a long-term understanding of ecosystem function to develop and implement scientifically informed and biologically meaningful recovery strategies.

One example of the commitment necessary to effectively manage the resources of Devils Hole is implementation of a long-term ecosystem monitoring strategy that collects, maintains, and synthesizes information pertinent to ecosystem condition and function. This need has been repeatedly identified by the Devils Hole pupfish recovery team, workshop participants, and agency managers. A panel of subject-matter experts was recently convened to discuss

approaches to ecosystem monitoring at Devils Hole. DEVA staff will shortly be translating these recommendations into a Devils Hole Ecosystem Monitoring Plan that will serve as our guide as we begin to investigate this complex environment. Long-term monitoring, by definition, requires a long-term commitment of funds in order to ensure sustainability. Resource monitoring has often been viewed as a one-time, project-related expense that can be cut in times of budget shortfalls. This approach, though common, can result in a reactive, crisis-driven management approach that strains rather than encourages partnerships, is fiscally inefficient, and can hinder the identification of scientifically robust recovery strategies. A more proactive approach that institutionalizes a commitment to long-term ecological monitoring at Devils Hole is needed. This budget identifies personnel, equipment, and basic laboratory costs associated with implementation of a long-term monitoring strategy. The budget further recognizes the advantages of short-term applied research by supporting partnerships and collaborative efforts as a means to gain additional insight into the Devils Hole ecosystem. In several instances, this budget identifies opportunities for creative collaborations that act to increase the flexibility of existing funds as well as support development of lasting partnerships with academic institutions.

Rather than consider the recovery effort for Devils Hole pupfish a temporary need until the population can be stabilized, this budget represents a long-term commitment to active aquatic ecosystem research, monitoring, and management at DEVA consistent with the Resource Management goals of the National Park Service and in collaboration with diverse partners. As knowledge is gained as a result of the initial phases of research and monitoring activities at Devils Hole, efficiencies will be sought that would act to free staff for collaborations with other Network Parks and increase regional capacity for aquatic resource management within the NPS.

Budget Categories

Personal Services

Current personnel assigned to the management of Devils Hole and the Devils Hole pupfish include one Fishery Biologist (full-time), one Hydrologist (part-time), and one Assistant Division Chief (part-time). Several additional positions are needed to fully implement a comprehensive research, monitoring, and management program at Devils Hole given its local, regional, and national importance. These include an Aquatic Ecologist, Biological Science Technician, and Hydrologic Science Technician, each of which is described in more detail below. Two additional roles were identified including Science Advisor and Data Management Specialist. Though these two roles could by filled by the addition of targeted positions to the DEVA Resources Management staff, existing capabilities and creative arrangements with academic institutions are identified that would fulfill these needs in a more efficient manner.

Addition of an Aquatic Ecologist to the Resources Management Division at DEVA would enable a broader range of investigation relative to the observed decline in the Devils Hole pupfish population and other aquatic resources with DEVA and adjacent Mohave Network Parks. An aquatic ecologist would complement existing staff and increase the capacity of DEVA to undertake holistic ecosystem investigations. For example, a portion of the biotic monitoring that has been proposed at Devils Hole relates directly to the field of aquatic ecology and less directly with the fields of fishery biology and hydrology. This position would collaborate with existing

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staff to develop methods to collect specific ecological data (e.g., algae and invertebrate surveys, trophic interactions) as a component of the Devils Hole Ecosystem Monitoring Plan and aid in the interpretation of current and historical information to better understand the ecological intricacies of Devils Hole and how the ecosystem has changed. This position would also participate as a key collaborator with academia as ecological research advances. As one example, current research on the potential role of nutrient dynamics and food availability in the observed decline in the Devils Hole pupfish population would benefit from the participation of an aquatic ecologist by increasing existing capacity to investigate complex trophic interactions among algae, invertebrates, and fish. Additionally, this position would increase existing capacity at DEVA to investigate the ecology of several unique aquatic ecosystems such as Badwater, Salt Creek, and Cottonball Marsh.

Two new technician positions would be added (Biological and Hydrological) to aid in the implementation of the Devils Hole Ecosystem Monitoring Plan. These positions would have primary responsibility for data collection and maintenance. Additional duties would include assistance with Devils Hole pupfish research, monitoring, and management activities at a suite of locations such as existing and planned refuge habitats, captive propagation facilities, and academic institutions. These two positions would further be available to aid in studies of regional processes and characteristics that could influence Devils Hole such as the dynamics of the Lower Carbonate Aquifer or regional trends in patterns of airborne particulate dispersal.

Though a Science Advisor position was strongly considered for inclusion in this budget, existing personnel such as the Assistant Resources Division Chief are felt to serve this role by critically evaluating scientific conclusions, challenging current dogma, and communicating issues of scientific method or interpretation through the chain of command.

The collection of a large dataset without due consideration of data management needs is non-sustainable and ineffective. Rather than employ a full-time Data Management Specialist, we envision a creative partnership between DEVA and an academic institution (e.g., DRI, UNLV, UCR) to provide data management services on an as-needed basis through an adaptive and non-traditional arrangement. This agreement would be utilized to design and implement Natural Resources Database Template (NRDT)-compliant database solutions for the storage and organization of ecological data from Devils Hole, development of a 'microscale' GIS solution at Devils Hole to allow storage and retrieval of spatial data, assistance with statistical analyses, and sporadic data management needs. It is important to consider this need an integral part of initial program development as there is an existing backlog of historical data to be organized and stored and any new data collected should be managed in a manner reflecting its importance to the Devils Hole pupfish recovery effort and the decision-making process.

As one more reflection of the long-term vision represented by the addition of several positions, this budget projects the costs of permanent, full-time employees rather than term employees or other more flexible appointment options. Past experiences indicate that the implementation of a scientifically-sound and cohesive long-term research, monitoring, and management program is problematic when implemented by a series of rotating, short-term employees. The critical and tenuous nature of the Devils Hole pupfish demands more consistency and reliability. Therefore, permanent positions are strongly encouraged. It is expected that these permanent positions will

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be more likely to aid in the institutionalization of an aquatic ecosystem management program than would positions that had a shorter shelf life. As the budget projections indicate, the cost of these positions is well within the anticipated budget increase while maintaining a commitment to collaborative efforts necessary to support an active research and monitoring program. It is expected that by advertising for permanent positions in support of a long-term commitment to science-based resource management, the best applicants will be recruited and retained to help increase our understanding of the aquatic ecosystems of Death Valley NP, recover the Devils Hole pupfish, and increase the NPS's regional capacity for aquatic resources management.

Collaborative Research

By acknowledging the inherent advantages of various agencies and institutions, we can build strong collaborative partnerships that act to leverage scarce funds. It is often unrealistic for any one NPS unit to employ personnel representing each academic specialization necessary to complete interdisciplinary ecosystem research such as statisticians, meteorologists, limnologists, chemists, and phycologists. To take full advantage of the state of science in regards to these diverse disciplines, it becomes necessary to pursue collaborations with academia. Though NPS units are often unable to employ each of these specialists, they are positioned perfectly to act as a steward of their resources including maintaining a current understanding of their condition (i.e., long-term monitoring). By leveraging our institutional advantage and commitment to maintain a current understanding of conditions at Devils Hole through implementation of an ecosystem monitoring strategy with the institutional advantage inherent in academia for targeted applied research, we can best improve our holistic understanding of the Devils Hole ecosystem.

This budget represents a strong commitment to science-based resource management by earmarking seed funds to target the most critical scientific questions. These seed funds would be utilized to collect preliminary data and initiate research projects while external funding is secured. Given the nature of active learning associated with the pursuit of these research efforts, it is often unrealistic to forecast the precise areas of investigation over multiple future years. Research efforts are best served by a more organic understanding of funding commitment that allows knowledge gained as a result of individual projects to grow into the next logical effort. It is frequently this failed understanding of research funding that limits the ability to maintain focus and direction towards understanding any one ecosystem. By institutionalizing a stable commitment to research at Devils Hole through collaborations with academia, we can ensure that active research efforts maintain the inertia necessary to test intricate hypotheses.

Equipment and Supplies

Implementation of an active monitoring and management program will require acquisition of a suite of basic analytical equipment and supplies through both one-time and cyclic expenditures. As the program matures over the years, investments in equipment will decline and be replaced by maintenance costs to secure assets. This occurrence is expressed as a gradual reduction in equipment costs and increasing maintenance costs within this budget.

A basic water lab is strongly recommended to carry out a suite of aquatic monitoring tasks such as equipment calibration, sample possessing and enumeration, species identifications, etc.

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Though this budget will support contractual arrangements to supplement the capabilities of a basic water lab, a minimal level of on-site capability will support basic functions of the aquatic resources program. Further, establishment of a basic water lab is in line with the vision to create an interdisciplinary research center within DEVA to support a variety of collaborative research efforts.

Travel and Training

Frequent travel among a suite of locations is a reality of the Devils Hole pupfish recovery effort. Refuge locations are separated by over 100 miles and frequent trips to Las Vegas are necessary for program coordination and planning meetings. Additionally, there have been frequent needs for invitational travel associated with pupfish counts, subject matter experts, and NPS collaborators. A conservative but sufficient training budget will enable the aquatic resources team to maintain frequent connection with the larger group of conservation professionals and develop and maintain rare skills.

Annual Allocations

Costs have been projected across five fiscal years in order to assess the influence of inflation and anticipated salary increases. The effects of increasing personnel costs are represented by a corresponding decrease in funding allocated to non-personal services. Additionally, though equipment acquisition is a recurring, sporadic expense, initial equipment costs are slowly replaced by increasing maintenance costs and funding emphases in other areas such as collaborative research.

External Funding

Funding sources external to the DEVA base funding budget, including NPS and non-NPS sources would be pursued to both leverage existing commitments to academic research and supplement capabilities. As these external funding sources cannot be guaranteed, this budget considers such funding a luxury that will be actively pursued, but not counted on to support the basic functions of the aquatic resources program. One such example is evident in the proposed budget. Funding that has been acquired through the SNPLMA project proposal process will be used to offset the initial costs of collaborative research efforts in order to enable investment in basic on-site laboratory capabilities.

Summary

This budget supports a holistc approach to research, monitoring, and management at Devils Hole by increasing capacity through addition of several needed positions, acquisition of specific equipment, establishment of basic laboratory capacity, and a commitment to academic research. This budget is thought to compliment the overall vision of the Resources Management Division at DEVA by increasing capacity to maintain a long-term commitment to the unique resources of Devils Hole that can be used as an example of effective and efficient resource stewardship.

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Table 1. Cost projections for the Devils Hole research, monitoring, and management program across five fiscal years.

Budget Category	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Assessments	$ 9,625	$ 9,625	$ 9,625	$ 9,625	$ 9,625
Personal services	$ 243,439	$ 274,921	$ 290,827	$ 306,489	$ 322,807
Collaborative research	$ 42,000	$ 52,000	$ 44,000	$ 31,500	$ 15,500
Equipment and supplies	$ 51,771	$ 30,056	$ 21,356	$ 18,155	$ 17,456
Travel and training	$ 38,000	$ 18,360	$ 18,738	$ 19,116	$ 19,498
	$ 384,835	$ 384,962	$ 384,546	$ 384,885	$ 384,887

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Table 2. Itemized cost projections for the Devils Hole pupfish research and management program for the period including Fiscal Years 2008 through 2012.

Item	Item Description	FY 2008	FY 2012	Assumptions
		Assessments		
General assessment	2.5% general assessment for Park base funds	$ 9,625	$ 9,625	Estimated rate based on average general assessments.
		$ 9,625	**$ 9,625**	

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Item	Item Description		FY 2008		FY 2012	Assumptions
		Personal Services				
Fishery Biologist	Fishery Biologist (GS-12) to implement an active research, monitoring, and management program for the Devils Hole pupfish and other native DEVA fishes, and collaborate with adjacent parks in the Mohave Network on aquatic resources management projects.	$	91,265	$	110,846	Cost computed by projecting the salary of the existing Fishery Biologist (GS-12).
Aquatic Ecologist	Aquatic Ecologist (GS-9/11) to support research and monitoring activities at Devils Hole and other aquatic ecosystems within Death Valley NP and the surrounding Mohave Network of Parks. This expertise is needed to complement existing skills related to fi	$	59,922	$	89,762	Cost based on hiring at the GS-9, step 1 level and progressing through the GS-11, step 4 level.
Biological Science Technician	Biological Science Technician (GS-5/6/7, FTE) to complete routine monitoring of biotic and abiotic habitat features within Devils Hole. Additional duties would include data management, compilation of historic and current datasets, and assisting in Devils	$	49,818	$	61,584	Cost based on hiring at the GS 05 during FY 2007, and advancing to the GS-07, step 4 level during FY 2012.
Hydrologic Science Technician	Biological Science Technician (GS-5/6/7, FTE) to complete routine monitoring of hydrologic features within Devils Hole and the greater Lower Carbonate Aquifer.	$	42,434	$	60,615	Cost based on hiring at the GS 06, step 1 level.
		$	**243,439**	**$**	**322,807**	

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Item	Item Description	FY 2008	FY 2012	Analytical assumptions
		Collaborative Research		
Research projects	Recurring support for academic research efforts at Devils Hole. Specific research cannot be accurately predicted as future year research priorities would be allowed to grow organically out of monitoring information and previous research conclusions. Ini	$ -	$ 12,000	Initial funding year (2008) would be supported by an IA with USFWS ($44,567). External funding will be pusued to leverage identified funds.
Data management support	Cooperative Agreement with a local academic institution (e.g., UNLV, DRI, UCR, etc.) to support 1) the development of an NRDT-compliant database to organize and store historic and current monitoring data collected at Devils Hole, 2) development of a 'micr	$ 35,000	$ -	Initial funding year (2008) would include agreements for initial database and GIS development. Future years would focus on short-term analytical and data management needs.
Weather station support	Cooperative Agreement with WRCC (DRI) to maintain weather station and implement a telemetry solution for water quality and meteorological data.	$ 2,000	$ 2,000	
Laboratory services	Contracted laboratory services supporting monitoring efforts (i.e., water chemistry analyses, specimen identifications).	$ 5,000	$ 1,500	Initial expenses will be greater until a wet lab can be sufficiently outfitted to allow for on-site processing of invertebrate and algal samples.
		$ 42,000	**$ 15,500**	

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Item	Item Description	FY 2008	FY 2012	Analytical assumptions
	Equipment and Supplies			
Monitoring equipment	Equipment needed to implement a basic monitoring strategy. Equipment includes *in situ* instrumentation such as meteorological instruments, light sensors, air quality sensors, and water quality sensors.	$ 8,000	$ -	
Monitoring supplies	Supplies needed to perform routine monitoring. Examples include fixatives (EtOH), sample containers, batteries, and calibration solutions.	$ 4,000	$ 4,333	Estimate based on expenditures during FY 2006 and 2007. Adjusted for each projection year by the OMB inflation index.
Monitoring equipment maintenance	Annual maintenance of existing and anticipated analytical instruments to ensure accuracy of instrumentation and prolong utility.	$ 1,000	$ 1,000	
Wet lab establishment and support	Includes basic start-up costs for a wet lab (cabinetry, sinks, freezer, refrigerator, microscopes, analytical instruments, oven for sample preparation) as well as continuing support for equipment maintenance and laboratory supplies.	$ 26,000	$ 1,000	Funding obtained through the USFWS ($19,500) will be used to supplement funds identified for wet lab establishment during FY 2008.
Vehicle lease	One additional vehicle will be needed to support field activities at Devils Hole.	$ 5,771	$ 6,250	Based on the 2007 lease ($261) and mileage ($0.21 per mile) rates for a full-size crew cab pickup, assuming 1000 miles per month, adjusted for each projection year by the OMB inflation index.
Vehicle supplies	Includes emergency equipment, additional spare tire, and tool kit.	$ 500	$ -	
Office supplies	Desks, chairs, etc	$ 2,000	$ -	
Dive program support	Includes SCUBA gear annual inspection and repair ($3,000), NITROX air fills (2 @ $250), and routine gear replacement ($1000).	$ 4,500	$ 4,874	Adjusted for each projection year by the OMB inflation index.
		$ 51,771	**$ 17,456**	

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Item	Item Description		FY 2008		FY 2012	Analytical assumptions
			Travel and Training			
PCS move	Funding reserved for moving expenses of Aquatic Ecologist.	$	20,000	$	-	In the event that moving expenses are not accrued, funding will be used to support research efforts or wet lab establishment.
Travel	Travel allowances for personnel associated with the Devils Hole pupfish recovery effort. Includes invitational travel for visiting scientists and NPS collaborators ($3000) as well as dive training and operations ($5000).	$	8,000	$	8,666	Two dive counts at Devils Hole per year @ $2500 per dive. Subsequent years have been adjusted by OMB inflation projections
Training	Includes attendance at professional society conferences or skill development training as needed.	$	10,000	$	10,832	Assumes one training session each year @ $2,000 for five FTE's. Subsequent years have been adjusted by OMB inflation projections.
		$	**38,000**	**$**	**19,498**	

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-XXX, Month 2009

National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

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Appendix B

Consultation Letters

Please contact Kevin Wilson, DEVA Aquatic Ecologist at (775) 537-0787, ext 207, or Leah Bonstead, DEVA Park Archeologist at (760) 786-3232 if you have any questions.

Sincerely yours,

for Sarah Craighead
Superintendent

Enclosures: Biological Assessment, June 2010 (11 pages)
Monitoring Plan Draft, April 2010 (142 pages)

bcc: Leah Bonstead, Death Valley Archeaologist, Leah_Bonstead@nps.gov
Kevin Wilson, Death Valley Aquatic Ecologist, Kevin_Wilson@nps.gov

Please contact Kevin Wilson, DEVA Aquatic Ecologist at (775) 537-0787, ext 207, or Leah Bonstead, DEVA Park Archeologist at (760) 786-3232 if you have any questions.

Sincerely yours,

Kelly Fuhrman

for Sarah Craighead
Superintendent

Enclosures: Biological Assessment, June 2010 (11 pages)
Monitoring Plan Draft, April 2010 (142 pages)

Cc: Barbara Durham, Timbisha Shoshone Tribal Historic Preservation Officer, Timbisha Shoshone, P.O. Box 206, Death Valley, CA 92328 (with all attachments)

bcc: Leah Bonstead, Death Valley Archeaologist, Leah_Bonstead@nps.gov
Kevin Wilson, Death Valley Aquatic Ecologist, Kevin_Wilson@nps.gov

Send separate letter with all attachments to: Richard Arnold, Tribal Chair, Pahrump Paiute Tribe, P.O. Box 3411, Pahrump, NV 89041