Appendix F - Public Emails & Letters

[EXTERNAL] Solar Project

[redacted]

Thu 10/21/2021 10:35 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

I am in support of this project. Please add me to your email list.

Sincerely,

[redacted]

From: Ransel, Beth E
To: BLM_NV_SND_EnergyProjects
Cc: Wirthlin, Whitney J; Pay, Nicholas B; Klein, Matthew D
Subject: Fw: [EXTERNAL] Rough Hat Solar LLC
Date: Thursday, October 28, 2021 1:00:18 PM

From: [redacted]
Sent: Thursday, October 28, 2021 12:24 PM
To: SNDO_Web_Mail, BLM_NV <lvfoweb@blm.gov>
Subject: [EXTERNAL] Rough Hat Solar LLC

[redacted] October 28, 2021

[redacted]

Good day,

This is a letter explaining why Rough Hat Solar, LLC should NOT be allowed to continue with the plans to build a solar farm near our lovely town, Pahrump.

1) They are listed in the business category as HATS.
   Clearly, they do not produce hats. They build huge solar farms
   This business listing is misleading.

2) This company is an LLC, located in Madrid. Outside of the United States.
   Why does Pahrump want to support a foreign company?

3) The location of this proposed solar farm will decimate ALL natural wildlife for miles.
   Why do the community supporters want to destroy or kill acres of our beautiful natural wildlife?

   Desert Tortoises often do not survive relocation. Desert Tortoises are a protected species.

4) The residents of Pahrump will not benefit from the solar farm – but they will see the devastation.

5) This YouTube video explains a lot: https://www.youtube.com/watch?v=Zfi-_wnBZh8

6) The eight to ten jobs that will most likely pay $15-$18 an hour is just not worth the devastation residents will see to the beautiful land that surrounds us.

7) How much electricity will Valley Electric purchase? At what cost? The electricity will be sold to the highest bidder.

8) I believe there are many other issues that need to be thoroughly investigated, perhaps even by an independent party, before moving forward with such a terrible, horrific solar farm.

9) Who in Pahrump will benefit from a solar farm and how?

Respectfully,

[redacted]

"Be thankful for everything you have and do not have" [redacted]

[EXTERNAL] Rough Hat Solar

[redacted]

Tue 11/16/2021 4:09 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Hello,

I STRONGLY object to anything being built by Rough Hat Solar, LLC.

1. this is a foreign entity that will gain everything but lose nothing in the event the project fails
2. they are listed as HATS under the business category NO TRANSPARENCY
3. residents do NOT want this in our backyard, killing off desert wildlife and destroying our beautiful desert
4. what plan, if any, does Rough Hat Solar have to replace the solar cells in 20 years?
5. they do not have a plan as they do not plan to be here in the US in 20 years
6. you are supposed to be managing the property NOT destroying it

Regards,

[redacted]

"Be thankful for everything you have and do not have" [redacted]

From:	Cannon, Kirsten S
To:	Ransel, Beth E; Wirthlin, Whitney J; Dooman, Shonna; Pay, Nicholas B; Bulletts, Angelita S; Glander, Ian
Subject:	Fw: [EXTERNAL] Solar Farm in Pahrump
Date:	Wednesday, November 17, 2021 12:54:09 PM

Hey folks,

NSO forwarded the below comment that came in through their website.

Kirsten Cannon, APR
Public Affairs Specialist
Southern Nevada District
4701 North Torrey Pines
Las Vegas, Nevada 89130
Office: 702-515-5057
Cell: 702-595-2034
::
Follow BLM Southern Nevada on Social Media
Twitter | Facebook | YouTube | Flickr

From: NVSO_Web_Mail, BLM_NV <BLM_NV_NVSO_Web_Mail@blm.gov>
Sent: Wednesday, November 17, 2021 11:17 AM
To: Cannon, Kirsten S <k1cannon@blm.gov>
Subject: Fw: [EXTERNAL] Solar Farm in Pahrump

Rough Hat comments.

Thank you
-Devin

From: [redacted]
Sent: Wednesday, November 17, 2021 11:09 AM
To: NVSO_Web_Mail, BLM_NV <BLM_NV_NVSO_Web_Mail@blm.gov>
Subject: [EXTERNAL] Solar Farm in Pahrump

Hello,

I am 100% AGAINST having a solar farm in Pahrump.

Here is why!

1. **IT IS BAD FOR THE DESERT WILDLIFE**
2. **PROTECTED WILDLIFE WILL BE KILLED**
3. **IT WILL DESTROY VALUABLE DESERT LAND**
4. **IT IS AN EYESORE**
5. **THE ROUGH HAT SOLAR COMPANY IS A FOREIGN COUNTRY - WHEN IT DOESN'T WORK - THEY ARE GONE. GONE. GONE**
6. **IT WILL NOT PRODUCE GOOD JOBS IN PAHRUMP - IT WILL PRODUCE LOW PAYING JOBS THAT NO ONE WILL WANTS**
7. **THE ROUGH HAT SOLAR COMPANY IS LISTED UNDER THE BUSINESS CATEGORY AS HATS - THAT'S NOT BEING HONEST**
8. **THERE IS NO PLAN ON WHAT TO DO WITH THE WORN-OUT SOLAR CELLS IN 20 YEARS - DOUBTFUL ROUGH HAT SOLAR WILL BE AROUND**
9. **BLM IS SUPPOSED TO MANAGE THE PROPERTY NOT DESTROY IT**

[redacted]

"Be thankful for everything you have and do not have" [redacted]

From: Pay, Nicholas B
To: Ransel, Beth E; Wirthlin, Whitney J
Cc: Dooman, Shonna; Bulletts, Angelita S
Subject: Fw: [EXTERNAL] Solar Farm Project in Pahrump
Date: Wednesday, November 17, 2021 1:09:44 PM

FYI

Nicholas B. Pay
Field Manager, Pahrump Field Office
npay@blm.gov
(702) 250-0864 (Cell)
(702) 515-5042 (Office Phone)

Bureau of Land Management
Department of the Interior Region 10
4701 North Torrey Pines Drive
Las Vegas, NV 89130

Learn from the Past,
Prepare for the Future,
Live & Work in the Present, and
Find JOY in Life.

From: Helseth, Gregory L <ghelseth@blm.gov>
Sent: Wednesday, November 17, 2021 12:31 PM
To: Pay, Nicholas B <npay@blm.gov>; Dooman, Shonna <sdooman@blm.gov>; Bulletts, Angelita S <abulletts@blm.gov>
Cc: Abernathy, Justin <jabernathy@blm.gov>
Subject: Fw: [EXTERNAL] Solar Farm Project in Pahrump

I believe this to be on/about Rough Hat

Gregory L. Helseth
Branch Chief Renewable Energy
Nevada State Office | Bureau of Land Management
Cell 775-560-3098

From: [redacted]
Sent: Wednesday, November 17, 2021 12:25 PM
To: Helseth, Gregory L <ghelseth@blm.gov>
Subject: [EXTERNAL] Solar Farm Project in Pahrump

I will not be able to participate in either of the two Zoom meetings, so am sending this to you. I am completely opposed to this project.

My husband and I retired a little over two years ago and moved here. We could have moved anywhere we wanted but we chose Pahrump because of the weather and because it is a beautiful, unspoiled area surrounded by an undeveloped desert. We wanted that ambiance.

Allowing those mirrors to be installed in a populated area would take away the natural beauty that was our purpose in coming.

We also came for health benefits. At the last meeting of the County Commissioners there were several who spoke to the negative health impact of construction, so I am not going to reiterate. We do not want to move again as we are old and thought we had found the place to spend our remaining years and now it is being threatened.

I would also like to point out that even if this project were a good idea (it is not), this is not the company to do the work. The representative they sent seemed to be as coherent as the dormouse at the Mad Hatter's tea party. The presentation was an insult. If this is the best they can do when trying to sell the project think about how badly it will be managed if they were to get signed contracts.

Finally, they said management would be onsite for the 30 years of the duration of the project. I expect to not be around then. For those who are, what kind of mess will be left for them to deal with or live with. What is the plan for dismantling and restoring the desert? It cannot be done. If the desert is destroyed it will be an ecological disaster.

There is no bonus to this project but plenty of onus. Please be wise as a serpent and as gentle as a dove when dealing with people's lives.

Thank you,
[redacted]

[EXTERNAL] Rough Hat Solar NOT A GOOD COMPANY NYE COUNTY SOLAR FARM PAHRUMP NV

[redacted]

Fri 11/19/2021 11:22 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

NYE COUNTY, PAHRUMP, NEVADA
ROUGH HAT SOLAR FARM.

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Hello,

I VEHEMENTLY OPPOSE THE THOUGHTS MUCH LESS MOVING FORWARD WITH ANY SOLAR FARMS FOR NYE COUNTY.

ROUGH HAT SOLAR IS A FOREIGN ENTITY.
THEY ARE NOT VESTED IN THE WILDLIFE OR ANY QUALITY OF LIFE FOR THE RESIDENTS OF PAHRUMP, NYE COUNTY, OR THE UNITED STATES.
RESEARCH THIS COMPANY BEFORE MAKING TERRIBLE DECISIONS WHERE THE DAMAGE CANNOT BE UNDONE.

WHEN THE PROJECT GOES BAD HOW DOES ONE EXPECT TO CONTACT THE 3 PRINCIPAL OWNERS? THEY RESIDE IN MADRID!

THE BLM IS SUPPOSED TO PROTECT AND MANAGE PROPERTY - NOT ALLOW FOREIGN AGENTS TO COME IN A DESTROY IT WHILE MAKING A PROFIT OFF THE BACKS OF THE UNITED STATES OF AMERICA RESIDENTS.

Company Name:	ROUGH HAT SOLAR, LLC
Entity Type:	**FOREIGN LIMITED-LIABILITY COMPANY**
File Number:	E17689682021-7
Filing State:	Nevada (NV)
Domestic State:	Delaware (DE)
Filing Status:	Active
Filing Date:	September 22, 2021
Company Age:	2 Months

Registered Agent: M Cogency Global Inc.
321 W. Winnie Lane #104
Carson City, NV 89703

ac

Report Due Date: September 30, 2022

Business Category **Hats**

The company has 3 principals on record.
The principals are
Ignacio D Davila from Madrid,
Jesus S Simon from Madrid,
Jorge B Lopez from Madrid_

https://www.bizaQedia.com/nv/rough-hat-solar-llc.html

Rough Hat Solar, LLC in Carson City, NV | Company Info & Reviews

Discover Company Info on Rough Hat Solar, LLC in Carson City, NV, such as Contacts, Addresses, Reviews, and Registered Agent

www.bizapedia.com

REGARDS,

[redacted]

"Be thankful for everything you have and do not have"

From: Cannon, Kirsten S
To: Ransel, Beth E; Wirthlin, Whitney J; Pay, Nicholas B; Dooman, Shonna; Bulletts, Angelita S; Glander, Ian
Subject: Fw: [EXTERNAL] Rough Hat Solar NOT A GOOD COMPANY
Date: Friday, November 19, 2021 1:32:17 PM

FYI - this came in through NSO's website

Kirsten Cannon, APR
Public Affairs Specialist
Southern Nevada District
4701 North Torrey Pines
Las Vegas, Nevada 89130
Office: 702-515-5057
Cell: 702-595-2034
::
Follow BLM Southern Nevada on Social Media
Twitter | Facebook | YouTube | Flickr

From: NVSO_Web_Mail, BLM_NV <BLM_NV_NVSO_Web_Mail@blm.gov>
Sent: Friday, November 19, 2021 1:29 PM
To: Cannon, Kirsten S <k1cannon@blm.gov>
Subject: Fw: [EXTERNAL] Rough Hat Solar NOT A GOOD COMPANY

fyi

Thank you
-Devin

From: [redacted]
Sent: Friday, November 19, 2021 6:46 AM
To: NVSO_Web_Mail, BLM_NV <BLM_NV_NVSO_Web_Mail@blm.gov>
Cc: Debra L. Strickland <dlstrickland@co.nye.nv.us>; NSBN@LISTSERV.STATE.NV.US <NSBN@LISTSERV.STATE.NV.US>
Subject: [EXTERNAL] Rough Hat Solar NOT A GOOD COMPANY

Hello,

I VEHEMENTLY OPPOSE THE THOUGHTS MUCH LESS MOVING FORWARD WITH ANY SOLAR FARMS FOR NYE COUNTY.

ROUGH HAT SOLAR IS A FOREIGN ENTITY.
THEY ARE NOT VESTED IN THE WILDLIFE OR ANY QUALITY OF LIFE FOR THE RESIDENTS OF PAHRUMP, NYE COUNTY, OR THE UNITED STATES.
RESEARCH THIS COMPANY BEFORE MAKING TERRIBLE DECISIONS WHERE THE DAMAGE CANNOT BE UNDONE.

THE BLM IS SUPPOSED TO PROTECT AND MANAGE PROPERTY - NOT ALLOW FOREIGN AGENTS TO COME IN A DESTROY IT WHILE **MAKING** A PROFIT OFF THE BACKS OF THE UNITED STATES OF AMERICA RESIDENTS.

Company Name:	ROUGH HAT SOLAR, LLC
Entity Type:	**FOREIGN LIMITED-LIABILITY COMPANY**
File Number:	E17689682021-7
Filing State:	Nevada (NV)
Domestic State:	Delaware (DE)
Filing Status:	Active
Filing Date:	September 22, 2021
Company Age:	2 Months
Registered Agent:	Cogency Global Inc. 321 W. Winnie Lane #104 Carson City, NV 89703
Report Due Date:	September 30, 2022
Business Category:	Hats

The company has 3 principals on record.
The principals are
Ignacio D Davila from Madrid ,
Jesus S Simon from Madrid ,
Jorge B Lopez from Madrid .

https-//www **bizapedia** com/nv/rough-bat-solar-llc html

Rough Hat Solar, LLC in Carson City, NV | Company Info & Reviews

D1sco•1er Company Info on Rough Hat Solar, LLC ln Carson Crty, NV, such as Contacts, Address€'>, llevjews, and Registered Agent_

www bizapedia.com

REGARDS,

[redacted]

[redacted]

"Be thankful for everything you have and do not have"

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]

Tue 11/23/2021 5:27 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This project needs to be halted for Rough Hat NYE/Clark County Solar Project All projects that are solar in or near Pahrump Nevada need to be stopped at once. The CiĀzens of Pahrump Nevada are against solar farms in Pahrump. At our town mee. ng in Pahrump there was not one person who was in favor of the project. This is our land and we do not want a solar farm in Pahrump running into and along our town.

As for the health for the people who live in the town, they will be affected by valley fever and more allergies from all the dust that comes with solar farms. My family has been affected by Valley Fever and this spore never leaves the body once you have it and it is deadly. It is also very hard to detect. The heat in the valley will also go up from the panels Water is a Hugh concern since we are in the desert, and we just do not have enough water for this project to take place.

Another word for desert is wasteland is this the reason they think its ok to bring this project here. Well, it's not it's not ok and we do not want it here

What about all the Joshua Trees, wildlife, turtles, birds, and other sensi ve animals and plants living their best life on the land and around it? The animals are god's creatures, and they need to be protected from solar projects.

The people of Pahrump use this beau ful land for many enjoyable reac onal ac ves and this project will end that pleasure for the profit of Candela Renewables which will give nothing to the people of Pahrump.

This project does not help anyone in this community and what it does is harm all of us living in the area They talk about tax dollars for us. Well, what about the tax dollars from the people who live here that will need to move away if this project is allowed to take place? And please don't men on the value of the property at that me which will be devalued. Is this fair? I say no. This is not right for the people of Pahrump NV.

This project will bring great destruction to the people in the valley and CANDELA RENEWABLES, LLC needs to go to a new location out of our backyard.

What the project will bring is Valley Fever, High Heat, Dust Storms, water levels dropping when we have a water problem as it is. Property value will decline in Pahrump and the view from the houses will be deplorable, not to even to men on the health of our children at the Hafen School and other Pahrump schools The children in Pahrump are America's future. How dare you allow this project to even move forward.

I am not in favor of the project and please cancel at once.

[redacted]

[EXTERNAL] There should be No Solar Farms in Pahrump area of Nye County!

[redacted]

Tue 12/7/2021 6:14 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Why do you insist on pushing your agenda on us when we said we don't want it here!?
We made our voices heard, and you continue to have meetings trying to convince us otherwise, when e've backed up all of our voices with evidence as to why this would be a bad idea in Pahrump. Why do you keep persisting to irritate us?

Go elsewhere with your solar farms.

[redacted]

[EXTERNAL] Comment: Re Rough Hat Clark County Solar Project Virtual Forum 12/8/21

[redacted]

Thu 12/9/2021 4:13 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Unfortunately the online format moved forward before answering all questions. That should be noted on record.

Please take the due diligence to be a good neighbor and personally speak with residents bordering the project for high conflict and incompatibility with other uses including recreation land use, habitat loss, water, dust, heat Island effect, and hazardous materials adjacent to residents of Pahrump Valley.

Carefully evaluate if project aligns with BLM mission.

The Bureau of Land Management's mission is to sustain the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations.

Renewable projects may be found best best suited for formally contaminated lands, landfills or mine sites.

Thank you for taking all of this into consideration.

---------- Forwarded message ---------
From: **Notification Gateway** <no-reply@zoom.us>
Date: Wed, Dec 8, 2021, 4:55 PM
Subject: Reminder: Rough Hat Clark County Solar Project Virtual Forum 12/8/21 starts in 1 hour
To: [redacted]

Hi [redacted],

This is a reminder that "Rough Hat Clark County Solar Project Virtual Forum 12/8/21" will begin in 1 hour on:
Date Time: Dec 8, 2021 06:00 PM Pacific Time (US and Canada)

[EXTERNAL] Use the Variance Process to reject the application for the Rough Hat Clark County Solar Project.

[redacted]

Sun 12/12/2021 11:39 PM

To BLM NV SND EnergyProject <BLM NV SND EnergyProject @blm gov>

To the BLM, Nevada office,

Please use the Variance Process to reject the applica on for the Rough Hat Clark County Solar Project

The project site contains old biological soil crusts and desert pavement that is about 100,000 years old. Removal of the desert surface will result in uncontrollable fugi ve dust. This will impact public health in nearby Pahrump, Nevada But it will also permanently destroy carbon sequestering desert lands, which we desperately need to combat climate change.

The project will cut off access to 3.75 square miles of public land and be visible from recrea on trails, Highway 160, Mt Charleston, the Kingston Range Wilderness in California and the South Nopah Range Wilderness also in California.

In addi on there are many issues related to the cri cal biodiversity of the area:

1 Approval of the project would result in the removal of over 69,000 old growth Mojave yuccas and cac which are not known to return a. er being bulldozed. Many of the plants are hundreds of years old and provide habitat and food to the wildlife of the area.

2 The project site is located in important desert tortoise habitat Candela did their desert tortoise survey in May of 2021 - a record breaking drought year - not op mal condi ons for tortoise surveys. When desert tortoises were moved off the Yellow Pine Site in May, 2021 just to the south of the Rough Hat Clark site, nearly 3 mes more tortoises than predicted were found and 30 of the 139 moved were killed by hungry badgers in drought condi ons Please do not allow a repeat of the recent desert tortoise disaster that took place on the Yellow Pine Solar site. Please require Candela Renewables to conduct new tortoise surveys.

3 The project site contains hundreds of rare Parish Club Cholla, sca ered Joshua trees, kit fox, desert iguana, burrowing owl, coyote and several other species. Millions of living organisms would be killed in the construc on of the project.

4 Solar projects can mimic lakes and will o. en kill a number of bird species The project would be in the vicinity of Stump Springs and the Amargosa River which a ract several birds.

In addi on, the project would be located near the Old Spanish Na onal Historic Trail. Developing 5 large solar industrial projects in the area will destroy the historic character of the region

The project applica on received a High Priority status because BLM claimed it has low conflicts. But the BLM can change that status and cancel the review of this project based on new informa on, including the higher than predicted popula on of desert tortoises on the Yellow Pine Solar site to the south alone could be informa on enough to cancel the review of this applica on. But addi onally, preserving the diverse Mojave Desert Habitat on public lands and the quality of life in Pahrump, Nevada, should be grounds for the BLM to reject the applica on for the Rough Hat Clark Solar Project.

Sincerely,

[redacted]

[redacted]

[EXTERNAL] Rough Hat Clark County Solar Project

[redacted]

Mon 12/13/2021 3:56 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Please be more critical of the application for the Rough Hat Clark County Solar Project. I suggest rejection.

It's a tortoise habitat, and also a relatively remote location. Solar is best placed on roofs near where the energy is used, and the land is already disturbed.

[EXTERNAL] Please deny the needlessly destructive Rough Hat Clark County Solar Project

[redacted]

Wed 12/15/2021 11:49 PM

To BLM NV SND EnergyProject <BLM NV SND EnergyProject @blm gov>

3 attachments (12 MB)

DTC Allison and McLuckie.2018.Popln trends in MDT.pdf; DTC 2019_Berry and Murphy_CRM_5_109_agassizii.pdf; BLM Necessary Reforms [redacted] August 2021.pdf;

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

December 15, 2021

Dear BLM officials:

Please use the Variance Process to reject the application for the Rough Hat Clark County Solar Project. Distributed solar, solar on degraded lands, and other much less-damaging alternatives are available. The climate and extinction crises are both worsening, and BLM should not let solutions on one become greater problems for the other.

Despite being ESA listed as threatened in 1990, most Mojave desert tortoise populations continue to rapidly decline, and some are likely already below the minimum level for future viability. BLM and FWS have not stopped, much less reversed this rapid decline. Stronger tortoise conservation measures are urgently needed. Please see the attachments with more detailed scientific information on the precarious situation with tortoises

Approval of the project would result in the removal of over 69,000 old growth Mojave yuccas and cacti which are not known to return after being bulldozed Many of the *plants are hundreds of years old and provide habitat and food to the wildlife of the area*

The project site is located in important desert tortoise habitat. Candela did their desert tortoise survey in May of 2021 a record breaking drought year not op mal condi ons for tortoise surveys. When desert tortoises were moved off the Yellow Pine Site in May, 2021 just to the south of the Rough Hat Clark site, nearly 3 mes more tortoises than predicted were found and 30 of the 139 moved were killed by hungry badgers in drought condi ons Please do not allow a repeat of the recent desert tortoise disaster that took place on the Yellow Pine Solar site. Please require Candela Renewables to conduct new tortoise surveys.

The project site contains old biological soil crusts and desert pavement that is about 100,000 years old. Removal of the desert surface will result in uncontrollable fugi ve dust. This will impact public health in nearby Pahrump, Nevada.

The project site contains hundreds of rare Parish Club Cholla, sca ered Joshua trees, kit fox, desert iguana, burrowing owl, coyote and several other species. Millions of living organisms would be killed in the construc on of the project

Solar projects can mimic lakes and will o. en kill a number of bird species. The project would be in the vacinity of Stump Spring and the Amargosa River which a ract several birds.

The project would be located near the Old Spanish Na onal Historic Trail Developing 5 large solar industrial projects in the area will destroy the historic character of the region.

The project will cut off access to 3.75 square miles of public land and be visible from recrea on trails, Highway 160, Mt. Charleston, the Kingston Range Wilderness in California and the South Nopah Range Wilderness also in California.

The project applica on received a High Priority status because BLM claimed it has low conflicts. But the BLM can change that status and cancel the review of this project based on new informa on The higher than predicted popula on of desert tortoises on the Yellow Pine Solar site to the south could be the informa on used to cancel the review of this applica on.

To preserve diverse Mojave Desert Habitat on public lands and the quality of life in Pahrump, Nevada, BLM should reject the applica on for the Rough Hat Clark Solar Project.

In a broader context, BLM's dominant management culture needs basic reforms. Please see the related a achment for my reform recommenda ons.

Thank you very much for your considera on

Sincerely,

[redacted]

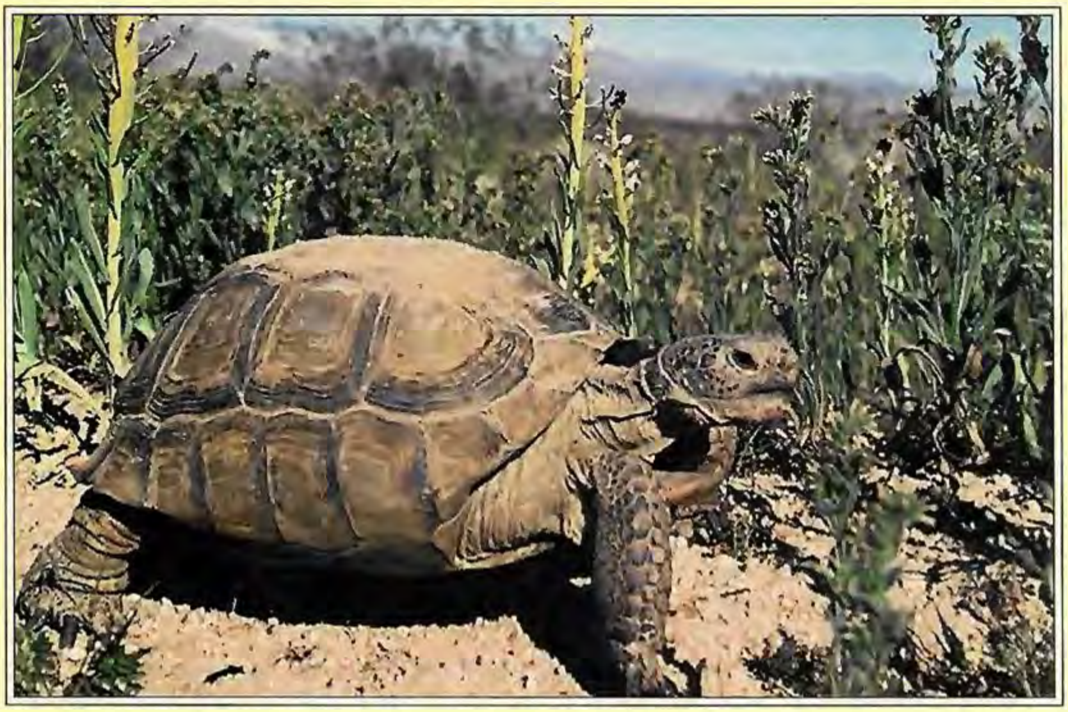
[redacted]

CONSERVATION BIOLOGY OF FRESHWATER TURTLES AND TORTOISES

A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group

EDITED BY

ANDERS G.J. RHODIN, JOHN B. IVERSON, PETER PAUL VAN DIJK, CRAIG B. STANFORD,
ERIC V. GOODE, KURT A. BUHLMANN, PETER C.H. PRITCHARD, AND RUSSELL A. MITTERMEIER



Gopherus agassizii (Cooper 1861) –
Mojave Desert Tortoise, Agassiz's Desert Tortoise

KRISTIN H. BERRY AND ROBERT W. MURPHY

CHELONIAN RESEARCH MONOGRAPHS
Number 5 (Installment 13) 2019: Account 109

Published by
Chelonian Research Foundation and Turtle Conservancy
in association with
IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Global Wildlife Conservation,
Turtle Conservation Fund, and International Union for Conservation of Nature / Species Survival Commission

Conservation Biology of Freshwater Turtles and Tortoises:
A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group
Rhodin, Iverson, van Dijk, Stanford, Goode, Buhlmann, Pritchard, and Mittermeier (Eds.)
Chelonian Research Monographs (ISSN 1088-7105) No. 5 (Installment 13), doi:10.3854/crm.5.109.agassizii.v1.2019

Gopherus agassizii (Cooper 1861) – Mojave Desert Tortoise, Agassiz's Desert Tortoise

Kristin H. Berry[1] and Robert W. Murphy[2]

[1]*U.S. Geological Survey, 21803 Cactus Avenue, Suite F, Riverside, California 92518 USA [kristin_berry@usgs.gov];*
[2]*Royal Ontario Museum, Toronto, Canada [bob.murphy@utoronto.ca]*

Summary. – The Mojave Desert Tortoise, *Gopherus agassizii* (Family Testudinidae), is a large terrestrial species that can reach >370 mm in straight midline carapace length (CL) but most individuals are smaller. Both sexes reach adulthood at 12 to 21 years and ca. 180 mm CL. The species is sexually dimorphic, with males typically larger than females; sexual characteristics of males become more obvious with increasing size and age. Females lay from 1 to 10 eggs per clutch and from 0 to 3 clutches annually, with eggs hatching after 67 to 104 days. Populations of *G. agassizii* have declined rapidly over the last several decades. Habitat throughout the geographic range has experienced major losses, degradation, and fragmentation as a result of urban and agricultural development, livestock grazing, military activities, transportation and utility corridors, high levels of visitor use, vehicle-oriented recreation, and energy development. Disturbed habitats were vulnerable to invading non-native grasses and forbs, creating an unnatural and destructive grass-fire cycle. When consumed by tortoises as their only diet, non-native (and native) grasses are harmful because of limited nutrients. Additionally, subsidized predators (Common Ravens, Coyotes, and dogs), infectious diseases, drought, and vandalism, add to the catastrophic effects of habitat loss and degradation. Tortoise populations have declined rapidly in density, and most populations are below viability, with fewer than 3.9 adults/km^2. These declines occurred despite protections afforded by federal and state laws and regulations, ca. 26,000 km^2 of federally designated critical habitat units, two Recovery Plans, and efforts to reduce the negative impacts of human activities. As noted by Allison and McLuckie (2018), the negative population trends in most of the critical habitat units suggest that under current conditions *G. agassizii* is on the path to extinction.

Distribution. – USA. Distributed in parts of the southern Great Basin, Mojave, and western Sonoran deserts in southeastern California, southern Nevada, northwestern Arizona, and southwestern Utah, north and west of the Grand Canyon/Colorado River complex, with the exception of a small population east of the Colorado River.

Synonymy. – *Xerobates agassizii* Cooper 1861, *Testudo agassizii, Gopherus agassizii, Gopherus polyphemus agassizii, Scaptochelys agassizii, Xerobates lepidocephalus* Ottley and Velázques Solis 1989.

Subspecies. – None currently recognized.

Status. – IUCN 2019 Red List: Vulnerable (VU A1acde+2cde; assessed 1996); TFTSG Provisional Red List: Critically Endangered (CR; assessed 2011, 2018); CITES: Appendix II (Testudinidae spp.); US ESA: Threatened.

Taxonomy. — The Mojave Desert Tortoise was first described as *Xerobates agassizii* by Cooper (1861), transferred to the genus *Testudo* by Cope (1875) and to *Gopherus* by Stejneger (1893). It was listed as a subspecies of *Gopherus polyphemus* by Mertens and Wermuth (1955) and referred to the genus *Scaptochelys* by Bramble (1982). *Gopherus lepidocephalus*, described by Ottley and Velázques Solis (1989) based on introduced specimens from the Cape Region of Baja California Sur, Mexico, is a junior synonym of *G. agassizii*. Bramble erected *Scaptochelys* for the clade containing the western species of *Gopherus*, but this name was preoccupied (Bour and Dubois 1984). Recently, Bramble and Hutchison (2014) advocated for the splitting of *Gopherus* into two genera, including *Xerobates* (for the desert species and *G. berlandieri*), but the splitting seems unnecessary, and their proposed taxonomy has not been followed. Recent genetic and morphological work on the previously wide-spread species *G. agassizii* sensu lato has led to the recognition and description of the Sonoran or Morafka's Desert Tortoise, *G. morafkai* (Murphy et al. 2011) in Arizona and Sonora, Mexico, and the Sinaloan Thornscrub Tortoise, *G. evgoodei* (Edwards et al. 2016a) in southern Sonora and Sinaloa, Mexico, markedly limiting the range of *G. agassizii* sensu stricto.

Phylogenetic Relationships. — The genus *Gopherus* contains six species that consist of two major sister-groups;

Figure 1. Adult *Gopherus agassizii* in desert candles at the Desert Tortoise Research Natural Area, Mojave Desert, California. Photo by Bev Steveson.

1) *G. polyphemus* and *G. flavomarginatus*, and 2) *G. berlandieri*, *G. evgoodei*, *G. morafkai*, and *G. agassizii*. The phylogenetic relationships in the second group are given in order of ascending relationships (Bramble and Hutchinson 2014; Murphy 2014; Edwards et al. 2016b). *Gopherus evgoodei* and *G. morafkai* may have originated via environmental-dependent parapatric speciation where exogenous selection limited genetic introgression (Edwards et al. 2016c). Later, the divergence of the sister species *G. agassizii* and *G. morafkai* may have been driven by either parapatric speciation or geographic isolation (Edwards et al. 2016b). Their divergence dates to about 4–8 million years ago, owing to the Bouse embayment (Lamb et al. 1989).

Description. — This and other sections focus primarily on peer-reviewed literature in journals and on recent articles summarizing topics. The published literature on *G. agassizii* contains papers on wild, free-ranging tortoises, tortoises maintained in small and large pens, head-started tortoises, and captives. For most topics, we emphasize studies on wild tortoises.

Adults of *G. agassizii* range in size from about 178 to >370 mm straight-line, midline carapace length (CL). Females tend to be smaller than males (Table 1), but the

Figure 2. Adult male *Gopherus agassizii* from the Desert Tortoise Research Natural Area, Mojave Desert, California. First captured in 1979 at a CL of 292 mm, he was recaptured repeatedly and in 2012 had a CL of 300 mm (these photos) and estimated to be at least 70 years old. Photos by U.S. Geological Survey, courtesy of Kristin H. Berry.

Figure 3. Adult male *Gopherus agassizii* at Chuckwalla Bench, California (Colorado Desert Recovery Unit). Photo by Steve Ishii.

Figure 4. Adult *Gopherus agassizii* with a green beak (from foraging) in spring. Photo by Mark Massar.

largest recorded wild individual was a female from Lucerne Valley, California, first marked in 1980 at 364 mm CL and recaptured in 1986 at 374 mm CL (U.S. Geological Survey files; Berry, unpubl. data). The largest recorded wild male was 330 mm CL, marked in 1982 at the Desert Tortoise Research Natural Area in the western Mojave Desert (Table 1). At that location, 8.9% of adult males were ≥300 mm CL. Larger tortoises may have been more common several decades ago. Ragsdale (1939) wrote that he frequently met healthy old tortoises 15 inches (ca. 380 mm) CL across the back 25–30 years prior (1909–1914), before paved highways came to the Colorado Desert area.

The carapace shape ranges from relatively high-domed and rounded in the west to low-domed and oval in the southern and eastern part of the range. Females have a flat plastron, as compared to the posterior plastral concavity that develops and deepens in males as they age. Shapes of the gular horn and tail are secondary sexual characteristics that also distinguish adults. Adult males have a larger gular horn, generally becoming more pronounced and upturned with size and age. In contrast, females have a smaller, shorter, and generally flatter gular horn. The gular horn tends to be notched early in adulthood but notching may disappear in old adults. The tails in males are longer than in females, projecting beyond the shell and often leaving a linear line or lines in sand when walking, whereas the tail of females does not extend beyond the carapace or plastron. Colors of the integument of limbs and shell vary with age and locality.

Bjurlin and Bissonette (2004) measured 91 wild hatchlings within 24 hours of emergence in the southern Mojave Desert, California; they had a mean CL of 43.8 ±2.15 (SD) mm (range 37.0-48.7 mm) and a mean weight of 21.3 ±2.91 SD g (range 14.4–28.2). Shells vary from light (light yellow) to dark (dark charcoal) with and without lighter areolae, whereas young adults range from shades of light to dark brown, gray, or black with yellowish, reddish, greenish, and olive tones. Limb colors also vary with axillary and inguinal scales tending to be lighter than hindlimb pads and anterior surfaces of forelimbs.

Gopherus agassizii is best separated from congeners *G. polyphemus* and *G. flavomarginatus* by having relatively smaller feet. Further, the distance from the bases of the first and third claws on the front feet is about the same as the distance between the bases of the first and fourth claws of the hind feet in *G. polyphemus* and *G. flavomarginatus*, but the distance from the bases of the first to fourth claws is the same on all feet in *G. agassizii* (Auffenberg and Franz 1978). *Gopherus agassizii* and closely related *G. berlandieri*,

Table 1. Mean sizes and weights of adult female and male Mojave Desert Tortoises (*Gopherus agassizii*) in three desert regions of the geographic range of the species. CL = straight midline carapace length (mm). None of the sites were in undisturbed habitat. The West Mojave site was grazed by cattle, then by sheep until 1980. The East Mojave site was grazed by cattle for decades previously, before and during the surveys. Both the East Mojave and Colorado Desert sites had tank tracks and litter from World War II military exercises.

Sizes and Weights	West Mojave: Desert Tortoise Research Natural Area Interior	East Mojave: Fenner Valley	Colorado Desert: Chuckwalla Bench
Year sampled	1982	1980	1979
Total sample size (n)	178	188	175
females, males	92, 86	77, 111	80, 95
Mean CL, mm (range):			
females	230.5 (182–267)	214.5 (183–247)	222.3 (188–254)
males	249.1 (180–330)	242.5 (182–307)	243.3 (190–291)
Mean weight, g (range):			
females	2522 (1200–3750)	2148 (1111–2915)	2215 (1350–3300)
males	3302 (1350–6950)	3044 (1115–6000)	2897 (1350–4750)

Figure 5. Young adult female *Gopherus agassizii* from Ward Valley in the Colorado Desert, California. Photos courtesy of San Diego Zoo Global.

Figure 6. Hatchling *Gopherus agassizii* from Edwards AFB in the western Mojave Desert, California. Photos courtesy of San Diego Zoo Global.

G. morafkai, and *G. evgoodei* individuals are most reliably distinguished by molecular data, especially in captivity, owing to extensive hybridization (Edwards et al. 2010) and abnormalities in shell, head and limb integument resulting from poor nutrition (Murphy et al. 2011). In wild tortoises, *G. berlandieri* differs from *G. agassizii* (and *G. morafkai* and *G. evgoodei*) in having a wedge-shaped versus a rounded snout (Auffenberg and Franz 1978). *Gopherus agassizii* differs from *G. morafkai* in having a significantly wider shell (Germano 1993), significantly longer gular scutes, and a significantly longer length of projection of the anal scales (Germano 1993), as well as a box-like versus a pear-shaped shell (Weinstein and Berry 1989). Finally, *G. agassizii* and *G. morafkai* both differ from the newly described *G. evgoodei* in having a higher shell in profile. *Gopherus evgoodei* also differs in having rounded foot pads, multiple enlarged spurs on the radial-humeral joint, a short tail, orange overtones in the skin and shell, and a distinctly shallower concavity on the plastron of males (Edwards et al. 2016a).

Distribution. — As originally described, the geographic range of *Gopherus agassizii* (sensu lato) extended from southeastern California, southern Nevada, and southwestern Utah south through Arizona and Sonora and into the northern part of Sinaloa, Mexico (Stebbins 1966; Auffenberg and Franz 1978). However, in 2011, *G. agassizii* was split into two species along the Colorado River (USA), with *G. agassizii* (sensu stricto) occurring to the north and west of the river, and the new species *G. morafkai* distribnted to the south and east (Murphy et al. 2011). With this division, *G. agassizii* (sensu lato) lost about 70% of its originally defined geographic range. Five years later, *G. morafkai* was further split into two species, with *G. evgoodei* described as encompassing the southern part of the geographic range in central to southern Sonora and northern Sinaloa, Mexico (Edwards et al. 2016a).

The northernmost locations of *G. agassizii* are in southern Owens Valley, California, Beatty, Nevada, and Red Cliffs

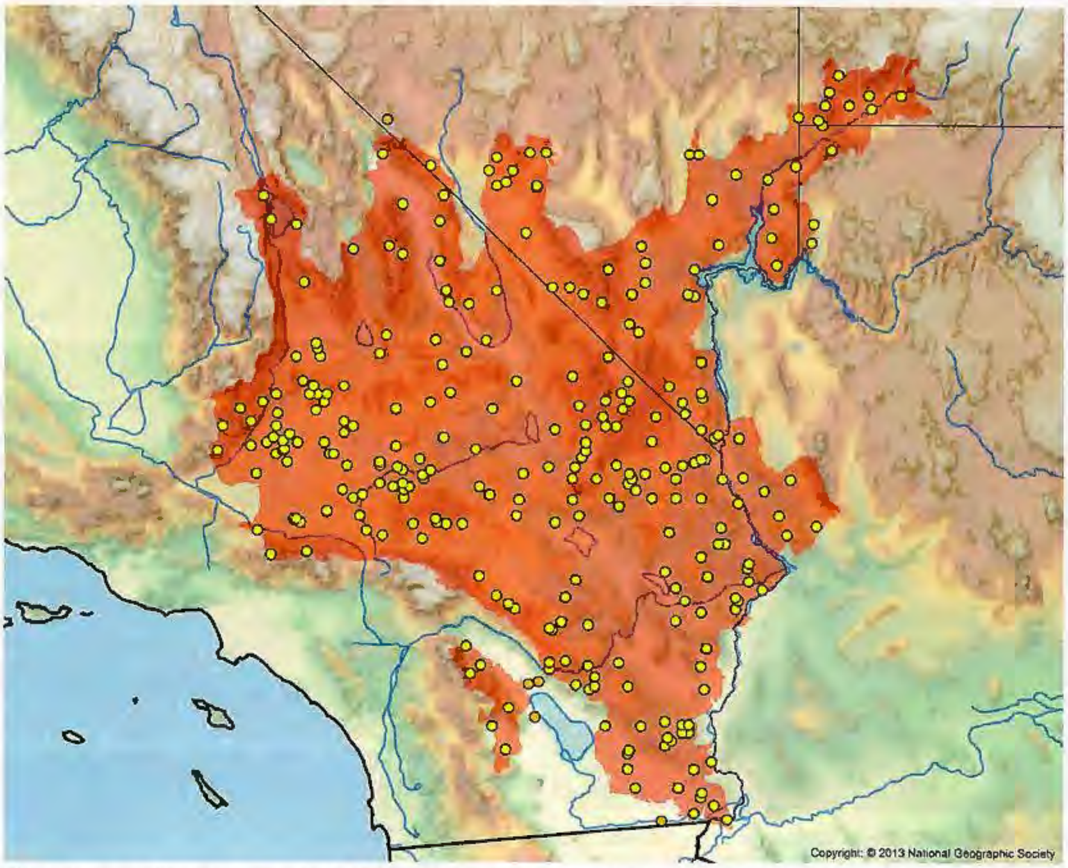


Figure 7. Distribution of *Gopherus agassizii* in California, Nevada, Utah, and Arizona in the USA. Yellow dots = museum and literature occurrence records of native populations based on Iverson (1992) plus more recent and authors' data; orange dots = uncertain native or introduced specimens; red shading = projected historic distribution. Distribution based on GIS-defined level 12 HUCs (hydrologic unit compartments) constructed around verified localities and then adding HUCs that connect known point localities in the same watershed or physiographic region, and similar habitats and elevations as verified HUCs (Buhlmann et al. 2009; TTWG 2017), and adjusted based on authors' subsequent data.

Desert Reserve and adjacent lands in southwestern Utah. The Colorado River forms the eastern and southern boundaries in California, parts of Nevada, northwestern Arizona, and Utah, with one exception. The exception to the Colorado River boundary is a small population of tortoises in Mojave Desert vegetation east of the Colorado River in the Black, Buck, and Hualapai mountains of Arizona (Edwards et al. 2015). Here, *G. agassizii* and *G. morafkai* meet in a contact zone where Mojave and Sonoran Desert vegetation types form an ecotone. With few exceptions, the two species have maintained their taxonomic identities. Nineteen hybrids were identified by Edwards et al. (2015), most as F_2 mixtures and were primarily in the ecotone; one additional hybrid individual, a backcross, was found in the Arrastra Mountains. Inman (2019) concurred, demonstrating separation of niches between the two species.

Most of the geographic range of *G. agassizii* occurs within the Mojave Desert and western Sonoran or Colorado Desert, with small areas of southern Great Basin Desert in the north and on the slopes of desert mountain ranges. The western boundaries of the range occur in ecotones with the lower slopes of the eastern Sierra Nevada and the Scodie and Tehachapi mountains, the lower north-facing slopes of the Transverse Range (specifically the San Gabriel and San Bernardino mountains), and the east-facing base of the Peninsular Range in the western Sonoran Desert. Using Recovery Units and critical habitat units or Tortoise Conservation Areas as a guide, approximately 55% of Tortoise Conservation Areas are in the Mojave Desert and 45% are in the western Sonoran Desert (USFWS 2015).

The boundaries of the historic geographic range of *G. agassizii* have contracted along the margins and fragmented in the interior, with losses from agricultural, urban, energy, and military developments, as well as transportation corridors and roads. Hundreds of square kilometers of tortoise habitat have been lost in the southwestern Mojave Desert, but do not yet show on maps of habitat (e.g., Nussear et al. 2009; Murphy et al. 2011). Similarly, major parts of valleys once supporting high densities of tortoises have become urban, ex-urban, and industrialized; examples include Indian Wells, Antelope, Victor, Apple, Chuckwalla, and Las Vegas valleys in California and Nevada, and St.

George in Utah. Averill-Murray et al. (2013) modeled potential linkages between Tortoise Conservation Areas (critical habitat units).

Gopherus agassizii can be found in unusual places and ecosystems outside its geographic range. Captives frequently escape, are released or translocated (unauthorized) without regard to sites of origin. Animals found in the Cape Region of Baja California Sur, Mexico, were mistakenly described as the purported new species, *G. lepidocephalus* (Ottley and Velázques Solis 1989). In addition, mass authorized translocations have occurred (see summaries in Murphy et al. 2007). In a study of the genetics of 180 captive tortoises in three cities in Arizona within the range of *G. morafkai*, more than 40% were *G. agassizii* from the Mojave Desert or were hybrids (Edwards et al. 2010). In a similar study of 106 captive tortoises from three desert communities in the Mojave Desert, the genotypes of only 44% were *G. agassizii* of local origin, 55% were assigned to one of seven *G. agassizii* genetic units from outside the local area, and one tortoise was genotyped as *G. morafkai* (Edwards and Berry 2013).

Population Genetics. — Murphy et al. (2007) provided the first analysis of population differentiation across the landscape to assess the correspondence between Recovery Units in the 1994 Recovery Plan and genetic patterning. Their analysis used mtDNA sequences from 125 Desert Tortoises and 16 microsatellite loci of 628 animals collected from 31 sample sites. Analyses recovered substantial differentiation within the Western Mojave Recovery Unit. However, the authors had very limited sampling in Nevada and Utah.

Hagerty and Tracy (2010) performed a similar assessment using 20 different microsatellite loci with larger sampling in Utah, Nevada, and the northern deserts of California, but relatively poor sampling in the western and southern part of the species' range; they recovered an alternative pattern. Later, Hagerty et al. (2011) applied landscape genetic analyses to those data and recovered patterns that were largely compatible with those of Murphy et al. (2007) when considering sample sizes; larger sample sizes in northern areas for Hagerty and Tracy (2010) and southern areas for Murphy et al. (2007) yielded more details. The U.S. Fish and Wildlife Service's (USFWS) Recovery Office assumed that a strategy of random sampling would outperform strategic sampling of populations, and therefore relied on the Hagerty and Tracy (2010) study. Rico et al. (2015) modeled the two sampling strategies and discovered that strategic population sampling vastly outperformed random sampling, thereby giving credence to the study of Murphy et al. (2007).

Recently, Sánchez-Ramírez et al. (2018) evaluated 6,859 single nucleotide polymorphisms from 646 tortoises to reassess genetic patterns. Their results, which used newer genetic methods, were largely consistent with those of Murphy et al. (2007) in identifying significant genetic substructuring in the western Mojave Desert. Their analyses also identified 12 highly differentiated outlier genes likely involved in adaptations.

On a microgeographic scale, Desert Tortoises at a study area in the central Mojave Desert exhibited weak genetic structure (Latch et al. 2011). Analyses identified two subpopulations with low genetic differences and evidence of gene flow. Topography, specifically slope (the predominant factor) and roads, influenced local gene flow, with the changes considered to be recent.

Habitat and Ecology. — The geographic range of *G. agassizii* covers parts of three deserts and mountain ranges within and along their boundaries. Tortoises live in habitats ranging from 200 m to about 1570 m asl and in several vegetation associations (Weinstein 1989; Rautenstrauch and O'Farrell 1998; Longshore et al. 2003; Keith et al. 2008; Berry et al. 2006, 2014a). Tortoises require topography, geological features, and soils suitable for cover and construction of shelters—burrows or dens, under rocks or rock crevices, and in banks or walls of ephemeral washes (Woodbury and Hardy 1948; Burge 1978; Rautenstrauch and O'Farrell 1998; Andersen et al. 2000; Berry et al. 2006; Mack et al. 2015).

Habitat Use. — Cover of shrubs or trees is essential for protection from extremes of temperature, precipitation, and predators. Over 70% of cover sites (burrows, pallets) occur beneath shrubs, with the larger shrubs or trees preferred (Burge 1978; Berry and Turner 1986). The vegetation of shrubs, trees, cacti, and perennial grasses differs regionally within the Mojave, southern Great Basin, and western Sonoran ecosystems. Regional differences are based on timing and amounts of precipitation, numbers of freezing days, and other climatic variables and topographic features (Rowlands et al. 1982; USFWS 1994, 2011). For example, throughout the geographic range, most rainfall occurs in fall and winter. However, in the eastern and northeastern Mojave and western Sonoran deserts, summer rainfall is important, resulting in shifts in vegetation types. Similarly, numbers of annual freezing days are high in the north (e.g., Desert Game Range, Nevada: 126 days) dropping to just a few days in the southern part of the range in the western Sonoran Desert (1 to 16 days) (USFWS 1994).

Within the Mojave Desert ecosystem, tortoises occur in several vegetation associations. At lower elevations or adjacent to dry lake beds, saltbush associations (*Atriplex* spp.) and other members of the Chenopodiaceae provide habitat. The most common associations contain creosote bush (*Larrea tridentata*), usually with white bur-sage (*Ambrosia dumosa*) or cheesebush (*A. salsola*) and several other species of shrubs, cacti, and perennial grasses. With increasing elevation, multiple species of woody shrubs and tree yuccas (Joshua tree, *Yucca brevifolia*, and Mojave yucca, *Y. schidigera*) become more common, with blackbrush (*Coleogyne ramosissima*) associations

Figure 8. Habitats of *Gopherus agassizii*. **a.** Ecotone between Mojave and Great Basin deserts, Utah, Upper Virgin River Recovery Unit. Photo by Ann McLuckie. **b.** Chemhuevi Valley, Colorado Desert, California (creosote bush-ocotillo). Photo courtesy of U.S. Geological Survey. **c.** Soda Mountains, central Mojave Desert, California, Western Mojave Recovery Unit. Photo courtesy of U.S. Geological Survey. **d.** Northwestern Mojave Desert, California, Western Mojave Recovery Unit. Photo by Freya Reder. **e.** Eastern Mojave Desert, California, after summer rains, Colorado Desert Recovery Unit (formerly Eastern Mojave Recovery Unit). Photo by Betty L. Burge. **f.** Chuckwalla Valley, California, Colorado Desert Recovery Unit (formerly Eastern Colorado Recovery Unit). Photo by Freya Reder. **g.** Mojave National Preserve, California, Eastern Mojave Recovery Unit. Photo by Freya Reder. **h.** Desert Tortoise Research Natural Area, California, Western Mojave Recovery Unit. Photo by Kristin H. Berry.

present in higher elevations. In the northeast corner of the geographic range, in the Red Cliffs Desert Reserve in Utah, vegetation is transitional between Mojave Desert and Great Basin, combined with sand dune systems. Sand sage (*Artemisia filifolia*), creosote bush, blackbrush, Nevada ephedra (*Ephedra nevadensis*), and big galleta (*Hilaria rigida*) are common (McLuckie et al. 2002).

The western Sonoran Desert is a warmer, hotter desert with a higher proportion of precipitation occurring in summer. This desert is also characterized by creosote bushes, but a major difference is the presence of microphyll woodlands of blue palo verde (*Parkinsonia florida*), smoke tree (*Psorothamnus spinosus*), and ironwood (*Olneya tesota*) in ephemeral stream channels separated by desert pavements or open desert with ocotillo (*Fouqueria splendens*) mixed with creosote bush, other shrubs, and cacti (Berry 1984).

More detailed descriptions of vegetation are in the first Recovery Plan and appendices, as well as in publications of individual field studies (USFWS 1994). Some sites have rich assemblages of shrubs, trees, cacti, and native bunch grasses, whereas others are low in shrub and grass diversity. Tortoises occur in very low densities or are absent where shrub cover is sparse, precipitation is low and timing erratic, and annual food plants are available only intermittently (e.g., the lower elevations in Death Valley). They are also in low densities in moderately to severely disturbed areas, regardless of desert or region (e.g., Bury and Luckenbach 2002; Keith et al. 2008; Berry et al. 2013).

Nussear et al. (2009) developed a quantitative habitat model using 16 layers of environmental data that were then joined with records on tortoise presence. Their model described the predicted habitat potential throughout the geographic range. This useful model does not exclude lands where tortoises no longer occur because of habitat lost to urbanization, agriculture, and other anthropogenic activities resulting in deteriorated habitat.

Adaptations. — Tortoises have several adaptations or exaptations for dealing with environmental extremes found within the geographic range, including behavioral responses, such as use of the burrow, cave, or den to escape extremes in environmental temperatures (e.g., Woodbury and Hardy 1948; Mack et al. 2015). They also exhibit physiological, hematologic and plasma biochemical responses for coping with lack of water, food, and shelter, and reduction in annual output of eggs in response to drought. We review these subjects below (Morafka and Berry 2002).

The Tortoise Burrow. — Tortoises spend >90% of their lives inactive and underground in burrows, pallets, caves, or other cover. For example, in the northern part of the range in Rock Valley, Nevada, where numbers of freezing days/year are high, Nagy and Medica (1986) reported that tortoises spent 98.3% of time underground. We define pallets as scrapes, often under a shrub, potentially the beginning of a burrow, covering only part of the shell; they are often used in spring as a temporary refuge. Burrows are dug in soil, are often 3 m or more in length with a soil cover of a meter or more in the deepest part, and have a downward slope. Dens occur in areas with well-developed calcic layers, are often in washes, the tunnels are generally horizontal and may have side rooms and chambers that can be used by multiple tortoises. Caves are similar to dens, larger than the tortoise, with an arched roof, and are not the size and shape of a tortoise. Use of burrows and dens allows tortoises to shelter during times of extreme temperatures and when there is a lack of water and food, and when in a deep burrow, tortoises reduce their metabolic rates (Henen et al. 1998).

Types of cover site or shelter (pallet, burrow, cave, den) differ throughout the geographic range and depend on topography, geology, and soil types as well as seasons (Woodbury and Hardy 1948; Bulova 1994; Berry et al. 2006). Regardless of type of cave or burrow, the opening for adult sites is half-moon shaped, curved side up, unless it has been altered by another species of animal (Woodbury and Hardy 1948). Wild juvenile and small immature tortoises also use small, half-moon shaped burrows matching their sizes at several Mojave and western Sonoran Desert sites (Berry and Turner 1986). In a study of head-started tortoises, most neonates (83%) hatched in pens constructed their own burrows within a few days of emergence from the nest; others used rodent burrows or shared artificial burrows constructed for adults (Morafka et al. 1997).

In the northern part of the range, caves and dens in the walls of ephemeral stream beds are more common than elsewhere. They occur in old alluvial deposits with consolidated gravels and sand and with well-developed calcite cementation (Woodbury and Hardy 1948; Mack et al. 2015). These retreats can be several meters in length and used by multiple tortoises. In the northeastern Mojave Desert, caves or dens were usually 2.4 to 4.6 m in length, occasionally 6.1 to 9.1 m with multiple side tunnels and rooms supporting as many as 17 tortoises simultaneously (Woodbury and Hardy 1948). Tortoises can use a combination of burrows, caves, and dens (Woodbury and Hardy 1948; Mack et al. 2015). In contrast, in the northwestern, western, and southern Mojave and Colorado deserts, tortoises primarily use burrows (Berry et al. 2006, 2013, 2014; Krzysik 2002; Harless et al. 2009).

Most cover sites were found beneath the canopies of large shrubs, regardless of size of the tortoise (Burge 1978; Berry and Turner 1986). At the Arden site in Nevada, Burge (1978) reported that 72% of large and small burrows were placed under shrubs with the greatest shade-giving properties (i.e., catclaw, *Senegalia greggii* [*Acacia greggii*], Mojave yucca and creosote bush). For wild juveniles and small immature tortoises, 79% of burrows were under canopies or basal branches of live or dead shrubs; creosote and white bur-sage were the most common species (Berry and Turner 1986).

The burrows of head-started juvenile tortoises in pens also were under the canopies of shrubs (Wilson et al. 1999a).

Tortoises use more than one burrow or cave per season or year (Woodbury and Hardy 1948; Burge 1978; Bulova 1994; Harless et al. 2009). The patterns of shelter type and tunnel length varied by season (Woodbury and Hardy 1948; Rautenstrauch et al. 2002), with tortoises tending to use shallower sites in spring and deeper and longer tunnels in fall and winter. Tortoises exhibited fidelity to specific burrows, repeatedly returning to burrows used from season to season (Burge 1978). If the burrow was damaged or collapsed, the tortoise would either rehabilitate it or construct another burrow adjacent to the collapsed burrow. Freilich et al. (2000) reported fidelity to the vicinity of a site, rather than to a specific burrow (i.e., 75% of all captures were within 300 m of a previous location). Woodbury and Hardy (1948) noted that tortoises tend to stay in familiar areas.

Tortoise dens, caves, and burrows are potentially important as home sites and temporary refuges from extremes of temperature or predation for many species of vertebrates and invertebrates. Woodbury and Hardy (1948) physically entered dens occasionally and thus were able to learn more about commensals and predators than the incidental observations reported more recently by others. We do not know the extent of use by commensals or transients. However, the following compiled list, while not comprehensive and excluding invertebrates, suggests that burrows, dens, and caves occupied by tortoises are critically important to desert ecosystems. They are shared by many other vertebrates, including mammals, birds, and reptiles.

Lizards observed in burrows or dens include the Gila Monster, *Heloderma suspectum* (Gienger and Tracy 2008), Desert Spiny Lizard (*Sceloporus magister*), Long-nosed Leopard Lizard (*Gambelia wislizenii*), and Desert Banded Gecko (*Coleonyx variegatus*) (Woodbury and Hardy 1948; Walde and Currylow 2015; Walde et al. 2015; Agha et al. 2017). Snakes observed in burrows or dens include the Spotted Night Snake (*Hypsiglena torquata*), Coachwhip (*Masticophis flagellum*), and five species of Rattlesnake: Sidewinder (*Crotalus cerastes*), Great Basin (*C. oreganus lutosus*), Red Diamond (*C. ruber*), Speckled (*C. mitchellii*), and Mojave (*C. scutulatus*) (Woodbury and Hardy 1948; Burge 1978; Lovich 2011; Walde et al. 2014; Agha et al. 2017; Berry et al., pers. obs.). Birds observed in dens or burrows include the Burrowing Owl (*Athene cunicularia*), Cactus Wren (*Campylorhynchus brunneicapillus*), Roadrunner (*Geococcyx californianus*), and Horned Lark (*Eremophila alpestris*) (Woodbury and Hardy 1948; Burge, 1978; Walde et al. 2009; Agha et al. 2017). Mammals observed were the Desert Woodrat (*Neotoma lepida*), Merriam's Kangaroo Rat (*Dipodomys merriami*), White-footed Mouse (*Peromyscus* spp.), Antelope Ground Squirrel (*Ammospermophilus leucurus*), Desert Cottontail (*Sylvilagus audubonii*), and Black-tailed Jackrabbit (*Lepus californicus*) (Woodbury and Hardy 1948; Burge 1978; Agha et al. 2017), as well as Desert Kit Fox (*Vulpes macrotis*; Berry, pers. obs.) and American Badger (*Taxidea taxus*) (Germano and Perry 2012).

In a camera study of tortoise burrows in the western Colorado Desert, Agha et al. (2017) substantially added to the list of vertebrates observed in or near the entrances of tortoise burrows with several additional species of mammals, birds, and reptiles. Excluding large vertebrates (e.g., Bighorn Sheep, Black Bears), additional mammals seen were Desert Kangaroo Rat (*Dipodomys deserti*), Desert Pocket Mouse (*Chaetodipus penicillatus*), and California Ground Squirrel (*Otospermophilus beecheyi*). Additional birds seen were Rock Wren (*Salpinctes obsoletus*), California Towhee (*Melozone crissalis*), Black-throated Sparrow (*Amphispiza bilineata*), Loggerhead Shrike (*Lanius ludovicianus*), Chukar Partridge (*Alectoris chukar*), Bewick's Wren (*Thryomanes bewickii*), California Quail (*Callipepla californica*), White-crowned Sparrow (*Zonotrichia leucophrys*), California Thrasher (*Toxostoma redivivum*), Common Raven (*Corvus corax*), and Verdin (*Auriparus flaviceps*). Additional reptiles seen were Great Basin Whiptail (*Aspidoscelis tigris tigris*), Western Side-blotched Lizard (*Uta stansburiana*), Sagebrush Lizard (*Sceloporus graciosus*), and Long-nosed Snake (*Rhinocheilus lecontei*).

Seasonal and Daily Activities. — Ambient temperatures above and below ground are an important factor in determining activity, but not the only factor. Tortoises primarily regulate body temperature by behavior, avoiding excess heat and cold by retreating to burrows, pallets, and dens. Early studies indicated that body temperatures of active tortoises were between 19.0 and 37.8°C, and that tortoises retreated to shade at 37–38°C; the critical thermal maximum of internal body temperatures was between 39.5 and 43.0°C, and the lethal maximum was 43.0°C (Brattstrom 1961, 1965). At the lower limit of the lethal range (39.5°C), a tortoise will produce copious amounts of saliva, which spread along the neck and axillary area in an effort at cooling (McGinnis and Voigt 1971).

Temperatures inside burrows and dens are cooler than on the mound or outside. Year-round temperatures 5.3 m inside deep dens on the Beaver Dam Slope of Utah (northeastern Mojave Desert) were between 10.0 to 15.6°C (Woodbury and Hardy 1948). In a study in the central Mojave Desert, Mack et al. (2015) compared annual temperatures under shrubs, and at the entrance to and inside caves and burrows dug in soils. Average maximum summer and winter temperatures ca. 1.5 m inside 24 caves were 33.7°C (range = 29.2–38.3°C) and 13.5°C, respectively. They did not place temperature probes as deeply as Woodbury and Hardy (1948) did to avoid disturbing the tortoises. Tunnel length had the greatest influence on temperatures: they were warmer in winter and cooler in summer compared to outside the burrow or cave

(Mack et al. 2015). Cover sites in consolidated gravels and soils were warmer than caves in summer, but not significantly cooler in winter.

The microhabitats of burrows and dens and length of tunnels affected humidity and thus water loss (Bulova 2002). Longer burrows with smaller entries tended to be cooler and more humid. Wilson et al. (2001) showed experimentally that hibernating juveniles lost body mass 1/20th as quickly as active juveniles. Juveniles in shorter burrows in the field lost body mass faster than those in the longer tunnels.

Time spent underground or in above-ground activities differed by year, individual, sex, size, and region (e.g., Berry and Turner 1986; Zimmerman et al. 1994; Rautenstrauch et al. 1998; Nussear et al. 2007; Agha et al. 2015a). All seasonal and daily activities were influenced by temperature tolerances of tortoises, temperature extremes in the environment, timing and amounts of precipitation, availability of free water to drink, and available forage (Woodbury and Hardy 1948; Brattstrom 1961; Nagy and Medica 1986; Zimmerman et al. 1994; Henen et al. 1998; Rautenstrauch et al. 1998).

The general pattern for seasonal activity involved emergence from hibernation or brumation in late winter or early spring, followed by above-ground foraging (when forage was available) and interacting with other tortoises, and by retreat to burrows, pallets, dens, and rock shelters in late spring, with occasional emergence during summer in June and July early in the day or late in the evening. Starting in August and September, tortoises emerged for short periods and traveled; they were active intermittently until mid- to late October or November, when they retreated underground for hibernation (Woodbury and Hardy 1948; Rautenstrauch et al. 2002). However, tortoises sometimes emerged from underground retreats to drink free water and change shelter sites at any time of year; they were especially likely to emerge with rainfall events during or after droughts (Medica et al. 1980; Henen et al. 1998). Males tended to be more active than females (Agha et al. 2015a).

Surface and air temperatures affected daily and seasonal emergence from and retreat to burrows for adult tortoises (Woodbury and Hardy 1948; McGinnis and Voigt 1971; Zimmerman et al. 1994). In late winter and early spring, tortoises sometimes emerged mid-morning and were active until late afternoon. However, from spring until October or November, above-ground activity became bimodal, with tortoises emerging earlier in the morning from burrows and retreating earlier to burrows, emerging again in afternoon or evening. In summer, some tortoises emerged in late afternoon or evening and remained above ground all night when burrow temperatures were warmer than the outside surface temperatures. However, not all tortoises emerge once or twice daily during the active seasons.

Small wild juvenile tortoises of <60 mm CL were observed to be active at significantly lower temperatures in March, April, May, and June than larger juveniles and small immature tortoises regardless of the month of observation in spring, e.g., 17.2°C (range 10.1–25.6°) in March (Berry and Turner 1986). Some head-started juveniles in pens were also active in winter (Wilson et al. 1999b). The small size and ability to be active at cold temperatures may have allowed small tortoises to be active on more days per season and year than observed for adults.

Rainfall, available water for drinking, and available, high quality forage strongly influenced seasonal and daily activities. In years when precipitation was above the long-term normal for the season and forage was plentiful or otherwise available, tortoises were more active above ground than during droughts (Henen et al. 1998; Duda et al. 1999; Freilich et al. 2000; Krzysik 2002; Jennings and Berry 2015). During drought years, home range size, numbers of burrows used, and distances traveled per day decreased substantially.

Physiology, Water Balance, and Energy Flow. — Thermoregulation, water balance and osmoregulation, metabolism, and responses to drought (deprivation of water and food) are critical to survival of tortoises in harsh environments. Henen et al. (1998) summarized several years of study concerning the effects of climate, specifically variation in rainfall and food availability, on metabolic rates and water flux rates in adult tortoises in western, eastern, and northeastern regions of the Mojave Desert. Availability of water (and forage) varied substantially from year to year and thus affected metabolic rates. Water flux-rates and availability of free water for drinking also varied highly. In years of high rainfall, metabolic rates and water flux-rates were higher than in dry years. Metabolic rates in males were higher than in females, possibly because of larger home ranges and courting females. In contrast, the annual field metabolic rate of females correlated positively with the number of eggs laid in spring. During droughts when forage and water were unavailable, metabolic rates and water influx rates were low. While some variations were due to season, rainfall was the critical factor in rates of metabolism and rates of water influx. Differences in region were due to differences in rainfall and with more summer rainfall occurring at the eastern and northeastern sites in the Mojave Desert. Overall, the results indicated that tortoises have both physiological and behavioral flexibilities critical to surviving droughts and periods of rainfall and food abundance.

Another important adaptation to drought and variability in rainfall involves drinking free water during rain, voiding their bladders, and rapidly increasing their mass (Peterson 1996). When droughts occur, tortoises can lose up to 40% of initial body mass. They can resorb water from their bladders and store wastes (sodium, chloride, and urea) both in blood plasma and the bladder.

Figure 9. Juvenile *Gopherus agassizii* eating lichen in the Red Cliffs Desert Reserve, Utah. Photo by Cameron Rognan.

Figure 10. Adult *Gopherus agassizii* eating blue dicks (*Dichelostemma apitatum*) in the Western Mojave Recovery Unit. Photo courtesy of Desert Tortoise Preserve Committee.

Tortoises may also void their bladders when handled or when approached by a human. Agha et al. (2015b), in a study of 42 tortoises captured 1008 times in the western Sonoran Desert, fonnd that tortoises voided on 8.2% of occasions. Factors contributing to higher probabilities of voiding were increased handling time regardless of size or sex and increased precipitation for juveniles and females. Models indicated a negligible effect of voiding behavior and sex on survivorship.

Christopber et al. (1999) reported seasonal differences in hematologic and plasma biochemical responses of adult tortoises in a five-year study in three Mojave Desert regions (western, eastern, northeastern). The authors reported yearly and seasonal variation in most variables associated with hibernation, the reproductive cycle, and seasonal rainfall. The effects of water and food intake were reflected in body weight and biochemical changes in blood plasma (decreased blood urea nitrogen [BUN] and increased uric acid), nutrient intake (increased concentrations of glucose, total protein, albnmin, phosphorus, cholesterol, iron, and potassium concentrations), and increased metabolic activity (increased alkaline phosphatase, aspartate amiaotransferase, alanine aminotransferase activities). The most sensitive indicator of food and water intake or lack was BUN. Seasonal changes, particularly during the dry summer or fall, were typical of decreased hydration: increased BUN, osmolality, electrolytes, and anion gap, and decreased body weight and total CO_2. Males and females differed in packed cell volume, aspartate transaminase activity, and concentrations of hemoglobin, cholesterol, triglycerides, calcium, and phosphorus.

Wild tortoises that were moribund from dehydration and starvation during or following droughts exhibited clinical signs, such as weight loss and abnormal behaviors (Berry et al. 2002). These tortoises also exceeded the range or 95th percentiles for four or more hematological and plasma biochemical analytes for healthy tortoises (Christopher et al. 1999). Hematologic abnormalities were low packed cell volumes and heterophil counts, and plasma biochemical analytes were hypocalcemia, hyperbilirubinemia, marked azotemia, and elevated sodium and chloride (Berry et al. 2002). Gross necropsies revealed differences in juveniles vs. the larger tortoises. Shells of juveniles were softer and more pliable, muscle mass was below normal, and osteopenia of some bones was evident. Handling and certain research activities also had detrimental effects, such as crowding of jnveniles in headstart pens.

Foraging Behavior and Diet. — Early field studies revealed that tortoises were herbivorous, foraged in spring and fall when food was plentiful, and consumed dry grass in summer (Woodbnry and Hardy 1948). Grasses were the native bush muhly (*Muhlenbergia porteri*) and the non-native red brome and cheat grass (*Bromus madritensis* ssp. *rubens* and *B. tectorum*); the non-native redstem filaree (*Erodium cicutarium*) was observed to be eaten in winter. During spring, tortoise ate wildflowers until domestic sheep herds reduced availability. Field biologists have not observed tortoises to eat shrubs (Woodbury and Hardy 1948; Nagy and Medica 1986).

The need to know what tortoises were eating in greater detail came with concerns about conflicts between livestock grazing and tortoises and federal listing of the tortoise population on the Beaver Dam Slope (Berry 1978; USFWS 1980). This conflict over food availability in spring was first described by Woodbnry and Hardy (1948) and was later observed and studied elsewhere in the Mojave Desert (Berry 1978; Avery and Neibergs 1997; Oftedal 2002; Oftedal et al. 2002; Jennings and Berry 2015).

Tortoises are selective in choice of food items, when conditions allow for it. In Rock Valley, Nevada, tortoises kept in large pens ate only four of >25 species of forbs and grasses available (Nagy and Medica 1986). Burge and Bradley (1976) observed foraging behavior of wild tortoises in late winter and spring and reported on species and plant parts eaten. Subsequent research involved counting every bite taken as well as plant parts and species available (e.g., Avery and Neibergs 1997; Henen 2002a; Oftedal et al. 2002; Jennings and Berry 2015). Results indicated that tortoises select species and plant parts, and that favored species differed by season, region, and availability. In late winter and spring of a highly productive year, tortoises prefer natives to non-natives, forbs to grasses, and succulent green plants to dry plants. Choices of plant species tracked the phenology of species available during spring (Jennings and Berry 2015). In drought years when species and biomass of plants were limited, some tortoises consumed cacti (Turner et al. 1984).

The list of plant groups eaten included winter and summer annuals, a few herbaceous perennials, succulents (cacti), and flowers and leaves of a few perennial shrubs. Tortoises favored species of forbs or herbaceous perennials from several plant families: Asteraceae, Boraginaceae, Cactaceae, Fabaceae, Malvaceae, Nyctaginaceae, Onagraceae, and Plantaginaceae (Burge and Bradley 1976; Avery and Neibergs 1997; Jennings and Berry 2015).

Oftedal (2002) and Oftedal et al. (2002) addressed why tortoises were selective in choices of plants and developed the concept of potassium excretion potential (PEP). Many plant species are high in potassium which requires loss of water and nitrogen to excrete; potassium is potentially toxic. The authors predicted that tortoises would choose plants high in water and protein but low in potassium. In a study of plants consumed or by-passed by juveniles in head-start pens during a year of high rainfall and thus abundant forbs, juveniles selected plants and plant parts high in water and nitrogen and low in potassium (Oftedal et al. 2002). The juveniles bypassed the abundant non-native Mediterranean grasses, *Schismus* spp.

Non-native forbs (e.g., redstem filaree) and grasses (Mediterranean grasses, red brome, and cheat grass) invaded and became established throughout the Mojave Desert and form >60% of the biomass in years with above normal precipitation and >90% in drought years in tortoise critical habitat units in the western, central and southern regions of the Mojave Desert (Brooks and Berry 2006). Other non-native species, such as Sahara or African mustard (*Brassica tournefortii*), invaded and proliferated rapidly in the western Sonoran Desert and appear to be displacing native annual forbs (Berry et al. 2014b).

The nutrient value of native vs. non-native forbs and grasses was the subject of several experiments with tortoises in a range of sizes (Nagy et al. 1998; Hazard et al. 2009, 2010). In the experiments, the forb species were the native *Malacothrix glabrata* and non-native redstem filaree, and the grasses were the native and perennial sand rice grass (*Stipa* [*Oryzopsis*] *hymenoides*) and non-native annual Mediterranean grasses (*Schismus barbatus*). The forbs were higher in dry matter and energy digestibilities than the grasses. The grasses provided little nitrogen and tortoises lost more water than they gained in processing them. Hazard et al. (2009) reported that juveniles gained weight rapidly when eating forbs but lost weight and body nitrogen when eating grasses. Dietary nitrogen might have limited growth of juveniles. Tortoises gained more minerals from forbs than from grasses (Hazard et al. 2010). When eating grasses, the tortoises lost phosphorus and only gained the nutrients calcium and magnesium at low rates.

In several experiments, individual tortoises did not thrive or became ill when fed grasses (Hazard et al. 2009, 2010). Two animals offered the non-native Mediterranean grasses became ill and died early in the study and two others refused to eat. Drake et al. (2016) tested effects of five diets—native forbs, native six weeks grass (*Festuca octoflora*), invasive red brome grass, and native forbs combined with either native or invasive grass—on growth, body condition, immunological responses, and survival on 100 captive neonate and juvenile tortoises. Tortoises fed native forbs had better body condition, growth, immune functions, and higher survival (>95%) than those fed the grass diets. About one-third of tortoises fed only grass diets died or were removed for poor condition. Tortoises fed the mixed forb and grass diet survived and were in good condition. In addition, tortoises consuming red brome were observed with persisting injuries to their jaws from seeds, and seeds were also embedded in a nostril and corner of an eye (Medica and Eckert 2007). Drake et al. (2016) made similar observations and noted inflammation. Collectively, these studies point out the importance of selected native forbs to the health and overall condition of tortoises. Tortoises also consume non-plant material: dirt and sand at apparent salt licks, rocks, bone, dead lizards, and caterpillars (Marlow and Tollestrup 1982; Avery and Neibergs 1997; Walde et al. 2007a; Jennings and Berry 2015).

Home Range, Site Fidelity, and Movements. — Sizes of home ranges for wild, free-ranging tortoises varied by type and length of study, sample sizes, sex, numbers of captures, location, and analytical techniques (e.g., Woodbury and Hardy 1948; O'Connor et al. 1994; Duda et al. 1999; Freilich et al. 2000; McLuckie and Fridell 2002; Harless et al. 2009, 2010; Franks et al. 2011). Most reports were for wild, free-living adult tortoises, involved small samples, and were confined to a few years. Woodbury and Hardy (1948) reported that home ranges were small, covering ca. 4 to 40 ha.

In studies where sizes of home range for both male and female adult tortoises were derived from radio-transmittered individuals, males had larger home ranges than females (Burge 1977a; O'Connor et al. 1994; Duda et al. 1999; Freilich et al. 2000; Harless et al. 2009). For example, Harless et al. (2009), in a study of home range and movements in the central Mojave Desert, described home range sizes of 43–49 ha for males and 16–17 ha for females using minimum convex polygons. Home ranges of juveniles were smaller than those of adults (Eric Coombs, unpubl. data).

Home range sizes potentially increased in wet vs. dry years (Burge 1977a; Duda et al. 1999; Franks et al. 2011). Similarly, movements were more limited during drought years than in years with higher precipitation and forage production, e.g., years with El Niño Southern Oscillation (Duda et al. 1999; Freilich et al. 2000; Ennen et al. 2012). O'Connor et al. (1994) noted that home ranges were not exclusive for individuals, in contrast to a study by Harless et al. (2009), who reported that home ranges of males overlapped but those of females did not. Tortoises exhibited fidelity to home ranges and activity areas; even after a fire when parts of home ranges were burned, tortoises continued to use the same areas (Drake et al. 2015; Lovich et al. 2018a).

Female Reproductive Cycle. — Female and male reproductive cycles are not synchronized (Rostal et al. 1994; Lance and Rostal 2002). In April, after emergence from hibernation, plasma estradiol, testosterone, corticosterone, and lipids in females were elevated but declined to low levels after eggs were laid. When nesting occurred in spring, progesterone levels increased, but rapidly decreased to baseline after eggs were laid. In summer, plasma levels of estradiol, lipids, and calcium (indicating vitellogenin levels) increased and were associated with vitellogenesis and growth of ovarian follicles. Ovarian follicles increased to ovulatory size before hibernation. Testosterone levels were high (mean 6.22 ng/mL) during spring courtship (April), declining to a mean of 0.37 ng/mL at the end of the nesting period (July), but again rose between July and October during the late summer and fall courtship and mating period.

Size and age at first reproduction vary across the geographic range. However, long-term studies have not been conducted for wild, free-ranging female tortoises for all regions. Woodbury and Hardy (1948) estimated age at first reproduction as 15–20 years in the northeastern Mojave Desert, whereas Turner et al. (1987) estimated 12 to 20 years for females in the eastern Mojave Desert, drawing on a multi-year study to develop a life table for the species. Curtin et al. (2009), in a study based on skeletochronology, estimated that females from the western Mojave Desert reached sexual maturity at 17–19 years. Medica et al. (2012), in a 47-year study of tortoises in 9-ha pens in the northeastern Mojave Desert, estimated sexual maturity to occur between 16 and 21 years (average 18.8 years) and at a minimum size of about 190 mm CL. Turner et al. (1987) treated size at first reproduction as 185 mm CL; they reported a female with eggs at 178 mm CL but four other small females (182–186 mm CL) did not produce eggs. In the far northern part of the range in Nevada, the smallest tortoise to produce eggs was 209 mm CL; 11 smaller tortoises estimated to be 15–26 years old did not produce eggs (Mueller et al. 1998). Generation time for *G. agassizii* has been estimated to be approximately 20–25 years (Turner et al. 1987; USFWS 1994), but this appears to need revision upwards based on the late age of maturity and high survivorship and longevity of adults.

Females place nests within the den or burrow, on the burrow mound, in a pallet, and under shrubs (Woodbury and Hardy 1948; Roberson et al. 1985; Turner et al. 1986; Baxter et al. 2008; Ennen et al. 2012; Lovich et al. 2014a; Sieg et al. 2015). Females dig nests within their normal activity areas but show no evidence of fidelity within or between seasons regarding locations (Lovich et al. 2014a). Oviposition occurs from April through July, depending on region, for first, second, and third clutches (Turner et al. 1986, 1987; Wallis et al. 1999; McLuckie and Fridell 2002; Ennen et al. 2012; Lovich et al. 2018a). Nesting may occur earlier in the western Sonoran Desert — Lovich et al. (2018a) noted nesting April 6 at a study site in Joshua Tree National Park, two weeks earlier than published previously. Lovich et al. (2012) also described how the timing and appearance of shelled eggs on X-rays appeared to be affected by inter-annual variations in climate, e.g., appearance of clutches was later in cool years.

Some females showed nest-guarding behaviors to Gila Monsters and humans (Henen 1999; Gienger and Tracy 2008; Agha et al. 2013). Beck (1990) studied Gila Monsters in southwestern Utah; 29% of their scats and observations were of predation on tortoise nests. Gienger and Tracy (2008) reported two different observations of Gila Monsters entering shelters with a female tortoise and egg shell fragments later observed at the nest. In one case, the female tortoise bit and chased the lizard. Henen (1999) reported that a 182 mm CL female rammed his leg and field equipment with her epiplastron a few days after laying her first clutch of eggs. In another case report, Agha et al. (2013) described a female tortoise twice resisting a researcher's attempts to remove her from her burrow, which contained a nest.

Few reports are available for incubation of eggs in wild, unconfined, or unprotected settings. Eggs of one wild female hatched after 98–101 days in southern Nevada (Burge 1977b) and of 12 wild females after 67–104 days with a mean incubation time of 89.7 days (±3.25 days SE) in southwestern Utah (McLuckie and Fridell 2002). Ennen et al. (2012) reported hatching from 74 to 100 days (mean, 84.6 days) at a site in the western Sonoran Desert. Incubation time was significantly longer in the first than in second clutches. Nest predation occurred commonly (Roberson et al. 1985; Turner et al. 1986; Ennen et al. 2012). Nests placed in cages to prevent predation may have hatched between 84 and 97 days in the eastern Mojave Desert (Roberson et al. 1985).

Dimensions and weights of eggs may vary by year, site, and whether measured directly or from radiographs. Measurements from radiographs may underestimate egg sizes slightly (Wallis et al. 1999). Burge (1977b) reported dimensions of four eggs from tortoises at Arden, Nevada (43.0 × 33.0, 45.0 × 36.0, 46.0 × 33.0, 47.0 × 34.0 mm). Using X-rays to measure eggs, Wallis et al. (1999) described egg sizes for first and second clutches and for two different years at Goffs (n = 137) in the eastern Mojave Desert and at the Desert Tortoise Research Natural Area (n = 330) in the western

Mojave Desert. Eggs from Goffs were generally about 40.9 mm in length and 34 mm in width, whereas those from the Desert Tortoise Research Natural Area females were about 45 mm in length and 37 mm in width. McLuckie and Fridell (2002) reported sizes of 81 eggs as having a mean length of 44.3 ± 0.33 mm SE (range 34–52) and mean width of 37.2 ± 0.26 mm SE (range 33–43) for tortoises from the Beaver Dam Slope, Utah. Ennen et al. (2012) reported mean width of eggs as 38.6 mm at a study area in the western Colorado Desert, and Lovich et al. (2018b) reported average x-ray egg widths of 36.5 ± 1.56 mm from a study area in Joshua Tree National Park, also in the Colorado Desert.

Site and body size of females can affect egg shape. In a comparative study of females from the western Mojave Desert in the Desert Tortoise Research Natural Area with females from the eastern Mojave Desert, the eastern females produced eggs that were significantly narrower and shorter than females from the western site, even after accounting for body sizes (Wallis et al. 1999).

The numbers of eggs laid per clutch range from 1 to 10, with females laying from 0 to 3 clutches per year (Turner et al. 1986; Mueller et al. 1998; McLuckie and Fridell 2002; Lovich et al. 2015). Studies undertaken at different sites and years described mean clutch sizes ranging from 3.25 to 5.91 eggs and clutch frequencies from 1.33 to 2.36 clutches/female/year (Turner et al. 1986; Mueller et al. 1998; Wallis et al. 1999; McLuckie and Fridell 2002; Bjurlin and Bissonette 2004; Baxter et al. 2008; Lovich et al. 2015, 2018b). At some sites, researchers reported that larger females produced larger clutches (Turner et al. 1986; Wallis et al. 1999; McLuckie and Fridell 2002) and females producing a single clutch laid larger eggs (Turner et al. 1986; Mueller et al. 1998). Clutch frequencies were correlated positively with carapace length (McLuckie and Fridell 2002), and annual fecundity was positively correlated with female size (Mueller et al. 1998; Wallis et al. 1999; McLuckie and Fridell 2002). Wallis et al. (1999) observed females at a western Mojave Desert site that produced fewer but larger eggs than females at an eastern Mojave site, and Sieg et al. (2015) reported that larger females produced larger eggs, but carapace length did not affect clutch size.

Timing and amounts of rainfall and the subsequent production of forbs and grasses consumed by tortoises likely affect one or more aspects of egg production and the effects may differ regionally. For example, precipitation occurred primarily in late fall and winter in the western Mojave Desert compared with precipitation occurring both in fall-winter and summer in the eastern Mojave (Turner et al. 1986). Environmental conditions in the previous year may affect egg production in a subsequent year, because ovarian follicles mature between July and October and the number maturing is dependent on available food and water (Henen 1997; Mueller et al. 1998). Henen (1997) also reported that the commitment of energy to eggs does not occur until the spring in which they are laid.

At a western Mojave location, females produced larger eggs, possibly increasing the chance of survival because of lack of summer rain (Wallis et al. 1999). In contrast, in the eastern Mojave Desert, eggs were smaller, possibly allowing the juveniles to take advantage of the summer rains and associated food sources. Also, in the eastern Mojave Desert, clutch frequencies were positively correlated with production of annual forbs and grasses (Turner et al. 1986), and Henen (1997) described how the paucity of spring annual plants contributed to lower egg production.

In the Colorado Desert, Lovich et al. (2015) reported that amounts of winter precipitation had no significant effect on clutch frequency or the percentage of reproducing females. Sieg et al. (2015) reported elevation to be a factor in a study of two sites in the northeastern Mojave Desert; females had larger egg volumes in first clutches at the higher elevation site than females at the lower elevation site. At the higher elevation site, precipitation was higher and values for species richness of shrubs, total cover of plants, and herbaceous plant biomass were all higher than at lower elevations.

Females appeared to use a breeding strategy intermediate between capital and income breeding with bet hedging (Henen 2002a, 2002b, 2004; Lovich et al. 2015). Desert Tortoises have shown the ability to relax or temporarily relinquish regulation of homeostasis regarding water, electrolytes, nitrogen, and energy. In field studies, females demonstrated extreme physiological tolerance and flexibility in their water and energy budgets (Henen 2002a). They reduced metabolic rates and produced eggs, even during periods of extreme droughts and lack of forage (Henen 2002b). Females exhibited characteristics of both capital and income breeders: they limited egg production during droughts and when body reserves were limited, acquired water and protein reserves prior to winter and used reserves to produce eggs, had full-sized follicles prior to hibernation, and ovulated prior to eating in spring (Henen 2002b). They also responded rapidly by producing more eggs when forage became available after hibernation. This mixed strategy constituted bet-hedging for reproducing in the extremes typical of desert environments. Lovich et al. (2015) provided an additional example with a study population in the western Sonoran Desert.

Turner et al. (1987), drawing on a multi-year study in the eastern Mojave Desert of egg production and nest successes, estimated that 93.9% of eggs were fertile, 93.4% were unbroken, and 62.9% were not destroyed by predators. Bjurlin and Bissonette (2004) described tracking success of 17 and 25 nests laid in 1998 and 1999, respectively, at a site in the southern Mojave Desert. Predation rates were high in 1998 (47% of nests), but less so in 1999 (12% of nests). The authors then protected nests with cages 70 days after incubation. Of the remaining 132 caged eggs, 81.6% and 83.0% hatched in 1998 and 1999, respectively. When ill and deformed neonates were excluded, the figures for normal neonates were 73.7% and 67.0% in 1998 and 1999, respectively. Ennen et al. (2012) described mean hatchling success (predation included) as 70.6% for the first clutch and 65.7% for the second clutch. Some eggs did not hatch, were infertile or nonviable, and a few hatchlings were ill or deformed in several studies (e.g., Turner et al. 1986; Bjurlin and Bissonette 2004; Ennen et al. 2012).

The sex of neonates was determined by temperatures during incubation in the nest (Rostal et al. 2002). In experiments, males were produced when incubation occurred at constant temperatures of ≤30.5°C, whereas females were produced at temperatures of ≥32.5°C. The pivotal temperature where sexes were in a 1:1 ratio was 31.3°C. Hatching success was high (90–100%) when temperatures ranged from 28 to 34°C and resulted in similar incubation times ranging from 68 to 89 days. When temperatures were lower or higher, survival was lower. Baxter et al. (2008), in a study of females in a head-starting enclosure in the central Mojave Desert, reported that early nests (22 May–2 June) were cooler and produced four all-male nests and two nests of mixed sexes. In contrast, six later nests (17 June–16 July) were significantly warmer and produced only females.

Adult female tortoises store sperm, potentially in the sperm-storage tubules within the albumen-secreting gland region of the oviduct (Palmer et al. 1998). In an experimental study, hatching success was 97.1% in females with sperm stored >2 years. Five of 12 clutches showed tentative evidence of multiple paternities. Davy et al. (2011) confirmed both polyandry and multiple paternities in clutches from females: of 28 clutches from 26 females with an average of six neonates per clutch, a minimum of 64% of females were polyandrous and a minimum of 57% of clutches had multiple sires.

Male Reproductive Cycle. — Testosterone primarily controls changes in the male cycle (Rostal et al. 1994; Lance and Rostal 2002). Testosterone levels were low when males emerged from hibernation and continued to decline until May, but then rose from late May to August and September, reaching a peak at a mean of 243.60 ng/mL, and then declined prior to hibernation. The low in testosterone levels (mean 18.37 ng/mL) occurred when females were nesting in May. Changes in the testes followed this cycle: when males emerged from hibernation, the seminiferous tubules were filled with debris from the previous cycle and by May the gonads were completely regressed. As summer progressed, mature spermatozoa appeared, and prior to hibernation in early fall, spermatogenesis was at a maximal level. Corticosterone levels were high when testosterone was high but higher than in females at any time of year. Body mass tracked these changes and was significantly higher from June to September than at other times during the year. The fall mating period may be more important than courtship activity in spring and may be associated with sperm storage in females (Palmer et al. 1998).

Table 2. Demographic data from early surveys of populations of *Gopherus agassizii*, primarily from 60-day spring studies on 2.59 km² plots in California, Nevada, Utah, and Arizona. Adults are defined as ≥180 mm carapace length. For most plots, data were summarized in Berry (1984), a compilation of plot data from 1948 through 1981. The population at Beaver Dam Slope population, Utah, was studied by Woodbury and Hardy (1948) and Hardy (1976), the population in the Pinto Basin, California, by Barrow (1979), and the population at Arden, Nevada, by Burge and Bradley (1976). Significance level: * = $p<0.05$.

Study area	Plot size (km²)	Year(s)	Study type	Total counts	Counts of adults	Counts of adults (per km²)	Sex ratio F:M	% adults: non-adults
Argus, CA	13.70	1971–1972	Year-long	47	35	2.6	25:10*	76:24
Fremont Valley, CA	2.59	1979	Spring, 60d	209	108	41.7	59:49	52:48
Desert Tortoise Research Natural Area (interior), CA	2.85	1981	Spring, 60d	186	134	47.0	67:67	72:28
Desert Tortoise Research Natural Area (interp. center), CA	7.80	1979	Spring, 180d	574	382	49.0	215:167*	67:33
Fremont Peak, CA	2.59	1980	Spring, 60d	43	27	10.4	11:16	63:37
Kramer, CA	2.59	1980	Spring, 60d	146	84	32.4	42:42	58:42
Calico, CA	2.59	1978	Spring, 30d	18	13	5.0	8:5	72:28
Stoddard Valley, CA	2.59	1981	Spring, 60d	97	70	27.0	34:36	72:28
Lucerne Valley, CA	2.59	1980	Spring, 60d	115	77	29.7	36:41	67:33
Johnson Valley, CA	2.59	1980	Spring, 60d	65	40	15.4	20:20	62:38
Shadow Valley, CA	3.89	1978	Spring-,70d	27	23	5.9	9:14	85:15
Ivanpah Valley, CA	2.59	1979	Spring, 60d	155	87	30.1	41:46	56:44
Goffs, Fenner Valley, CA	2.59	1979	Spring, 60d	296	186	62.8	74:112*	63:37
Upper Ward Valley, CA	2.59	1980	Spring, 60d	140	81	31.3	31:50*	58:42
Pinto Basin, CA	2.59	1978	Spring & fall, 19+4d	41	29	11.2	12:17	71:29
Chemehuevi Valley, CA	4.66	1979	Spring, 60d	149	100	21.5	43:57	67:33
Chuckwalla Bench, CA	2.59	1979	Spring, 60d	265	166	64.1	81:85	63:37
Chuckwalla Valley II, CA	2.59	1980	Spring, 60d	91	50	19.3	27:23	55:45
Arden, NV	3.03	1974–1975	Multi-season	127	90	29.7	57:53	71:29
Last Chance, NV	3.89	1980	Spring, 30d	10	9	2.31	n/d	90:10
Piute Valley, NV	2.59	1979	Spring, 60d	79	48	18.5	26:22	61:39
Sheep Mountain, NV	2.59	1979	Spring, 60d	31	22	8.5	10:12	71:29
Beaver Dam Slope, UT	4.86	1930–1946	Primarily fall-winter	281	n/d	23.9	151:101*	99:01

Figure 11. Adult male *Gopherus agassizii* with enlarged chin glands, a secondary sexual characteristic during the high testosterone season (August to October). Photo by Michael Tuma.

Physical changes in male chin glands occurred in association with the seasonal rise and fall of testosterone (Alberts et al. 1994). Chin gland volume changed seasonally, reaching a maximum in late summer when testosterone levels were highest. In experimental studies, socially dominant individuals tended to have larger chin glands than subordinates. Both sexes were able to discriminate between chin gland secretions of familiar and unfamiliar males.

Population Structure. — Tortoises have been evaluated for size-class structure in populations using CL and grouped into seven size classes: juvenile 1, <60 mm; juvenile 2, 60–99 mm; immature 1, 100–139 mm; immature 2, 140–179 mm; subadult (small adult or young or both), 180–207 mm; adult 1, 208–239 mm; and adult 2, ≥240 mm (Berry 1984; Berry and Christopher 2001). Season, time of day, and method of searching have profoundly affected reported size-age class structure. For example, in the classic study by Woodbury and Hardy (1948), the authors focused search efforts on removing tortoises from dens in late fall and winter (November–February) in Utah. They marked 281 tortoises and published metrics for 117. Of the 117 reported animals, 85 (72.7%) were very large adults (adult 2 class), 25 (21.4%) were in the adult 1 class, 6 (5.1%) were subadults, and 1 (0.85%) was an immature 2. Thus, about 99% were adults and most were large. In contrast, searches and surveys of plots in California for all sizes of tortoises conducted in spring, between March and early June using two censuses, produced a higher proportion of populations in the juvenile and immature classes, especially when the surveyors focused on finding small tortoises (Berry and Turner 1986). Examples of study results where different survey techniques were used between the 1930s and early 1980s when tortoises were more common are presented in Table 2 (e.g., Berry 1984). With few exceptions, when two censuses were conducted in spring and efforts focused on finding juveniles, more juvenile and immature tortoises (28–48%) were located.

McLuckie et al. (2002) reported finding 850 tortoises over a 4-year period at the Red Cliffs Desert Reserve, Utah, in a distance sampling effort focused on subadults and adults. The size-age structure was 7.1% juveniles, 10.4% immatures, and 82.59% subadults and adults. Keith et al. (2008) described a 187.7 km^2 site (where tortoises were rare)e and only four adults were observed in 760 one-ha, randomly located plots. Berry et al. (2008) described surveys of a 4 km^2 site within a western Mojave State Park; 9 tortoises (4 immature, 1 subadult, and 4 adults) were observed. Lovich et al. (2011a) studied a population in the western Sonoran Desert with 69 marked tortoises of which 72.5% were adults. Berry et al. (2013) evaluated a 5.42 km^2 site in the northwestern Mojave Desert and located 28 tortoises, of which 46.5% were adults and 53.6% were immature and juvenile tortoises. Berry et al. (2014a), in a study using randomly placed 1 ha plots in three management areas in the western Mojave Desert, located 17 tortoises; adults formed 76.5% of the sample.

Sex Ratios. — In studies conducted between the 1930s and early 1980s, sex ratios of adults in most populations were not significantly different than the expected 1:1 ratio (female:male; Table 2). Since the 1990s, sample sizes for adults in some studies were small and results varied by location. In the central Mojave Desert, Berry et al. (2006) reported that sex ratios differed significantly from the expected 1:1 ratio at 1 of 7 sites; the single site had a female to male ratio of 2:9. At two sites in the western Mojave Desert, few adults were observed; female to male sex ratios were 1:3 and 3:1 with one unidentified individual at each site (Berry et al. 2008; Keith et al. 2008). In the northwestern Mojave Desert, Berry et al. (2013) reported a 10:3 ratio, which differed significantly from the expected 1:1 ratio. In a western Mojave research project comparing three management areas, the sex ratio for the combined areas was 9:4, but did not differ significantly from the expected 1:1 ratio (Berry et al. 2014a). Berry et al. (2015a) evaluated 1,004 adult tortoises in an epidemiological study in the central Mojave Desert: the female to male sex ratio was 1:1.58. In the western Sonoran Desert, Lovich et al. (2011a) reported that a sex ratio of 51 marked tortoises did not differ from the expected 1:1 ratio.

Growth Rates. — Early studies on growth of wild adult tortoises revealed a range of rates. Woodbury and Hardy (1948) reported negligible growth in some adults over periods of ≤7 years; however, one male grew from 206 to 302 mm in 4.3 years and one female grew from 204 to 239 mm in 7 years. Hardy (1976) re-visited the Woodbury and Hardy study area and described growth over periods of 17 to 26 years for four males and two females. Males grew <0.5 mm per year and females grew 0.36 mm and 0.04 mm per year.

Medica et al. (2012) conducted a 47-year study under semi-wild conditions in 9 ha pens in the northern part of the geographic range. They tracked growth in 17 hatchling and juvenile tortoises to adulthood and death. Growth (plastron length) did not differ significantly between females (7.03 mm/year) and males (7.49 mm/year) until the tortoises reached 23 to 25 years; after that female growth was limited and males continued to grow slowly. One small female was stunted and did not grow to sexual maturity. Growth rates were positively correlated with winter precipitation and growth of ephemeral vegetation. Growth rates were higher in years of high rainfall and were minimal when winter rainfall was <26 mm. Mack et al. (2018) reported a mean annual growth of 9.6 mm/year in wild juvenile and immature tortoises at the Desert Tortoise Research Natural Area over multiple years.

Morbidity and Mortality. — Vulnerability to death varies by life stage, size, sex, and location or region. Predators and human activities are sources of injury or death. Droughts and diseases contribute directly and indirectly to deaths. We review the many causative factors below.

Drought, Dehydration, Starvation, and Temperature Extremes: – Tortoises of all sizes are vulnerable to death from dehydration and starvation during or shortly after droughts, and especially if droughts are prolonged (Peterson 1996; Berry et al. 2002; Longshore et al. 2003; Field et al. 2007; Lovich et al. 2014b; Nagy et al. 2015a). Necropsies of starving and dehydrated tortoises have revealed several potential bacterial pathogens, e.g., *Bordetella bronchiseptica*, *Pasteurella testudinis*, and *Pseudomonas cepacia* (Berry et al. 2002). Head-started juveniles released from pens and translocated adults have provided valuable information on sources of mortality: some juveniles released from head-start pens die of exposure, dehydration, and starvation, as do some translocated adults (Nussear et al. 2012; Nagy et al. 2015a,b).

Disease: – Infectious diseases described as contributing to illness and death in wild tortoises were upper respiratory tract diseases caused by *Mycoplasma agassizii* or *M. testudineum* or both (Brown et al. 1994, 1999; Christopher et al. 2003; Jacobson et al. 1991, 2014) and herpesviruses (Christopher et al. 2003; Jacobson et al. 2012). Johnson et al. (2006) reported high levels of exposure (86%) to *M. agassizii* or herpesvirus or both in captive tortoises living in the western, central, and southern Mojave. Berry et al. (2015a) described consistently higher prevalence of test-positive tortoises close to human households in the central Mojave Desert for both *M. agassizii* and *M. testudineum*. The distribution of tortoises with *M. agassizii* and *M. testudineum* differed within the study area. Aiello et al. (2016) designed an experiment to model risk of transmission of *M. agassizii*. The models predicted low probability of infection when tortoise to tortoise interactions were brief, whereas tortoises with higher loads of the bacterium were predicted to transmit disease regardless of length of interaction. They observed encounters to be short in the wild and thus predicted more variability in responses. In another experimental study with captive tortoises, Aiello et al. (2018) discovered that tortoises were shedding bacteria regardless of the severity of clinical signs, although tortoises with severe clinical signs (nasal discharge) generally tended to shed more bacteria. Germano et al. (2014) conducted an experimental study to determine effects of *M. agassizii* on olfaction; the presence of a nasal discharge reduced smell and thus the ability to find food.

Bacterial and fungal pneumonia were reported in 3 of 24 necropsied wild tortoises (Homer et al. 1998). Dickinson et al. (2001) described higher levels of *Pasteurella testudinis* in ill tortoises, and Christopher et al. (2003) reported that 62% of all tortoises in a multi-year study at three Mojave Desert sites had moderate to heavy growth of *P. testudinis*.

Several non-infectious diseases were identified. Cutaneous dyskeratosis, a shell disease, was associated with illness, deaths, and population declines in the eastern Mojave and Colorado deserts (Jacobson et al. 1994; Homer et al. 1998; Christopher et al. 2003). Nutritional deficiencies or elemental toxicants may have caused this disease. Jacobson et al. (2009) described oxalosis, a disease of calcium oxalate crystals in the kidney and thyroid. Renal and articular gout occurred in a tortoise experiencing starvation and dehydration (Berry et al. 2002) and polyarticular and visceral gout was seen in a translocated tortoise (Jacobson and Berry 2012). Urolithiasis was documented in several tortoises in different areas of the desert (Jacobson 1994; Homer et al. 1998; Berry et al. 2002; and Christopher et al. 2003). Jacobson (1994) described osteopenia in bones of 24 tortoises from the Beaver Dam Slope, Utah, and northwestern Arizona; malnutrition was identified as responsible for the condition.

Elemental Toxicants and Toxicosis: – Elemental toxicants may affect health and contribute to responses to diseases (Jacobson et al. 1991; Jacobson et al. 1994; Selzer and Berry 2005; Chaffee and Berry 2006). Jacobson et al. (1991) reported that mercury concentrations in livers of tortoises with upper respiratory tract disease were significantly higher than in controls. Toxicosis was noted as a potential cause of cutaneous dyskeratosis (Jacobson et al. 1994). Selzer and Berry (2005), drawing on 4 necropsied tortoises from Homer et al. (1998), reported elevated levels of arsenic in ill tortoises but not in the control. Selzer and Berry (2005) detected arsenic in scutes using ICP-MS analyses and obtained results similar to Homer et al. (1998).

Parasites: – Ectoparasites include argasid ticks and an unidentified trombiculid mite (Woodbury and Hardy 1948; Jacobson 1994). Christopher et al. (2003) noted that ticks (*Ornithodorus* spp.) were significantly more likely to occur on tortoises in the year prior to observing oral lesions. Descriptions of internal parasites have included cysts of

Figure 12. Rainwater catchment guzzler for wildlife at Mojave National Preserve, California; tortoises can become entrapped in guzzlers. Photos courtesy of Mojave National Preserve.

Sarcocystis-like protozoa in skeletal tissues, pinworms, and *Balantidium*-like protozoa in the colon (e.g., Jacobson 1994; Homer et al. 1998; Berry et al. 2002).

Entombment and Burrow Collapse: – Tortoise burrows may collapse due to human-related activities (domestic livestock grazing, vehicle use) or heavy winter precipitation. Nicholson and Humphreys (1981) observed sheep grazing on a Desert Tortoise study area in the western Mojave Desert; they reported damage and collapse of tortoise burrows and entrapment of a marked juvenile tortoise in its burrow (they dug out the burrow because the tortoise was unlikely to escape without assistance). Homer et al. (1998) reported the results of a necropsy of an adult female tortoise entombed in a burrow after winter rains; the tortoise had a cutaneous fungal infection and multicentric visceral inflammation resulting from the entombment. Loughran et al. (2011) described entrapment of four tortoises in burrows; one was encased in dried soil and died, but the others were able to escape. Tortoises can also become entrapped when burrows collapse from heavy rains and flooding (Homer et al. 1998; Christopher 1999; Field et al. 2007; Lovich et al. 2011b; Nussear et al. 2012).

Entrapment in Guzzlers and Cattle Guards: – Hoover (1995) examined 89 upland wildlife guzzlers (constructed rainwater catchments) in tortoise habitats in the western, northeastern, and eastern Mojave Desert and in the Colorado Desert. He found remains of 27 tortoises and one live tortoise in 18 guzzlers. Tortoises were trapped in the guzzlers and remains were found in all four desert regions. Later, Andrews et al. (2001) examined 13 tanks and guzzlers in the Colorado Desert, but did not find tortoise remains. Cattle guards are another source of entrapment for juvenile tortoises; they fall through the bars in the guards and are trapped below with no way to escape (Berry, pers. comm.).

Anthropogenic Trash: – Balloons, garbage, cans, paper, plastic bags, shooting targets, casings from shotgun shells, and ordnance are common in Desert Tortoise habitats (Berry et al. 2006, 2008, 2013, 2014a; Walde et al. 2007b; Keith et al. 2008). Some studies have shown a negative relationship between trash and tortoise sign (e.g., Keith et al. 2008). In one study, models revealed a positive association between tortoise sign and trash (Berry et al. 2014a), but this was an exception. Large objects (cars, refrigerators, detritus from construction sites) are also deposited in the desert. Tortoises can be attracted to and are known to consume balloons and other detritus that can negatively affect health and cause deaths (Donoghue 2006; Wyneken et al. 2006; Walde et al. 2007b). Trash, especially edible items, also has attracted subsidized predators of tortoises, such as the Common Raven (*Corvus corax*) and Coyotes (*Canis latrans*) and can have a negative influence (Boarman and Berry 1995; Cypher et al. 2018).

Livestock Grazing and Trampling: – Early discussions about effects of livestock grazing on tortoises focused primarily on competition for food, loss of food for the tortoises, trampling, and deterioration of habitat (Woodbury and Hardy 1948; Berry 1978). Berry (1978) described the evidence for probable trampling and death of a juvenile tortoise as well as potential conflicts in food availability and loss of shrub cover. Nicholson and Humphreys (1981) conducted a study of the effects of sheep grazing on a long-term, 2.59 km^2 tortoise plot in the western Mojave Desert. Sheep used about 77% of the plot, 10% of 164 monitored burrows were damaged, 4% were destroyed, and one juvenile was trapped inside a trampled burrow. Nussear et al. (2012), in a study of both resident and translocated tortoises, noted that one tortoise died when livestock collapsed the burrow.

Predation: – Tortoise eggs are a food source for carnivorous vertebrates. Among reptiles, the Gila Monster consumes eggs (Beck 1990, Gienger and Tracy 2008) in the parts of the geographic range where the species overlap. Predatory mammals of tortoise eggs include Desert Kit Fox, *Vulpes macrotis* (Roberson et al. 1985; Turner et al. 1987; Bjurlin and Bissonette 2004; Sieg et al. 2015), Coyote (Roberson et al. 1985; Turner et al. 1987; Esque et al. 2010a; Berry et

Figure 13. Juvenile *Gopherus agassizii*, killed by Common Ravens with typical peck holes in shells. Photo by Bev Steveson.

al. 2006; Lovich et al. 2014a; Sieg et al. 2015), American Badger, *Taxidea taxus*, and Spotted Skunks, *Spilogale gracilis* (Roberson et al. 1985; Sieg et al. 2015).

Neonates and juveniles may be attacked and killed by ants, including Fire Ants, *Solenopsis* spp. (Nagy et al. 2015a; Mack et al. 2018), Common Ravens (Campbell 1983; Farrell 1989; Lovich et al. 2011a; Berry et al. 2013; Hazard et al. 2015; Nagy et al. 2015a,b), Bobcats, *Lynx rufus* (Nagy et al. 2015b), Desert Kit Fox (Kelly et al. 2019), rodents (Nagy et al. 2015a,b), and Burrowing Owls (Walde et al. 2008). Common Ravens are very successful predators of juvenile and small immature tortoises and leave typical patterns on the remains of shells (Campbell 1983; Berry et al. 1986; Boarman and Berry 1995). Multiple kills of juveniles by Common Ravens have been described along fence lines, transmission lines, towers and poles, utility poles, and at perches and nests (e.g., Campbell 1983; n = 136, along a multi-kilometer fence line; Farrell 1989, n = 115, single nest). Kills have also been observed on open ground (Berry et al. 1986). Knight et al. (1998) reported finding remains of juveniles at cattle stock tanks. Parts of tortoises also were found in scats or pellets collected from the nests of Common Ravens (Camp et al. 1993).

Populations of Common Ravens have grown rapidly in the Mojave and western Sonoran deserts, supported by perennial food sources and water in urban and agricultural areas, small towns, and settlements (e.g., Knight et al. 1993; Boarman and Berry 1995; Boarman et al. 2006). The expansion of transportation and utility corridors, energy developments, livestock allotments, and recreational areas has supported growth of Common Raven populations, such that they are now considered subsidized predators—subsidized by anthropogenic activities (e.g., Kristan and Boarman 2003, 2007; Kristan et al. 2004; Webb et al. 2004, 2009; Boarman et al. 2006). These developments have not only provided food and water to allow Ravens to survive and thrive, but also enabled their perching and nesting in hitherto inaccessible areas, thus penetrating into Desert Tortoise range areas previously inaccessible to Ravens.

Remains of juvenile tortoises also were observed in pellets of Red-tailed Hawks (*Buteo jamaicensis*) nesting on transmission line towers in the Colorado Desert (Anderson and Berry 2019). Red-tailed Hawks may be a subsidized predator, expanding perch and nest sites using transmission line towers throughout the range of the tortoise. Spenceley et al. (2015) described a failed attempt of a Glossy Snake (*Arizona elegans*) to kill a juvenile, head-started tortoise. Coyotes and Bobcats preyed on immature tortoises (Nagy et al. 2015b).

Carnivorous avian and mammalian predators have attacked and eaten wild and free-living adult tortoises. Common Ravens were observed to attack an adult tortoise (Woodman et al. 2013). Golden Eagles (*Aquila chrysaetos*) kill and eat adult tortoises; multiple broken shells were observed below eagle nests in the Mojave Desert (Berry, unpubl. data). Mammalian predators include Coyotes (Peterson 1994; Esque et al. 2010a; Lovich et al. 2014b), Bobcats and Mountain Lions (*Puma concolor*; Woodbury and Hardy 1948; Field et al. 2007; Medica and Greger 2009), American Badgers (Emblidge et al. 2015), and domestic dogs (*Canis lupus familiaris*; Berry et al. 2014b). Both dogs and Coyotes were considered subsidized predators (Esque et al. 2010a; Cypher et al. 2018).

Collecting: – People have collected Desert Tortoises for food, commercial sale, and pets, and these activities have resulted in losses to wild populations, which we view as equivalent to deaths. Some Native American tribes, early settlers, and later residents engaged in collecting (e.g., Anonymous 1881; James 1906; Stephens 1914; Camp 1916; Jaeger 1922; Battye 1924; Grant 1936; Miller 1932, 1938; Woodbury and Hardy 1948; Schneider and Everson 1989).

In 1939, the California Fish and Game Commission published a regulation stating sale or purchase of any Desert Tortoise was unlawful (California Dept. of Fish and Game Code 1939–1981). By 1961, the regulation was amended to prohibit take, harm, and shooting. In 1972, regulations on possession and transport of tortoises were added, with the provision that persons able to demonstrate possession of a Desert Tortoise prior to publication of the 1972 regulations could retain the tortoise under certain conditions. Further constraints on possessing tortoises followed in 1989, culminating in the state and federal listings as a Threatened species (California Department of Fish and Wildlife 2016; USDI 1990). Other states did not have such stringent regulations as early.

In a collection of unpublished studies from the western Mojave Desert, Berry et al. (1996) summarized incidents of illegal take of tortoises using multiple data sources: law enforcement records, visual observations of poachers, signs of tortoise burrows dug up with shovels on transects and a long-term mark-recapture plot, demographic data from two long-term mark-recapture plots, and other information. The observations occurred between the mid-1980s and mid-1990s; in retrospect, the observations appeared linked with the Asian Turtle Trade (see van Dijk et al. 2000). Several Cambodian nationals were arrested with 29 tortoises from a long-term plot, and several other Asians were observed in suspicions activities associated with collecting tortoises. Glenn Stewart (pers. obs.) reported the disappearance of 29% of radio-transmittered tortoises between 1986 and 1990 on his project; they were probably collected. Berry et al. (1996) estimated >2000 tortoises were removed from four study areas over a 10-year period.

Illegal collecting has continued, e.g., from highways and roads, and some of these collected tortoises were transported to urban communities, parks, preserves, Natural Areas, and out of their native states. Grandmaison and Frary (2012) conducted a study on the probability of decoy Sonoran Desert Tortoises (*G. morafkai*) being detected and collected from paved roads, and maintained and non-maintained gravel roads; out of 561 opportunities for detection, motorists detected tortoises 19.3%, and when detected, 7.4% of motorists attempted to collect the tortoise. Detection was greatest on maintained gravel roads. This finding points out the vulnerability of tortoises living within short distances of non-paved roads.

In a genetic study comparing captive tortoises from three desert communities in California and Nevada, only 44% of the captives were from the local communities and one was a *G. morafkai* (Edwards and Berry 2013). Studies of captive tortoises in desert communities in Arizona within the range of *G. morafkai* revealed that a high proportion of captives (25%) were *G. agassizii* and an additional 14% were hybrid *G. agassizii* x *G. morafkai* (Edwards et al. 2010). These findings indicated transport of *G. agassizii* into the geographic range of *G. morafkai*. In the last decade, wild *G. agassizii*, marked as part of research projects, have appeared in urban and ex-urban areas, obviously taken from the desert (Mark Massar, pers. obs.; California Turtle and Tortoise Club Adoption Program to Berry, pers. obs.).

Unauthorized Releases of Non-Native Tortoises: – Examples of unauthorized releases into *G. agassizii* habitat include a Texas Tortoise (*Gopherus berlandieri*) and a Box Turtle at the Desert Tortoise Research Natural Area (Berry et al. 1986). Several African Spurred Tortoises (*Centrochelys sulcata*), commonly sold as pets in the Southwest, were released illegally, discovered, and then removed from the Mojave and Sonoran deserts of California, Utah, and Arizona (e.g., Nelson 2010; Goolsby 2016; Anonymous 2018). This species can grow to a very large size (68 kg). Two African Spurred Tortoises were discovered and removed in October 2018 inside the Red Cliffs Desert Reserve, and officials at the Reserve expressed concern about the non-natives spreading disease and damaging habitat (Anonymous 2018).

Figure 14. Residual impacts in 2009 of tank tracks and military training of troops in 1942 (67 years earlier) conducted by General Patton in Chemehuevi Valley, Colorado Desert, California. Photo courtesy of U.S. Geological Survey.

Figure 15. Unauthorized motorcycle race across the Desert Tortoise Research Natural Area, western Mojave Desert, California, creating new destructive trails. Photo by Kristin H. Berry.

The introduction of infectious and other diseases by turtles and tortoises from other parts of the United States and other countries has the potential for devastating effects on naïve *G. agassizii*. For example, in 2013, an ill Central Asian Tortoise (*Testudo horsfieldii*) was found and removed from the central Mojave Desert (Western Expansion Area of Fort Irwin), California. It was necropsied and tested positive for *Mycoplasma agassizii* using ELISA and also tested positive for a new herpesvirus using PCR, previously unreported in *G. agassizii* or *T. horsfieldii* (Jacobson et al. 2013; J. Wellehan, pers. obs.). The predominant bacteria in the nasal discharge was *Mannheimia haemolytica*, the cause of the epizootic pneumonia in cattle known as Shipping Fever (Jacobson et al. 2013).

Vandalism: – Numerous early reports documented vandalism, such as deliberately running over tortoises with vehicles, shooting, and maiming (Ragsdale 1939; Jaeger 1950; Bury and Marlow 1973; Uptain 1983). Berry (1986) evaluated 635 carcasses collected between 1976 and 1982 from 11 sites in the Mojave and western Sonoran deserts of California; 91 (14.3%) remains showed evidence of gunshot. Gunshot deaths were more common in the western Mojave

Desert (14.6–28.9%) than in the eastern Mojave (0.0–3.1%) and Colorado deserts (1.8–2.8%). The higher levels of gunshot deaths in the western portion of the geographic range were attributed to much higher recreational use than in the east and south. Evidence of gunshot deaths was seen at Goldstone and within the southern edge of the Fort Irwin National Training Center (Berry et al. 2006). On the Alvord Slope, 8.5% of 47 shell remains showed evidence of gunshot. In the western Mojave Desert at Red Rock Canyon State Park, 5 of 58 shells showed evidence of gunshot (Berry et al. 2008). Also in the western Mojave Desert, evidence of tortoises killed by shooting occurred both in the Desert Research Natural Area and in adjacent designated critical habitat for the tortoise (Berry et al. 2014a).

Vehicular Impacts: — Records of tortoise injuries and kills by vehicles are frequent in the literature (e.g., Woodbury and Hardy 1948; Homer et al. 1998; von Seckendorff Hoff and Marlow 2002; Lovich et al. 2011a). Woodbury and Hardy (1948) considered the killing of tortoises on roads and removal by tourists and others as one of the dangers to the species. In a study of paved roads, von Seckendorff Hoff and Marlow (2002) found remains of 6 dead tortoises hit by vehicles on the shoulders of two- and four-lane roads in southern Nevada. Hughson and Darby (2013), in a study of 216 km of paved and two-lane roads in the Mojave National Preserve, estimated a minimum of 5.3 deaths of tortoises annually. Lovich et al. (2011a) found 11 dead tortoises over a 13-year period at a wind energy study site in the western Colorado Desert; one of the dead tortoises was killed by a vehicle.

Four studies have been undertaken to define the zone of influence of roads of different ages and traffic volumes on tortoises, with the assumption that roads serve as mortality sinks for adjacent tortoise populations. von Seckendorff Hoff and Marlow (2002) studied the effects of the road impact zone at intervals parallel to the roadways on roads with differing traffic volumes (25 to 5,000 vehicles per day) and during different seasons. They found effects (reduction in abundance of tortoise sign) at distances of >4,000 m from the road at the highest traffic level. However, the zone of impact ranged from 1,090 to 1,389 m for graded and maintained electric transmission line access roads.

Boarman and Sazaki (2006) conducted a more limited study along one major highway in the Mojave Desert with traffic of 8,500 vehicles per day. They found significant differences in sign counts between the highway edge and 400 m distant from the highway. Nafus et al. (2013) studied road effects in the Mojave National Preserve, California, and reported that tortoise sign was in greatest abundance along roads with low traffic volumes (<1 vehicle/day) compared with roads of intermediate (30–60 vehicles/day) and high traffic volumes (320–1100 vehicles/day). Importantly, tortoise size negatively correlated with traffic volume. Highways and roads could affect the potential for population growth rates because reproductive tortoises were absent near the roads.

Hughson and Darby (2013), using the techniques of Boarman and Sazaki (2006), also saw similar depressions in tortoise sign near roads within the Mojave National Preserve. Agha et al. (2017) reported that mesocarnivore visits to tortoise burrows increased as distance to dirt roads decreased at a windfarm facility in the western Colorado Desert; however in an earlier study at the windfarm, tortoise burrows were more likely to occur closer to roads than at random points (Lovich and Daniels 2000).

Berry et al. (2006) studied Desert Tortoise populations on 21 plots on a military reservation; remains with signs of vehicle crushing were present on all plots with military maneuvers and represented from 2.1 to 45.5% of deaths on 20 of these plots. In a study in the northwestern Mojave Desert, Berry et al. (2013) modeled variables affecting distribution and abundance of tortoises on a military installation where no vehicle-related maneuvers occurred; the models included paved roads, denuded areas, ordnance, signs of mammalian

Figure 16. Adult *Gopherus agassizii* standing in burned habitat soon after the 2005 fire at the Red Cliffs Desert Reserve in Utah. Photo by Ann McLuckie.

Figure 17. Impacts from fire and the resulting invasion of red brome grass (*Bromus madritensis* ssp. *rubens*) in the Red Cliffs Desert Reserve, Utah, two years post-fire (2007). Photo by Ann McLuckie.

predators, and observations of Common Ravens. The models suggested that densities of tortoises increased with distances from paved roads and denuded areas, as well as some other variables.

Bury and Luckenbach (2002) found an immature tortoise crushed on a vehicle trail in a recreational vehicle use area. Remains of tortoises likely killed by unauthorized vehicle use were found in the Desert Tortoise Research Natural Area, an area closed to recreational vehicles (Berry et al. 2014a).

Fires: – Wildfires injure and kill tortoises (Woodbury and Hardy, 1948; Homer et al. 1998; Esque et al. 2003; Lovich et al. 2011c; Nussear et al. 2012; Ann McLuckie, pers. obs.). Woodbury and Hardy (1948) reported deaths of about 14 tortoises from a fire covering ca. 5.2 km² on part of the Beaver Dam Slope south of Bunkerville in 1942. In a post-fire study, Lovich et al. (2011c) described a fire in the western Sonoran Desert that killed an adult female tortoise and injured five other adult tortoises. Nussear et al. (2012) reported that three of 30 tortoises died from fire during a comparative study of translocated and resident tortoises. In the Red Cliffs Desert Reserve and critical habitat in Utah, 687 tortoises died in 2005 in a fire that burned ca. 23% of the approximately 251 km² habitat (A. McLuckie, pers. comm.). Drake et al. (2012) described a tortoise recovering from burns three years post-fire.

Two studies, one in the northeastern Mojave Desert and a second in the western Sonoran Desert, revealed that activity areas of tortoises remained unchanged in the first few years after a burn, indicating site fidelity, regardless of habitat condition (Lovich et al. 2018b). However, Drake et al. (2015) reported that six to seven years post-fire, tortoises contracted areas of activity because the post-fire growth of herbaceous perennial species (globemallow, *Sphaeralcea ambigua*) declined.

Mining: – Tortoises have been found alive and dead in mining shafts and pits, often in mining districts such as the Rand Mining District in the western Mojave Desert where pits and shafts are common (Berry, pers. obs.). Nussear et al. (2012) reported that two of 30 translocated and resident tortoises under study in the northeastern part of the geographic range were found dead in mineshafts.

Rattlesnake Bites: – An adult male tortoise, translocated 17 days previously as part of a mass translocation program, was attacked in the orbit and ultimately died from probable envenomation by a rattlesnake (Jacobson and Berry 2012; Berry et al. 2016a). Based on the appearance of the wound at necropsy, venom was most likely from the Speckled Rattlesnake, *C. pyrrus*, or Panamint Rattlesnake, *C. stephensi*. Rattlesnake bites or strikes as a cause of tortoise deaths are likely undercounted. Finding a tortoise dying of snake bite and obtaining a confirming necropsy would be unlikely, unless a tortoise was under observation or being tracked.

Mortality Rates. — Death rates are summarized following the reporting styles of the authors. Most studies focused on annualized death rates of subadult and adult tortoises (CL ≥180 mm). In some cases, but not all, sites with little human use had lower mortality rates than sites with human-related activities. In their study of Desert Tortoises on the Beaver Dam Slope, Woodbury and Hardy (1948) reported a 1% annual death rate for a large sample of mostly adults. In a demographic study of tortoises on 21 study plots sampled between 1997 and 2003 in a military installation in the central Mojave Desert, adult (≥180 mm CL) death rates (adults dying / [yr km^{-2}]) differed by location, and current and historical uses; death rates ranged from 1.9 to 95.2% annually (Berry et al. 2006). Fifteen plots within the Goldstone area had the highest death rate at 95.2%. Sites with recent military vehicle use ranged from 4.7 to 13.3% and those with ongoing military vehicle-oriented war games ranged from 1.9 to 23.8%. The single site surveyed adjacent to and outside of the military base had an annual death rate of 9.7% (Berry et al. 2006).

In the western Mojave Desert, Berry et al. (2008) studied a population within Red Rock Canyon State Park and reported a death rate of 67% for adults between 2000 and 2004 (ca. 24% annually); the death rate exceeded recruitment rates. In a survey of a 5.42 km² plot on a naval test facility in the northwestern Mojave Desert, Berry et al. (2013) described a crude annual death rate of 1.8% for adults during the period 2006–2010. This site had limited public access with no livestock and no vehicle-oriented recreation. Berry et al. (2014a) compared demographic attributes of tortoises in three differently managed areas in the western Mojave Desert and provided crude annual death rates for adults for the 4 years preceding the survey. Death rates were lowest (2.8%/yr) for the most protected area, the Desert Tortoise Research Natural Area, 20.4%/yr in critical habitat, and 6.3%/yr on unfenced private lands with unrestricted human use (but recently acquired for conservation, 2000–2009).

Survival. — Few substantive studies have provided estimates of survival rates of Mojave Desert Tortoise populations. The most comprehensive of these was a study in the eastern Mojave Desert of California by Turner et al. (1987), covering the period 1977–1985. The study drew on 11 sex-size groups (CL in mm), of which the first six were pre-reproductive: <60, 60–79, 80–99, 100–119, 120–139, 140–154, 155–179, females 180–208, males 180–208, females >208, and males >208. The authors, using mark-recapture data, calculated annual survival rates for four periods between 1977 and 1985, as well as the geometric mean annual survival. The smallest three classes (juveniles) had geometric annual survival rates of 0.767 to 0.804, and the immature tortoises (100–179 mm CL) had rates of 0.821 to 0.861. Estimates for adult females were 0.901 to 0.944 and for adult males were 0.876 to 0.907. All estimates had wide confidence intervals. Using this and other information, Turner et al. (1987) prepared a life table and estimated an annual rate of increase of the population of ca. 2%. However, this population unfortunately crashed between 1994 and 2000, apparently due to disease and other factors (Christopher et al. 2003). Freilich et al. (2000), in a 1991–1995 mark-recapture study in Joshua Tree National Park, reported survival rate estimates of 0.84 or 0.901, depending on method used, for both sexes of adult tortoises.

In the western edge of the Sonoran Desert, Agha et al. (2015c) compared apparent annual survival rates of adult tortoises over 18 years at two sites: inside a wind energy facility, a disturbed landscape, and nearby in an undisturbed landscape. Estimates of survival rates were 0.96 ± 0.01 for the wind energy facility, significantly higher than observed for the undisturbed site, 0.92 ± 0.02. High survival was attributed in part to limited human use.

In Nevada, Longshore et al. (2003) studied tortoises at two sites at Lake Meade National Recreation Area between 1994 and 2001. These authors reported annual survival rates of 0.985 at Grapevine and 0.829 at Cottonwood sites, where drought conditions existed from 1996 to 1999.

Population Status. — Historic and recent reports provide data for evaluating changes in status of tortoise populations. Before describing data, we briefly discuss sampling techniques because the methods used affect the types of results available.

Albeit limited, only observational reports on local abundance of tortoises exist from the early 1900s until the Woodbury and Hardy (1948) publication. For example, Grant (1936) described tortoises collected near Helendale in the western Mojave Desert.

Since the Woodbury and Hardy (1948) study until the early 2000s, mark-recapture studies on plots of various sizes have measured population attributes (structure, densities, sex ratios, growth, survival, causes of death), and some plots became long-term plots of about 2.6–7.8 km^2 (Berry 1984). Selection of sites to study demography differed from one investigator to another and from state to state. In California, most sites represented habitat in valleys throughout the Mojave and Colorado deserts, whereas in Nevada, sites were chosen where belt transects indicated high counts of tortoise sign (Berry 1984). Mark-recapture surveys often spanned multiple years. Densities, one of several critical measures of population status and trends for the species, were frequently assessed through two or more mark-recapture surveys within a season. Data were analyzed using the Lincoln-Peterson index, stratified Lincoln index, Schnabel method, and other analytical techniques. In some cases, professional judgment was used to estimate densities. In addition, amounts of effort per unit area differed as well as season of survey. Changes in densities coupled with data on short-term trends in death rates or annualized mortality rates and survival for adults also provide supporting information and are presented above.

To summarize datasets on live tortoises from 1936 through the early 1980s briefly, we used the following counts: (1) all sizes of tortoises, and (2) all sizes of adults (≥180 mm CL). These counts occurred within boundaries of plots (Table 2). Data are available for 24 sites with counts of ≥2 tortoises/km^2; sites with lower densities were not included but are available in Berry (1984). Plot sizes ranged from 2.59 to 13.7 km^2, with most plots 2.59 km^2 and receiving two censuses or complete surveys in spring, when tortoises were likely to be above ground (Zimmerman et al. 1994). Counts of tortoises were converted to adults/km^2 for rough comparisons between sites and over time, and ranged from 2.31 to 71.8 adults/km^2 (Table 2). With few exceptions, most study plots listed in Table 2 are within critical habitat units designated by USFWS (1994).

From 1985 to 2006, counts and estimated densities of populations in many study areas declined markedly after the studies were initiated (e.g., Woodbury and Hardy 1948; Hardy 1976; Berry 1984; Jacobson et al. 1991, 1994; Berry and Medica 1995; Brown et al. 1999; Berry et al. 2002; Christopher et al. 2003). The population studied by Woodbury and Hardy (1948) on the Beaver Dam Slope was federally listed as Threatened in 1980 because of population declines and other factors (USFWS 1980). The listing of the entire metapopulation north and west of the Colorado River followed in 1990 (USDI 1990).

Examples of declines on mark-recapture plots include changes in adult tortoise populations in the Desert Tortoise Research Natural Area between 1982 and 1992, a decline of ca. 94% to about 6 tortoises/km^2 (Brown et al. 1999). The population (all sizes) in the western Sonoran Desert at Chuckwalla Bench also experienced a marked decline between 1979 and 1992. In contrast, adult densities remained relatively high during three surveys in Ivanpah Valley conducted between 1979 and 1994 (between 80 and 100/km^2 per survey) and during four surveys conducted at Goffs between 1980 and 1994 (between 145 and 190/km^2 per survey) (Berry and Medica 1995; Berry et al. 2002). The Goffs population experienced 92–96% decreases between 1994 and 2000 (Christopher et al. 2003). In Nevada, four populations with densities of adults <50/km^2 either remained stable, increased slightly, or decreased in the 1980s or between the 1980s and early 1990s (Berry and Medica 1995).

At least two mark-recapture plots listed in Table 2, Arden in Nevada and Fremont Peak in California, no longer have tortoises. Arden became urbanized shortly after the surveys were completed and is now part of Las Vegas (B.L. Burge, pers. obs), and Fremont Peak experienced sheep grazing and intensive vehicle-oriented recreation (Berry, pers. obs.).

Brief or one-time surveys of plots or study areas produced snapshots in time of both densities and mortality rates of breeding adults for the four years prior to each study (e.g.; Berry et al. 2006, 2008, 2014a). While limited in time, these types of studies supplement long-term mark-recapture research and monitoring of changes in density conducted at a landscape scale. For example, one-time surveys undertaken at 15 plots on Goldstone and an additional six plots on the National Training Center at Fort Irwin revealed mean densities of adults of 0.79/km² with a very high death rate of 95.2% annually for adults on the 15 Goldstone plots. In contrast, adult densities ranged from 1.4 to 15 adults/km² and death rates of adults from 1.9 to 23.8% annually on six Fort Irwin plots. In a health and disease research project spanning five years (1990–1995), annualized mortality rates for adult tortoises with radio transmitters were available for three sites: the western (2.5%), northeastern (2.4%), and eastern (5.1%) Mojave Desert regions (Christopher et al. 2003). Tortoises missing (some were potentially dead) at each site ranged from 22.9% (eastern Mojave) to 37.5% (western Mojave) over the 5-year study. One-time studies using hectare plots or study areas also indicated high mortality rates in some areas (Berry et al. 2006, 2008; Keith et al. 2008). Small, remnant and potentially isolated populations remained in the north central and northwestern Mojave in the early 2000s (Berry et al. 2006, 2008, 2013; Keith et al. 2008). Death rates of adults tracked with radio-transmitters were high in some studies (Longshore et al. 2003; Christopher et al. 2003), but not in others (Agha et al. 2015c).

Surveys at the Landscape Scale. — The first *G. agassizii* Recovery Plan published in 1994 recommended sampling on a landscape scale within designated areas designed for conservation of the Desert Tortoise, i.e., Desert Wildlife Management Areas, in addition to maintaining long-term plots, where appropriate (USFWS 1994a). After testing different approaches, in 2004 the USFWS implemented annual distance sampling of adults (≥180 mm CL) within designated critical habitat units (now called Tortoise Conservation Areas, TCAs) throughout the geographic range (McLuckie et al. 2002; USFWS 2015; Allison and McLuckie 2018). The primary population attribute published from distance sampling was density of adults within critical habitat units or TCAs (Table 3). The first Recovery Plan also recommended separating populations into six Recovery Units, each of which contained one or more populations (e.g., critical habitat units), with a total of >25,000 km² (USFWS 1994). In the revised Recovery Plan, the USFWS (2011) reduced the number of Recovery Units to five and realigned boundaries based solely on genetic information in Hagerty and Tracy (2010).

Range-wide, the five Recovery Units contain 17 TCAs scattered in the Mojave and western Sonoran deserts of the four states (Table 3). Grouped data for all TCAs showed a decline of 32.18% in adult tortoises between 2004 and 2014, with declines of 26.57 to 64.70% for 11 individual TCAs (USFWS 2015). Six TCAs showed increases of 162.36

Table 3. Summary of 10-year trend data for five Recovery Units and 17 Tortoise Conservation Areas within the Recovery Units for the Mojave Desert Tortoise, *Gopherus agassizii*, between 2004 and 2014 (modified from Table 10 in USFWS 2015). This table includes the area of each Recovery Unit and Tortoise Conservation Area (= critical habitat), the percent of total habitat in each of the five Recovery Units and 17 Tortoise Conservation Areas, density (number of breeding adults/km² and standard errors, SE), and the percent 10-year change between 2004–2014. Note: according to Table 2 in the revised recovery plan (USFWS 2011), the total critical habitat is 26,039 km², whereas the text states 24,281 km². Numbers in bold represent the totals for each Recovery Unit. * = Populations falling below the viable level of 3.9 breeding individuals/km². [1]Chocolate Mountains Aerial Gunnery Range.

Recovery Unit Tortoise Conservation Area	Surveyed area (km²)	% of total habitat in Recovery Unit & TCA	2014 density/km² (SE)	% 10-year change (2004–2014)
Western Mojave, CA	**6,294**	**24.51**	***2.8 (1.0)**	**–50.7 decline**
Fremont-Kramer, CA	2,347	9.14	*2.6 (1.0)	–50.6
Ord-Rodman, CA	852	3.32	*3.6 (1.4)	–56.5
Superior-Cronese, CA	3,094	12.05	*2.4 (0.9)	–61.5
Colorado Desert (1° CA)	**11,663**	**45.42**	**4.0 (1.4)**	**–36.3 decline**
Chocolate MAGR[1], CA	713	2.78	7.2 (2.8)	–29.8
Chuckwalla, CA	2,818	10.97	*3.3 (1.3)	–37.4
Chemehuevi, CA	3,763	14.65	*2.8 (1.1)	–64.7
Fenner, CA	1,782	6.94	4.8 (1.9)	–52.9
Joshua Tree, CA	1,152	4.49	*3.7 (1.5)	+178.6
Pinto Mountain, CA	508	1.98	*2.4 (1.0)	–60.3
Piute Valley, NV	927	3.61	5.3 (2.1)	+162.4
Northeastern Mojave, NV, UT, AZ	**4,160**	**16.2**	**4.5 (1.9)**	**+325.6 increase**
Beaver Dam S., NV, UT, AZ	750	2.92	6.2 (2.4)	+370.3
Coyote Spring, NV	960	3.74	4.0 (1.6)	+ 265.1
Gold Butte, NV & AZ	1,607	6.26	*2.7 (1.0)	+ 384.4
Mormon Mesa, NV	844	3.29	6.4 (2.5)	+ 217.8
Eastern Mojave, NV & CA	**3,446**	**13.42**	***1.9 (0.7)**	**–67.3 decline**
El Dorado Valley, NV	999	3.89	*1.5 (0.6)	–61.1
Ivanpah Valley, CA	2,447	9.53	*2.3 (0.9)	–56.1
Upper Virgin River, UT	**115**	**0.45**	**15.3 (6.0)**	**–26.6 decline**
Red Cliffs Desert Reserve, UT	115	0.45	15.3 (6.0)	–26.6
Total Amount of Land	**25,678**	**100.00**		**–32.2 decline**

to 384.37%. Ten TCAs were below a density of 3.9 adult tortoises/km^2, a figure established for population viability described in the first Recovery Plan (USFWS 1994). No data are available on the sex ratios of females to males in the 17 TCAs.

Most TCAs (10 of 17, 75.9%) occur in California. Nine of these 10 populations declined by 29.77 to 64.70% between 2004 and 2014, and eight were below the numeric level of viability (not considering the Standard Error, Table 3). The two populations that were above viability also declined, and one population, Joshua Tree, showed an increase (USFWS 2015).

Nevada, with 17.9% of TCAs, has parts or all of six populations and five of these show increases; two of the six were below viability. About 4% of TCAs (parts of two populations) occur in Arizona and are shared with Nevada and Utah. Both TCAs were increasing but one was below viability. Utah has <2% of populations in TCAs: the Beaver Dam Slope which is showing an increase, and the Red Cliffs Desert Reserve which is declining. In addition, observations of juveniles have decreased (Allison and McLuckie 2018). Reviewing all these results, Allison and McLuckie (2018) concluded that "The negative population trends in most of the TCAs [critical habitat units] for Mojave Desert Tortoises indicate that this species is on the path to extinction under current conditions."

Populations in protected or partially protected areas (State Parks, National Park system, Research Natural Areas, Reserves, Areas of Critical Environmental Concern) experienced downward trends and/or high mortality rates with few exceptions (Berry and Medica 1995; Longshore et al. 2003; Berry et al. 2008; Lovich et al. 2014b; USFWS 2015 [Red Cliffs Desert Reserve]). A one-season study undertaken in the western Mojave in 2011 compared effects of different management practices on population status in a fenced and protected area (Desert Tortoise Research Natural Area), adjacent unfenced private land, and critical habitat (Berry et al. 2014a). Significantly higher density of tortoises occurred in the protected area (10.2 adults/km^2, 95% Confidence Interval [CI]: 9.9–10.4) compared with adjacent private land (3.7 adults/km^2; 95% CI: 3.6–3.8) and critical habitat (2.4 adults/km^2, 95% CI: 2.3–2.6). Death rates of adults from 2007 to 2011 were also lower in the protected area (2.8%/yr) than on private land (6.3%/yr) or in critical habitat (20.4%/yr).

Threats to Survival. — The decline of *G. agassizii* is often described by scientists as death by a thousand cuts. Population declines can be ascribed simply to the rate of loss of individuals greater than the rate of recruitment and the rate of loss or degradation of habitat. Causes of declines vary locally and regionally within the geographic range and by critical habitat unit or TCA (e.g., Jacobson et al. 1991; Berry et al. 2014a; Tuma et al. 2016). Overall, the causes are multiple, cumulative, and often synergistic, but the most important drivers are anthropogenic activities. The same and similar anthropogenic drivers are the basis for environmental change and degradation elsewhere in the American West (Leu et al. 2008).

In the section on Morbidity and Mortality above, we described multiple sources of illness, death, and loss of individual tortoises to populations. High on this list of threats are disease, poor nutrition, starvation and dehydration, predation by subsidized predators (e.g., Common Raven, Coyote, dog), loss to vehicle impacts, and destructive wildfires. The importance of other hazards and causes of mortality should not be discounted or minimized, especially because tortoise population densities are so low, bordering or below viability for breeding adults (Table 3; viability summarized in USFWS 1994). With continuing growth of human populations and industrial developments within and on the edges of the geographic range for *G. agassizii* (e.g., Hughson 2009), we expect that deaths from known and additional sources will continue and likely increase.

Habitat Loss and Fragmentation. — Constrictions to and fragmentation of the geographic range of the Desert Tortoise began when early settlers arrived in the 1800s. Settlements grew into towns and cities and land was converted to agriculture, ranching, and scattered mining operations. Transportation and utility corridors developed, and recreational focal points became popular.

As of 2018, the southwestern part of the geographic range in Antelope, Victor, Apple, and parts of Brisbane and Peerless valleys were in urban, ex-urban, industrial, and agricultural developments. The western edge of the range was similarly compromised. Habitat across the southern, central, eastern, and northeastern regions of the Mojave and Colorado deserts experienced similar losses and fragmentation of habitat until and after the time of the federal listing in 1990 (e.g., Norris 1982; Hughson 2009; USFWS 2010). Subsequently, the area of tortoise habitat (including critical habitat) has continued to decrease, with development of private and federal lands for urban, ex-urban, agricultural, industrial, and energy developments, and expansion of Department of Defense military bases in the central, southern, and northeastern Mojave Desert and elsewhere (e.g., USFWS 2010). For example, between 1992 and 2001, 4.57 km^2 of critical habitat was lost from agricultural development, a small amount compared to the past, but nevertheless a continuing issue. Range-wide, 1,802 km^2 of critical habitat occurred on U.S. Department of Defense lands (USFWS 2010). Due to the expansion of the National Training Center at Fort Irwin in the central Mojave Desert, 760 km^2 of tortoise habitat was lost or degraded; ca. 304 km^2 of this loss was part of critical habitat (USFWS 2010). The expansion of the Marine Corps Air Ground Combat Center at Twentynine Palms in the southern Mojave Desert has had and is likely to have continued and profound effects on tortoise populations within and outside critical habitat units (USDD 2017; Henen 2018). Since 2000, development of renewable energy has resulted in loss of about 25 km² of high value tortoise habitat (but not critical habitat) in the northeastern Mojave Desert and ca. 81 km² of marginal habitat in the Colorado Desert (Mark Massar, U.S. Bureau of Land Management, in litt. 25 Oct 2018).

Transportation, energy and utility corridors, and railroads connect cities, towns, settlements, and developments across and within the geographic range of the tortoise, resulting in lost and degraded habitat, fragmentation of habitat, and loss of connectivity (Forman et al. 2003; Chaffee and Berry 2006). The USFWS (2010) reported a total length of 13,350 km of paved roads and highways in critical habitat in 1990, with a slight difference in 2008. If the 13,350 km are treated solely as two-lane highways with shoulders (width, 11.6 m), then total loss is 1,548 km². This figure does not include 4- and 6-lane or divided highways. The revised Recovery Plan showed substantially fewer kilometers of roads where fencing is needed, but does not resolve discrepancies with the 2010 report (USFWS 2010, 2011). The USFWS (2010) also noted 1,634 km of utility lines within corridors encompassing 1,743 km² (width of utility corridors = 1.067 km). Utility corridors have one or more access roads, often dirt with berms, and the roads have increased in length and area with development of renewable energy facilities on public and private lands. Data on other linear disturbances are available for TCAs, e.g., for railroads, 368 km (USFWS 2011).

In addition to acting as a mortality sink for tortoises, roads, whether dirt or paved, and railroads are sources of contaminants such as asbestos, cadmium, chromium, lead, nickel, petroleum products, and organic compounds (Forman et al. 2003; Chaffee and Berry 2006).

Solar and wind energy developments are present in Desert Tortoise habitat (habitat modeled by Nussear et al. 2009). For example, as of 2010, solar development was implemented on 114 km² of all modelled habitat, with additional solar and wind projects pending for 230 km² (USFWS 2011). As of 2018, more solar and wind sites are proposed or in development, generally not in critical habitat, but occasionally close to or adjacent to critical habitat or protected areas.

The U.S. Bureau of Land Management has received pressure from users of off-highway vehicles since the early 1970s to provide easy access to the desert, and places for unrestricted play (e.g., USBLM 1973, 1980, 2019). Several off-highway vehicle "Open Areas" where unrestricted vehicle use occurs were designated in California in 1980 and reaffirmed with the Desert Renewable Energy Conservation Plan in California, resulting in the gradual loss of ca. 898 km² of good, if not prime, tortoise habitat (USBLM 1980, 2016; Mark Massar, U.S. Bureau of Land Management, in litt. 6 Nov 2018).

The pressure for vehicle-oriented recreation off-highways and off-roads came from thousands of users and continues to have a growing influence on degrading tortoise habitat through thousands of routes, trails, congregating areas for races (called pit areas), and the proliferation of unauthorized, cross-country use (e.g., Bury and Luckenbach 2002; Berry et al. 2014a). Numerous research articles on effects of vehicle travel off-road on soils and vegetation in the Mojave Desert have been published documenting severe damage to the environment (e.g., Adams et al. 1982; Webb and Wilshire 1983; Wilshire and Nakata 1976; Lei 2009; Brooks and Lair 2009). Although several management plans designed to limit off-highway or off-road use were published, proliferation of these uses into unauthorized areas has continued on both federal and private lands (USBLM 1973, 1980, 2016, 2019). In parts of critical habitat in the western, central, and southern Mojave Desert, visits and visitor days recorded annually from 2008 to 2018 ranged from 55,874 to 94,474 visits and from 26,218 to 90,445 visitor days per year (USBLM 2019, Table 3.6-4). Off-highway and off-road use has also grown in the Colorado Desert in the Chuckwalla Bench critical habitat, where some vehicle users have pushed down signs indicating "closed to vehicle use" and driven into sensitive areas, such as washes (Berry, pers. obs., 2018).

As of 2017, existing routes and trails developed by off-highway vehicle users covered an estimated 3,765 km in critical habitat in the Western Mojave Recovery Unit alone, with an additional 148 km² negatively affected by stopping, parking, and camping adjacent to the trails and routes (USBLM 2019). These figures do not include unauthorized tracks, trails, and routes, which are common in the region (Goodlett and Goodlett 1992; Keith et al. 2008; Egan et al. 2012; Berry et al. 2014a; Piechowski 2015).

The high density of off-road routes and trails, both authorized and unauthorized, in critical habitat and other sensitive areas for rare, threatened, and endangered species in this region continues to be of concern to nonprofit organizations and government agencies and is the subject of court cases (USDC 2009, 2011). The final management plan developed by the U.S. Bureau of Land Management for federal lands (USBLM 2019) indicates only 3,314 km of open and limited routes for off-highway vehicle (OHV) use, and 98 km² for camping, parking, and stopping adjacent to routes within critical habitat. When all disturbances from transportation linear features (all linear features on the ground) are considered, the figure is 4,173 km (USBLM 2019, Alternative 5). Therefore, density of existing linear disturbances from OHV routes and other linear transportation features in critical habitat in the Western Mojave Recovery Unit is 1.05 km/km² (4173 km/3963 km² of critical habitat). These figures do not include individual tracks or areas degraded from parking, camping, and stopping of OHVs, mining, piospheres created by livestock grazing, and other land uses. Although figures are not available for other Recovery Units, the Colorado Recovery Unit faces increasing and new pressures from unauthorized cross-country vehicular travel.

Subsidized Predators. — Direct links exist between subsidies for Common Ravens, Coyotes, and dogs (e.g., road kills, trash, and domestic pets) and desert cities, towns, and settlements. This also involves transportation corridors (roads, railroads, utility corridors), renewable energy facilities, and recreation vehicle use areas (Boarman 1993; Knight and Kawashima 1993; Knight et al. 1993, 1999; Fedriani et al. 2001; Kristan et al. 2004; Esque et al. 2010a; Cypher et al. 2018). Utility poles and transmission line towers serve as perches for foraging and nest sites for Common Ravens, allowing access to previously uninhabited or rarely used and remote parts of the desert.

In surveys conducted in the eastern Mojave Desert, the Common Raven was the most commonly observed bird (Knight et al. 1999); it also was the most common species observed over seven survey years at the Desert Tortoise Research Natural Area in the western Mojave Desert between 1979 and 2012 (Berry et al., in review). Ravens form small and large flocks (250 to 5,900 individuals) at roosts in trees and along utility lines in or near desert towns and ex-urban areas in the western, southern, and eastern Mojave Desert (Tim Shields, pers. obs. 2011 to 2018; Debra Hughson, pers. obs.). One such roost covered an area of 0.8 x 0.8 km and regularly had from 1,000 to 5,900 ravens. Shields (pers. obs.) reported that counts peak in late fall and winter. Kristan and Boarman (2003) in a study of raven predation on tortoises in the western Mojave Desert described patterns of spillover predation and hyperpredation and stated that "anthropogenic resources for ravens could indirectly lead to the suppression, decline, or even extinction of desert tortoise populations." Ravens also were observed to attack adult tortoises (Woodman et al. 2013).

Another subsidized predator, the Coyote, kills and eats tortoises. In a study of nine sites in the Mojave Desert, Esque et al. (2010a) reported that high mortality of adult tortoises correlated with sizes of nearby human populations, surface roughness of the landscape, and size and sex of the tortoise. Potential contributing factors were distance of the human population and density of roads. Tortoises were more likely to be killed during and after droughts, when populations of typical prey—hares and rodents—were low. Mortality rates at the nine sites ranged from 0 to 43.5%; two sites experienced no deaths. In a 5-year study of Coyote diets in the central Mojave Desert, Cypher et al. (2018) reported that in years of low precipitation, the diet of Coyotes included more anthropogenic food items. They also observed higher frequencies of tortoise remains in Coyote scats in the two years following releases of translocated tortoises.

Domestic dogs, also subsidized predators, attack, injure, and kill captive tortoises and were observed to attack wild tortoises (Boyer and Boyer 2006; Berry et al. 2014a; Berry, pers. obs.). Dogs occur singly and in large packs (e.g., 12–35 dogs) and have been observed in the western, central, and southern Mojave Desert (Berry, Rhys Evans, Michael Tuma, Mark Bratton, pers. obs.). Without exception, dog packs were close to military installations and associated with urban or ex-urban settlements. In all observations, dogs threatened the field workers.

Habitat Degradation. — Many sources of habitat degradation exist, such as military maneuvers, livestock grazing, and mining. Military maneuvers (tanks, other vehicles, troops) have negative effects on tortoise habitat. During World War II, between 1942 and 1944, General Patton trained an estimated one million troops for North Africa on 50,000 km^2 in southeastern California, southern Nevada, and western Arizona, using thousands of tanks and other vehicles (Prose 1986; Prose and Wilshire 2000). In 1964, Operation Desert Strike trained in much of the same area and covered 2,000 km^2. The affected habitats extend from the central Mojave Desert in the Western Mojave Recovery Unit east into the Eastern Mojave Recovery Unit, and south to the entire Colorado Desert Recovery Unit.

Depending on site and year of impact, tank tracks from military vehicles and camps caused substantial and often significant and negative effects on soils and plants (Prose 1985, 1986; Prose et al. 1987, Prose and Wilshire 2000). Examples include, but are not limited to, compaction of soils in tank tracks, lowered infiltration rates of soil, removal of the top layer of soil, and alteration of densities of drainage channels. Recovery of cryptobiotic crusts was lower in tank tracks (Prose and Wilshire 2000). Cover and density of creosote bushes were greatly reduced where significant alterations occurred in the substrate; pioneer species of shrubs dominated in most disturbed areas (Prose et al. 1987). Cover of some annual forbs consumed by tortoises, e.g., desert dandelion (*Malacothrix glabrata*) and Fremont's pincushion (*Chaenactis fremontii*) was lower in tank tracks (Prose and Wilshire 2000). However, annual forbs were often in higher densities in tank tracks than in control areas, but plants were smaller in size. Grasses also were in greater densities in tank tracks. As of 2018, the scars of the tracked vehicles from the 1942 maneuvers remained evident on desert pavement (Berry, pers. obs.).

Grazing by cattle, sheep, horses, and feral burros began in the mid-1800s in the Mojave and Colorado deserts and is responsible for habitat degradation in many areas (e.g., Spears 1892; Wentworth 1948; Webb and Stielstra 1978; Johnston 1987; Stone 1989; Fleischner 1994; Abella 2008). The USFWS (2010) reported that ca. 12,881.5 km^2 or approximately 50% of critical habitat was grazed at the time of the federal listing in 1990; subsequently 8,479.9 km^2

of the allotments and leases involved were closed, leaving 4,401.7 km^2 (17.1%) of critical habitat still with allotments and leases. Recently, some allotments were renewed for 10 years in the West Mojave Recovery Unit.

Fleischner (1994) described three broad categories of negative effects of grazing to habitat, including alteration of species composition in vegetation associations, disruption of ecosystem functioning, and changes to ecosystem structure. Reduction in biomass and diversity of native annual and herbaceous perennial species has remained a critical issue for the Desert Tortoise, a selective forager, as has competition for forage (e.g., Avery and Neibergs 1997; Oftedal 2002; Oftedal et al. 2002; Jennings and Berry 2015).

The U.S. Bureau of Land Management, responsible for issuing leases and managing allotments and licenses on public land, recognized the negative effects of sheep when establishing the Desert Tortoise Research Natural Area between 1972 and 1980 (Webb and Steilstra 1979; Berry et al. 2014a), and sheep were therefore excluded within the boundaries. In 1990, the year the Desert Tortoise was listed as a Threatened species, sheep grazing was removed from areas expected to become critical habitat. Tuma et al. (2016), in a model of anthropogenic impacts to two study sites within the geographic range, listed grazing livestock and feral burros as the most important disturbances contributing to severe declines in tortoise populations. Some cattle grazing allotments remain in critical habitat as of 2018.

Long-term grazing in the desert results in reduction and loss of cover of shrubs and changes in the species composition of shrubs, favoring short-lived, weedy species (Webb and Steilstra 1979; Brooks et al. 2006). The composition and biomass of annual and perennial vegetation changes at sites where livestock concentrate: water sources, bedding areas, and loading and unloading areas (Webb and Steilstra 1979; Nicholson and Humphreys 1981; Brooks et al. 2006). Short-lived, colonizing shrubs and non-native grasses, tolerant of disturbances and inedible or less desirable as forage by livestock, are more common than in relatively undisturbed areas. Brooks et al. (2006) described piospheres, a disturbance gradient associated with watering sites for domestic grazers. Vegetation was denuded and soils compacted within 15 to 70 m of the tanks and troughs, with significant effects extending up to 200 m from the watering sites. Densities of the alien forb redstem filaree and alien Mediterranean grasses increased with increasing proximity to the water source, whereas native annuals decreased in cover and species richness with increasing proximity to the stock tank or other water sources. Cover and species richness of shrubs also decreased with increasing proximity to sources of water. Livestock prefer certain forbs, when they are available, and can rapidly deplete available favored food plants of the tortoise through trampling and foraging (Berry 1978, Webb and Stielstra 1978). The seedbank for native annuals and herbaceous perennials may also be reduced (Brooks 1995).

When livestock are moved from one place to another, whether in open desert or along stock driveways (e.g., Wentworth 1948), soils are disturbed and clouds of dust created. Importantly, stock tanks also are an attractant to and a subsidy used by ravens (Knight et al. 1998). Beschta et al. (2013) recommended removing or reducing livestock and feral burros and horses across public lands to make the lands less vulnerable to climate change.

Miners came to the Mojave and Colorado deserts seeking riches in the 1800s (e.g., Spears 1892; Vredenberg et al. 1981) and mining continues to be a source of loss, disturbance, and deterioration to tortoise habitat (e.g., Chaffee and Berry 2006; Kim et al. 2012, 2014). Early miners left pits, diggings, and shafts that trapped tortoises and that remain today; some shafts and pits are fenced and some are not.

Chaffee and Berry (2006), in an analysis of soil, stream sediments, and food plants of tortoises in the Mojave and Colorado deserts of California, reported anomalies in arsenic desert-wide. In the Rand and Atolia Mining Districts (Western Mojave Recovery Unit) they reported elevated levels in soil of arsenic, gold, cadmium, mercury, antimony, and/or tungsten 15 km from the mining source and plant anomalies for arsenic, antimony, and/or tungsten up to 6 km from the mining source. Elevated levels of mercury occurred as much as 6 km from old tailings piles. Arsenic and mercury were potential causes of illness in tortoises found in the area (Jacobson et al. 1991; Selzer and Berry 2005). Elevated levels of arsenic also occurred in the Goldstone Mining District and extended outward about 8 km. The highest arsenic concentrations occurred in 13 species of plants, of which five were species of legumes favored by tortoises (e.g., Jennings and Berry 2015). Kim et al. (2012, 2014) reported fluvial and aeolian transport of arsenic from several mining communities (Western Mojave Recovery Unit). Fluvial transport of arsenic from mining tailings occurred (and still occurs) in pulses with episodic rain events, and, depending on location, extends to 15 km from the source. The authors described aolian transport to 6 km from the source and calculated the cancer exposure risk to humans. Elemental toxicants can enter tortoises though breathing dust, consumption of contaminated plants, and contact with the skin. Foster et al. (2009) identified endogenous sources of arsenic in both shell and lung tissues.

Invasive Plants. — As a result of the disturbances to soil and vegetation described above, tortoise habitats in the Mojave and Colorado deserts have become vulnerable to invasion and establishment of non-native (alien, exotic) plants from arid areas in the Mediterranean, North Africa, Middle East, and Asia. Changes in plant composition and structure, especially cover and selected forage plants, are great threats to remaining tortoises. Several authors (e.g., D'Antonio and Vitousek 1992; Kemp and Brooks 1998) suggested that most exotic species arrived in the desert during the middle-to-late 18th century after the Gold Rush of 1849 and became established with livestock grazing and construction of roads and railroads. Later land-disturbing uses such as agriculture, ranching, settlements, cities, and towns were additional contributors (Brooks 2009).

The following non-native species of grasses and a forb composed most of the annual biomass in tortoise habitats in the early 2000s: Mediterranean grasses, red brome, cheat grass, and redstem filaree (Hunter 1991; Kemp and Brooks 1998), until the more recent appearance of Sahara mustard (*Brassica tournefortii*) (see below). In critical habitat within the Western Mojave Recovery Unit, non-native annuals composed 66% of the annual biomass in wet years and 91% in dry years, and positive correlations existed between richness of alien annual plant species and density of dirt roads in a wet year and with nitrogen in the soil during a dry year (Brooks and Berry 2006). During a wet year, total alien biomass correlated positively with proximity to the nearest urban area or paved roads and area and numbers of recent fires. During a dry year, total alien biomass was negatively correlated with diversity of annuals and positively correlated with biomass of native annuals, and the history of off-highway, recreational vehicle use. Total alien annual biomass, especially grasses, correlated positively with numbers of fires and area burned between 1980 and 1994 within 5 km of sampled plots in both wet and dry years, likely due to the flammability of alien grasses. Further, Brooks (2000, 2003) found that non-native grasses were especially effective in competing with native forbs and the exotic forb redstem filaree.

Increased atmospheric nitrogen deposited in soils from urban or other areas enhances dominance of alien annual plants, which in turn contributes to increases in frequency of fires (e.g., Brooks 2003; Rao and Allen 2010). Rao et al. (2011) followed with additional studies, and reported that large-scale patterns in disturbance and exotic species negatively affected diversity of native annual plant species; native annuals persisted locally, however. Increases in atmospheric CO_2, an effect and cause of global climate change, may enhance the long-term success and dominance of exotic annual grasses (e.g., red brome) in the Mojave Desert (Smith et al. 2000).

Seed banks reflected the status of habitat disturbance and invasion of alien species. At the Desert Tortoise Research Natural Area (fenced to exclude off-road vehicle use and grazing), Brooks (1995) reported that seed biomass was two to four times greater inside the fence than outside. Schneider and Allen (2012) noted that where invasions of non-natives were low, seeds of natives were in higher densities in seed banks. In high invasion sites, non-natives were higher in both seed banks and above-ground vegetation. Esque et al. (2010b) reported that invasive species (Mediterranean grasses, bromes, redstem filaree, and plantain, *Plantago* spp.) composed >95% of the seed bank following experimental fires of moderate temperatures in the Parashant National Monument of Arizona.

The non-native and invasive Sahara mustard was observed first in the Colorado Desert in the 1920s (Minnich and Sanders 2000). Subsequently, it spread rapidly northward and westward into the Mojave Desert (museum records, Jepson Flora Project 2018; Berry, pers. obs.). It has invaded most Recovery Units and is well established desert-wide. It can grow up to >1.5 m in height, produce large numbers of seeds, become a "tumble mustard" that can blow across landscapes, and appears to be a vigorous competitor of native annuals in the Mojave and western Sonoran deserts (Trader et al. 2006; Bangle et al. 2008; Barrows et al. 2009; Berry et al. 2014b). Sahara mustard is a highly successful invader that probably poses a considerable threat to native annuals because of early germination and rapid phenology, and its ability to disperse quickly across valleys and fans and in ephemeral stream channels (Bangle et al. 2008; Marushia et al. 2012; Suazo et al. 2012; Berry et al. 2014b). Desert Tortoises do not forage on Sahara mustard.

Fires. — Fires and invasive annual grasses are closely linked (D'Antonio and Vituosek 1992). Vegetation in the Mojave and western Sonoran deserts did not evolve with fire; occasional wildfires, ignited by lightning or campfires, occurred but were small because fuel was limited (Brooks and Chambers 2011). With the invasion and establishment of alien grasses, fuels became available and created an unnatural and destructive grass-fire cycle in which fires increased in frequency and area, potentially in intensity, and were followed by regrowth of the alien grasses (D'Antonio and Vitousek 1992; Brooks and Matchett 2006).

According to D'Antonio and Vitousek (1992), the invasion of cheat grass and associated fires was the most significant plant invasion in North America. Mediterranean grasses and red brome also play important roles and have different rates of fire spread across interspaces—slowly and discontinuously with Mediterranean grasses and more rapidly and continuously with bromes (Brooks 1999). The results suggested that red brome and cheat grass fueled faster moving, hotter fires, while Mediterranean grasses fueled slower moving, cooler fires.

Fires increased in frequency between 1980 and 2004 across the Mojave and Colorado deserts in critical habitat and in California (Brooks and Esque 2002; Brooks and Matchett 2006). The latter authors reported that 8,699 fires burned 2,920 km^2 between 1980 and 2004. Most fires occurred in shrub associations at middle elevations where typical tortoise habitat occurs, e.g., creosote bush, Joshua tree, and blackbrush vegetation associations. In 2005, a total of 576 km^2 burned in the northeastern Mojave Desert and Upper

Virgin River (USFWS 2010). The percentages of critical habitat burned varied: 3% of Mormon Mesa, 13% of Gold Butte-Pakoon, 25% of Beaver Dam Slope in the Northeastern Mojave Recovery Unit, and 19% of the Upper Virgin River Recovery Unit. Many tortoises died, but numbers were not provided in the USFWS (2010) report. According to Brooks and Matchett (2006), the trend from the 1990s and on for human-caused fires was toward a decreasing number of ignitions and a greater area burned.

Burned habitat affects the tortoises living there. Drake et al. (2015) studied how tortoises respond when about 45% of their home ranges were burned after a lightning-caused fire. They traveled increasingly deeper into the burned area to forage during the first 5 years post-fire, but returned to the unburned area for cover. One of the important forage plants common after the burn, globemallow, declined 6–7 years after the burn. At that time, tortoises reduced use of the burned area. In spite of damage from the fire, tortoises maintained reproductive output and health during the study. Lovich et al. (2018a) compared populations of tortoises in burned and unburned areas after a wind turbine fire; tortoises in the burned area continued use of the same activity areas after the fire.

Briefly, the many sources of habitat loss and degradation continue to have profound negative effects on the diversity, composition, and biomass of native annual and herbaceous perennial forbs and perennial shrubs and, importantly, the food supply and cover of shrubs essential for continued survival of *G. agassizii*. This pattern of changes and loss to the flora are not confined to the tortoise (Minnich 2008).

Climate Change and Projected Effects. — Global warming and changes in rainfall patterns are added negative impacts (Seager et al. 2007, Garfin et al. 2014; Allen et al. 2018; Sarhadi et al. 2018) and are likely to have severe effects on remaining, declining, and fragmented Desert Tortoise populations. The U.S. Global Change Research Program (USGCRP 2017) has predicted increased drying with reduced winter and spring precipitation in the American Southwest. Reduced precipitation in winter and spring (droughts) and higher temperatures contribute to deterioration in composition, structure, diversity, and biomass of trees and shrubs (Munson et al. 2016). Annual and herbaceous perennial plants would be similarly affected. Forage of native food plants is likely to become more limited in dry years (see Brooks and Berry 2006).

Models of the effects of climate change and warming on tortoises at the Mojave-Sonoran interface indicated that some available habitat will be lost (Barrows 2011). Tortoises may respond by shifting distribution to higher elevations and away from the western Sonoran Desert if they have time and opportunity to do so. With increasing droughts, survival of tortoises is likely to be severely reduced (e.g., Berry et al. 2002; Longshore et al. 2003; Lovich et al. 2014b). Climate refugia can be modeled to identify areas where existing populations may survive at warmer temperatures and where tortoises may be successfully translocated (Barrows et al. 2016). Such models will need to take into account the prediction "that the risk of American Southwest megadroughts will markedly increase with global warming" (Steiger et al. 2019).

Consequences of Fragmentation. — The many land uses described above have resulted in degradation, fragmentation, and loss of connectivity between populations within the metapopulation of *G. agassizii*. As habitat fragments become smaller and increasingly isolated, they become more vulnerable to increased genetic drift and inbreeding, reduction of genetic variation, and decrease in heterozygosity—an extinction vortex (Gilpin and Soulé 1986; Fagan and Holmes 2006). With the rapid decline in densities of tortoises in critical habitat units between 2004 and 2014, and the non-viability of many populations in critical habitat (USFWS 1994, 2011), the remaining populations are increasingly vulnerable to additional disturbances, long periods of drought, and catastrophic events. The impacts and demands of rapidly expanding human populations across the geographic range add to the severity of the problem (Hughson 2009).

Recovery of Habitat after Disturbance. — Tortoise habitats are likely to require centuries, if not thousands of years for recovery. Creosote bushes, a prominent species in tortoise habitat, form long-lived clones in the Mojave Desert and some very large clones are estimated to be as much as 11,700 years old (Vasek 1980). Over the past approximately 70 years, scientists have investigated how quickly vegetation can recover naturally after disturbances in creosote bush associations in the Mojave and Sonoran deserts. Most studies in tortoise habitats focused on natural recovery of shrubs (with minimal interventions) after disturbances from pipelines, aqueducts, borrow pits, and old military activities (e.g., Lathrop and Archbold 1980a,b; Vasek et al. 1975a,b; Prose et al. 1987; Abella 2010; Berry et al. 2016b). The composition of perennial shrubs goes through successional stages in the recovery process. Estimates for the time required for recovery to pre-disturbance values for canopy cover of shrubs may be decades, whereas a return to pre-disturbance levels for floristic structure and composition may require centuries.

Few publications exist on natural and enhanced recovery of communities of native annual and herbaceous perennial species after different types of disturbances (Johnson et al. 1975; Vasek 1979, 1980, 1983; Hessing and Johnson 1982; Prose and Wilshire 2000; Berry et al. 2015b). Vasek (1983) suggested that "some constellations of annual species may be members of stable old communities [referencing creosote bush scrub associations] and therefore probably have evolved intricate highly integrated adaptations for long persistence in stable desert conditions." Estimated recovery times for cover, floral composition, density, and biomass of annuals vary, but are likely to be much longer than for shrubs, depending on causes of disturbance, treatment and types of the soils, and whether or not non-native grasses and forbs are present. Berry et al. (2015b) concluded that return to pre-disturbance levels may require many centuries in their study of annuals recovering after 36 years of disturbance along a utility corridor in the western Mojave Desert. During the recovery process, annual communities may go through several seral stages (Hessing and Johnson 1982; Berry et al. 2015b).

Cumulative and Synergistic Impacts. — We have reviewed numerous causes of declines and how many of these causes are linked to each other and to human activities. In response to requests from managers to identify the most important cause(s), some scientists have quantified and modelled negative impacts in specific areas (e.g., Keith et al. 2008; Berry et al. 2008, 2014a; Tuma et al. 2016). Berry et al. (2014a) reported that in critical habitat with recent exclusion of livestock, limited vehicular traffic, and a partial fence, tortoise abundance (counts of live and dead tortoises and tortoise sign) was negatively associated with vehicle tracks and positively associated with mammalian predators and debris from firearms. Tuma et al. (2016) modelled severity of population decline rates at two sites, one in the central Mojave Desert and another in the northeastern Mojave Desert. In the central Mojave Desert, models indicated that the most severe decline rates were associated with human presence, followed by subsidized predators, and habitat degradation on inholdings. In contrast, in the northeastern Mojave Desert (Gold-Butte Pakoon critical habitat), livestock and feral burros were associated with the most significant declines, followed by human presence, subsidized predators, and wildfires.

Conservation Measures Taken. — *Gopherus agassizii* has been listed as federally Threatened under the U.S. Endangered Species Act (US ESA) since 1990. It was assessed as Vulnerable for the IUCN Red List in 1996 and provisionally re-assessed for the Red List as Critically Endangered by the IUCN Tortoise and Freshwater Turtle Specialist Group in 2011 and again in 2018 (TCC 2018; Rhodin et al. 2018). It has been listed on Appendix II of CITES (2017) since 1975 as part of the genus listing of *Gopherus*, and since 1977 as part of the family listing of Testudinidae.

Gopherus agassizii occurs in several areas with some degree of protection. The Desert Tortoise Research Natural Area in California is the most protected, followed by the Red Cliffs Desert Reserve in Utah. Limited protection is available in three national parks, especially in remote areas and where suitable habitat exists (Joshua Tree National Park and Mojave National Preserve in California, and Death Valley National Park in California and Nevada) and eight state parks (Red Rock Canyon State Park, Anza Borrego State Park, and Providence Mountains State Recreation Area in California; Red Rock Canyon National Recreation Area, Valley of Fire State Park, Lake Mead National Recreation Area, and the Desert National Wildlife Range in Nevada; and Snow Canyon in Utah). None of the national or state parks protect tortoises from paved or dirt roads with exclusion fencing, and at least one of the national parks (Mojave National Preserve) still maintains a cattle grazing allotment and feral burros within critical habitat.

Tortoises in parks with heavy visitor use are vulnerable to collecting and vandalism and road kills (e.g., Berry et al. 2008; Hughson and Darby 2013). For example, Mojave National Preserve contains two critical habitat units (Ivanpah and Fenner); in both, tortoise populations are declining (Table 3). Visitor use in the Preserve between 2004 and 2018 ranged from 537,250 to a high of 787,404 per year in 2018. In contrast, Joshua Tree National Park had a low density of tortoises, but the population was increasing (Table 3); visitor use in the Park was 2,942,382 in 2018. Lake Mead National Recreation Area has had over one million visitors per year since 1946 and growing; in 2018, 7.6 million visits occurred.

As noted in the section on Threats, the State of California took incremental protective measures for tortoises beginning in 1939. Grass-roots efforts advocating greater protection for a site with high densities began in the early1970s with the establishment of the Desert Tortoise Research Natural Area in the western Mojave Desert. The formation of the Desert Tortoise Preserve Committee, Inc. and Desert Tortoise Council, two non-profit, tax-exempt organizations, occurred about 1976. The Desert Tortoise Preserve Committee focuses efforts on public education, land acquisition and protection, fencing of protected areas, removing livestock grazing and recreational vehicle use from the Desert Tortoise Research Natural Area and other acquired lands, and research. The Desert Tortoise Council's goals and objectives include education through annual symposia and workshops, grants for travel and studies, and participation in government activities affecting tortoises and their habitats. Both organizations have promoted state and federal listings of the tortoise as a Threatened species. After the Beaver Dam Slope population of Desert Tortoises was federally listed as Threatened in 1980 under the U.S. Endangered Species Act (USFWS 1980), the Desert Tortoise Council submitted a comprehensive report to the U.S. Fish and Wildlife Service in 1984 to also list the tortoise throughout its range (Berry 1984). Studies and research on the tortoise and its habitats, supported by federal and state agencies and academia, began in the early 1970s and continued intermittently thereafter.

In 1980, the U.S. Bureau of Land Management, the agency managing substantial amounts of tortoise habitat range-wide, published the *California Desert Plan, 1980*. The Plan described the Desert Tortoise as a sensitive species, identified several crucial habitats (precursors to critical habitat units), established Areas of Critical Environmental Concern for the tortoise, and outlined expansive areas for future habitat management plans for the species (USBLM 1980). The Desert Tortoise Research Natural Area was formally designated in this Plan, a protective fence surrounding the area and a kiosk for visitors were completed, and a long-term mark-recapture study was initiated. In 1989, California designated the Desert Tortoise as a Threatened species (California Department of Fish and Wildlife 2006). The U.S. Fish and Wildlife Service listed the tortoise as Endangered on an interim basis in August of 1989 and issued a final rule as Threatened in April of 1990 (USFWS 1990). The U.S. Fish and Wildlife Service published a Recovery Plan in 1994 and designated > 25,000 km² of critical habitat units north and west of the Colorado River in the same year (USFWS 1994). In response to the pending listing and designation of critical habitat, federal, state, and county governments formed a Management Oversight Group composed of senior managers who address a wide variety of topics associated with recovery of the species at meetings held at least once a year.

The 1994 Recovery Plan contained numerous recommended management actions for Desert Wildlife Management Areas (defined as the best examples of Desert Tortoise habitat within regions): secure habitat, develop and implement reserve-level management, monitor tortoise populations within recovery areas, and develop environmental education programs (USFWS 1994). Several examples highlight recommended regulations and activities to be prohibited: all vehicle activity off designated roads and all competitive and organized events on designated roads; habitat-destructive surface disturbance that diminishes capacity of land to support tortoises; domestic livestock grazing and grazing by feral burros and horses; vegetation harvest, except by permit; collection of biological specimens, except by permit; dumping and littering; deposition of captive or displaced tortoises except under authorized translocation research projects; uncontrolled dogs out of vehicles; and discharge of firearms, except for hunting of game from September through February. The recommended actions included the following: control vehicular access; enforce regulations, restore disturbed areas; sign and fence Desert Wildlife Management Areas; implement appropriate administration; modify ongoing and planned activities to be consistent with recovery objectives; control use of landfills and sewage ponds by predators of tortoises; and establish environmental education programs and facilities. An important recommendation was to monitor tortoise populations in critical habitat units at a landscape scale. This latter effort was initiated in 1999 and the early 2000s, e.g., Table 3.

Government agencies responded to the Recovery Plan by preparing nine new or revised land management plans to better protect the Desert Tortoise on public lands (Berry 1997). Additional plans on military installations were revised or amended to include the Desert Tortoise. In 2011, the USFWS published a revised Recovery Plan which incorporated many actions described in the first Recovery Plan (USFWS 1994, 2011). The revised Recovery Plan described numerous recommendations for future research. One important issue, hyper-predation by ravens, was the topic of a special plan, which has involved surveys, selected removal of limited numbers of ravens, and egg-oiling (USFWS 2008). Part of the revised Recovery Plan was development of regional Recovery Implementation Teams composed of representatives from government agencies and non-profit organizations. Participants in these teams prepare proposals for recovery actions, seek funding to support the proposals, and assist with implementation when funding becomes available.

In the nearly 30 years since the Desert Tortoise was first listed range-wide in 1990, much has been accomplished by changes in land use. Unfortunately, positive actions have remained insufficient in amount and extent to stabilize tortoise populations in the designated critical habitat units (USFWS 2015; Table 3; Allison and McLuckie 2018). Land acquisition for the Desert Tortoise Research Natural Area, which began in the late 1970s, has continued. The U.S. Bureau of Land Management and other government agencies and conservation organizations have acquired substantial amounts of private lands in small and large parcels to convert critical habitat and other protected areas to federal and conservation management.

Sheep grazing has been removed from critical habitat, but cattle continue to graze on about 17% of critical habitat, and feral burros encroach on a few critical habitat units. Tortoise-exclusion fencing was constructed along many kilometers of roads; however, as of 2010, thousands of kilometers of roads and railroads remained unfenced (USFWS 2010). Experimental efforts to reduce vehicle speed on roads within the Mojave National Preserve to reduce road kills were unsuccessful (Hughson and Darby 2013). One of the more intractable problems is the high density of routes and tracks created by recreational vehicle use, the high levels of unauthorized and cross-country travel on 2- and 4-wheeled vehicles, and the negative effects on tortoises and their habitats (Goodlett and Goodlett 1992; Egan et al. 2012; Piechowski 2015; USBLM 2019).

The federal (and state) listings of the Desert Tortoise as Threatened stimulated a great deal of interest and effort in addressing basic questions about the species, such as status and distribution of populations, ecology, genetics, and diseases, as well as solving conflicts with the many users of Desert Tortoise habitats. Conflicts existed over degradation of habitat and threats to Desert Tortoises from historical users (livestock grazing, mining, and recreation), developers, and some government agencies. Other agencies, academicians, and non-profit organizations held more conservation-oriented views. As a result, many basic and applied research projects were undertaken and completed, and the results were published in peer-reviewed journals between 1980 and 2018 (Grover and DeFalco 1995; >400 published papers, Berry et al. 2016c). Notably, many agencies and developers provided substantial funds to support studies and research, e.g., U.S. Department of the Interior (U.S. Bureau of Land Management, U.S. Geological Survey), U.S. Department of Defense (Army, Air Force, Marines), California Department of Fish and Game, California Department of Parks and Recreation, California Energy Commission, Utah Division of Wildlife Resources, and several universities. Many other entities also provided funds but not on the same scale.

Two current conservation research topics are augmentation of populations through head-starting and translocation. Experimental research has been conducted and continues in four desert regions on head-starting to learn more about neonates and juveniles and their habitat requirements, to determine factors affecting survival both before and after release, and to augment depleted populations (e.g., Morafka et al. 1997; Wilson et al. 1999a,b, 2001; Nagy et al. 2015a,b, 2016; Todd et al. 2016; Mack et al. 2018). However, caution needs to be exercised, as some research manipulations, such as crowding in head-start pens and cystocentesis of adults, can lead to increased morbidity and mortality (Berry et al. 2002; Mack et al. 2018).

Translocations to remove Desert Tortoises from areas scheduled for development continue and are important research topics (e.g., Field et al. 2007; Nussear et al. 2012; Farnsworth et al. 2015; Hinderle et al. 2015; Brand et al. 2016; Nafus et al. 2016; Mulder et al. 2017; Henen 2018). Most research topics on translocation were short term (1–3 years). The research undertaken by Farnsworth et al. (2015), Brand et al. (2016), and others were for short-distance translocations covering five years. When all elements of this study are published, they will provide a valuable addition to the topic. Publications preparatory for and during mixed long and short-distance translocations include Esque et al. (2010a), Berry et al. (2015a), and Mulder et al. (2017). When these longer-term projects (10 years) are published, more information will be available on survival of translocated animals. In an important paper, Mulder et al. (2017) reported on genetic integration of tortoises translocated long distances. After four years, translocated males produced significantly fewer off-spring than resident males in the same area. The length of delay in integration of translocated males into resident populations needs to be addressed through future research.

Another important recovery objective is restoration of disturbed and burned Desert Tortoise habitats (e.g., Abella 2010; Abella and Newton 2009; Abella and Berry 2016; Abella et al. 2009, 2015a,b). Topics being addressed include methods for salvaging soils and seed banks, restoring seed banks of native plants, improving survival of shrubs after seeding and planting, keeping transplanted shrubs alive and growing, and planting forage species for tortoises.

Conservation Measures Proposed. — Most of the >400 papers published on Desert Tortoises and their habitats after the federal listing in 1990 contained recommendations for recovering the tortoise and its habitats (Berry et al. 2016c). The revised Recovery Plan also contains a list of recovery actions to be taken, including development of partnerships to facilitate recovery, protection of existing populations and habitat, augmenting depleted populations, conducting applied research and modeling, and implementing an adaptive management program (USFWS 2011). The Recovery Implementation Teams have submitted projects for restoration of burned habitats and areas denuded by livestock, management of trash (a source of food for subsidized predators), control of invasive plants, fencing of major highways, and many other topics.

Research on genetics of tortoises provides a framework for changes in management. The most detailed genetic analyses of tortoise populations published to date (Sánchez-Ramírez et al. 2018) provided data on population differences within and between recovery units, as well as identification of 12 genes likely involved in adaptations. The results of this paper suggested that the Western Mojave Recovery Unit could defensibly be divided into three separate Recovery Units: western, central, and southern, since these three subunits are genetically equivalent to each of the other four Recovery Units. The results also suggested that it could be valuable to update Averill-Murray and Hagerty (2014), who had used Hagerty and Tracy (2010) and Hagerty et al. (2011) as a basis to suggest that tortoises could be translocated within a 200–276 km straight-line radius of their native sites without moving animals between different genetic subunits. The results of Sánchez-Ramírez et al. (2018) suggested that caution is warranted when implementing such a practice, since such distances may involve different genetic units or subunits.

Another publication by Drake et al. (2017) coupled standard clinical and classic blood diagnostics with gene transcription profiles in ill and normal tortoises. These findings indicate promise for more robust diagnostic procedures in evaluating ill and healthy tortoises and for tortoises subjected to disturbances. Publications of the genome sequences for *G. agassizii* and *Mycoplasma testudineum* provide a basis for further advances in diagnostic procedures (Tollis et al. 2017; Weitzman et al. 2018), with Weitzman et al. (2017) offering another example through a comparison of different testing techniques for the pathogen *M. agassizii* with range-wide sampling.

Captive Husbandry. — Captive husbandry falls into two categories: research associated with head-starting and augmenting wild populations (see above), and management of tortoises kept as pets, in many cases for decades. In California, 13 chapters of the California Turtle and Tortoise Club manage adoption programs for domestic or pet *G. agassizii* and other chelonian species under agreements with the California Department of Fish and Wildlife (https://tortoise.org/). In Nevada, this function is accomplished by Tortoise Group (https://tortoisegroup.org/). These organizations (and others) provide information on husbandry, state and federal regulations, and education.

Current Research. — Research on basic ecology, demography, and distribution continues, as does in-depth work on genetics, infectious and other diseases, epidemiology of diseases, effects of anthropogenic activities on tortoises, augmentation of populations, and effects of drought and global climate change. Updates on modelling viability of populations, survival rates of the different size classes, and causes of death are important building blocks for recovery strategies and adaptive management. Ongoing applied research focuses on a wide array of topics, such as effectiveness of different augmentation strategies, including head-starting and translocation, control and management of subsidized predators, and restoration of habitats degraded by livestock grazing, recreational vehicle use, and industrial and energy developments. The effects of different anthropogenic impacts on tortoises remain an area of interest. New technologies (e.g., drones) are also areas of interest.

Acknowledgments. — Thanks are due to the hundreds of scientists who have conducted and published studies and research designed to address basic natural history, ecology, and health of Desert Tortoises, as well as the many drivers of anthropogenic impacts. Mark Massar, Jeff Aardahl, and Debra Hughson provided answers to our many questions about ongoing activities. We thank Betty L. Burge, Steve Ishii, Mark Massar, Ann McLuckie, Freya Reder, Cameron Rognan, Bev Steveson, Michael Tuma, Desert Tortoise Preserve Committee, Mojave Natural Preserve, San Diego Zoo Global, and U.S. Geological Survey for the use of their photos. Anders Rhodin improved the manuscript with his editing, and reviews from John Iverson, Peter Paul van Dijk, Taylor Edwards, Diane Elam, Keith Miles, and Barbara Ralston were constructive and added to the paper.

LITERATURE CITED

Abella, S.R. 2008. A systematic review of wild Burro grazing effects on Mojave Desert vegetation, USA. Environmental Management 41:809–819.

Abella, S.R. 2010. Disturbance and plant succession in the Mojave and Sonoran deserts of the American Southwest. International Journal of Environmental Research and Public Health 7:1248–1284.

Abella, S.R., and Newton, A.C. 2009. A systematic review of species performance and treatment effectiveness for revegetation in the Mojave Desert, USA. In: Fernandez-Bernal, A. and De La Rosa, M.A. (Eds.). Arid Environments and Wind Erosion. Nova Science Publishers, Inc., pp. 46–74.

Abella, S.R. and Berry, K.H. 2016. Enhancing and restoring habitat for the Desert Tortoise *Gopherus agassizii*. Journal of Fish and Wildlife Management 7:1–25.

Abella, S.R., Spencer, J.E., Hoines, J., and Nazarchyk, C. 2009. Assessing an exotic plant surveying program in the Mojave Desert, Clark County, Nevada, USA. Environmental Monitoring and Assessment 151:221–230.

Abella, S.R., Chiquoine, L.P., Newton, A.C., and Vanier, C.H. 2015a. Restoring a desert ecosystem using soil salvage, revegetation, and irrigation. Journal of Arid Environments 115:44–52.

Abella, S.R., Chiquoine, L.P., Engle, E.C., Kleinick, K.E., and Edwards, F.S. 2015b. Enhancing quality of Desert Tortoise habitat: augmenting native forage and cover plants. Journal of Fish and Wildlife Management 6:278–289.

Adams, J.A., Endo, A.S., Stolzy, L.H., Rowlands, P.G., and Johnson, H.B. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. Journal of Applied Ecology 19:167–175.

Agha, M., Lovich, J., Ennen, J., and Wilcox, E. 2013. Nest-guarding by female Agassiz's Desert Tortoise (*Gopherus agassizii*) at a wind-energy facility near Palm Springs, California. Southwestern Naturalist 58:256–260.

Agha, M., Augustine, B., Lovich, J.E., Delaney, D., Sinervo, B., Murphy, M.O., Ennen, J.R., Briggs, J.R., Cooper, R., and Price, S.J. 2015a. Using motion-sensor camera technology to infer seasonal activity and thermal niche of the Desert Tortoise (*Gopherus agassizii*). Journal of Thermal Biology 49–50:119–126.

Agha, M., Murphy, M.O., Lovich, J.E., Ennen, J.R., Oldham, C.R., Meyer, K., Bjurlin, C., Austin, M., Madrak, S., Loughran, C., Tennant, L., and Price, S.J. 2015b. The effect of research activities and winter precipitation on voiding behavior of Agassiz's Desert Tortoises (*Gopherus agassizii*). Wildlife Research, http://dx.doi.org/10.1071/WR14196

Agha, M., Lovich, J.E., Ennen, J.R., Augustine, B., Arundel, T.R., Murphy, M.O., Meyer-Wilkins, K., Bjurlin, C., Delaney, D., Briggs, J., Austin, M., Madrak, S.V., and Price, S.J. 2015c. Turbines and terrestrial vertebrates: variation in tortoise survivorship between a wind energy facility and an adjacent undisturbed wildland area in the desert Southwest (USA). Environmental Management 56:332–341.

Agha, M., Smith, A., Lovich, J.E., Delaney, D., Ennen, J.R., Briggs, Fleckenstein, L.J., Tennant, L.A., Puffer, S.R., Walde, A., Arundel, T.R., Price, S.J., and Todd, B.D. 2017. Mammalian mesocarnivore visitation at tortoise burrows in a wind farm. Journal of Wildlife Management 81:1117–1124.

Aiello, C.M., Nussear, K.W., Esque, T.C., Emblidge, P.G., Sah, P., Bansal, S., and Hudson, P.J. 2016. Host contact and shedding patterns clarify variation in pathogen exposure and transmission in threatened tortoise *Gopherus agassizii*: implications for disease modelling and management. Journal of Animal Ecology, https://doi:10.1111/1365-2656.12511.

Aiello, C.M., Esque, T.C., Nussear, K.E., Emblidge, P.G., and

Hudson, P.J. 2018. The slow dynamics of mycoplasma infections in a tortoise host reveal heterogeneity pertinent to pathogen transmission and monitoring. Epidemiology and Infection 1–10, https://doi.org/10.017/S0950268818002613.

Alberts, A.C., Rostal, D.C., and Lance, V.A. 1994. Studies on the chemistry and social significance of chin gland secretions in the Desert Tortoise, *Gopherus agassizii*. Herpetological Monographs 8:116–124.

Allen, M., Babiker, M., Chen, Y., de Coninck, H., Connors, S., van Diemen, R., Dube, O.P., et al. 2018. Global warming of 1.5°C, an Intergovernmental Panel on Climate Change Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Summary for Policymakers. Approved and accepted by the 48th Session of the IPCC, Incheon, Republic of Korea, 6 October 2018.

Allison, L.J. and McLuckie, A.M. 2018. Population trends in Mojave Desert Tortoises (*Gopherus agassizii*). Herpetological Conservation and Biology 13:433–452.

Andersen, M.C., Watts, J.M., Freilich, J.E., Yool, S.R., Wakefield, G.I., McCauley, J.F., and Fahnestock, P.B. 2000. Regression-tree modeling of Desert Tortoise habitat in the central Mojave Desert. Ecological Applications 10:890–900.

Anderson, K. and Berry, K.H. 2019. *Gopherus agassizii* (Agassiz's Desert Tortoise). Predation. Herpetological Review 50:351.

Andrew, N.G., Bleich, V.C., Morrison, A.D., Lesicka, L.M, and Cooley, P.J. 2001. Wildlife mortalities associated with artificial water sources. Wildlife Society Bulletin 29:275–280.

Anonymous. 1881. A water carrying tortoise. San Francisco, CA: Mining and Scientific Press, Dewey and Co., p. 320.

Anonymous (Staff and Wire Reports). 2018. Wildlife officials find non-native tortoises in Red Cliffs Desert Reserve. St. George Spectrum and Daily News, Oct. 21, 2018 online.

Auffenberg, W. and Franz, R. 1978. *Gopherus agassizii*. Catalogue of American Amphibians and Reptiles 212.1–212.2.

Averill-Murray, R.C. and Hagerty, B.E. 2014. Translocation relative to spatial genetic structure of the Mojave Desert Tortoise, *Gopherus agassizii*. Chelonian Conservation and Biology 13:35–41.

Averill-Murray, R.C., Darst, C.R., Stout, N., and Wong, M. 2013. Conserving population linkages for the Mojave Desert Tortoise (*Gopherus agassizii*). Herpetological Conservation and Biology 8:1–15.

Avery, H.W. and Neibergs, A. 1997. Effects of cattle grazing on the Desert Tortoise, *Gopherus agassizii*: nutritional and behavioral interactions. In: Van Abbema, J. (Ed.). Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference. New York: New York Turtle and Tortoise Society and the WCS Turtle Recovery Program. pp. 13–20.

Bangle, D.N., Walker, L.R., and Powell, E.A. 2008. Seed germination of the invasive plant *Brassica tournefortii* (Sahara mustard) in the Mojave Desert. Western North American Naturalist 68:334–342.

Barrow, J. 1979. Aspects of the ecology of the Desert Tortoise, *Gopherus agassizii*, in Joshua Tree National Monument, Pinto Basin, Riverside County, California. Desert Tortoise Council Symposium Proceedings 1979:105–131.

Barrows, C.W. 2011. Sensitivity to climate change for two reptiles at the Mojave-Sonoran Desert interface. Journal of Arid Environments 75:629–635.

Barrows, C.W., Allen, E.B., Brooks, M.L., and Allen, M.F. 2009. Effects of an invasive plant on a desert sand dune landscape. Biological Invasions 11:673–686.

Barrows, C.W., Henen, B.T., and Karl, A.E. 2016. Identifying climate refugia: a framework to inform conservation strategies for Agassiz's Desert Tortoise in a warmer future. Chelonian Conservation and Biology 15:2–11.

Battye, C. 1924. An episode of the early days at Needles, California. Santa Fe Magazine 28:37–39.

Baxter, P.C., Wilson, D.S., and Morafka, D.J. 2008. The effects of nest date and placement of eggs in burrows on sex ratios and potential survival of hatchling Desert Tortoises, *Gopherus agassizii*. Chelonian Conservation and Biology 7:52–59.

Beck, D.D. 1990. Ecology and behavior of the Gila Monster in southwestern Utah. Journal of Herpetology 24:54–68.

Berry, K.H. 1978. Livestock grazing and the Desert Tortoise. Transactions of the 43rd North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, DC.

Berry, K.H. (Ed.) 1984. The Status of the Desert Tortoise (*Gopherus agassizii*) in the United States. Report to the U.S. Fish and Wildlife Service from the Desert Tortoise Council on Order No. 11310–0083–81.

Berry, K.H. 1986. Incidence of gunshot deaths in Desert Tortoises in California. Wildlife Society Bulletin 14:127–132.

Berry, K.H. 1997. The Desert Tortoise Recovery Plan: an ambitious effort to conserve biodiversity in the Mojave and Colorado Deserts of the United States. In: Van Abbema, J. (Ed.). Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference. N.Y. Turtle and Tortoise Society, pp. 430–440.

Berry, K.H. and Christopher, M.M. 2001. Guidelines for the field evaluation of Desert Tortoise health and disease. Journal of Wildlife Diseases 37:427–450.

Berry, K.H. and Medica, P. 1995. Desert Tortoises in the Mojave and Colorado deserts. In: LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J. (Eds.). Our Living Resources. A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service, pp. 135–137.

Berry, K.H. and Turner, F.B. 1986. Spring activities and habits of juvenile Desert Tortoises, *Gopherus agassizii*, in California. Copeia 1986:1010–1012.

Berry, K.H., Shields, T., Woodman, A.P., Campbell, T., Roberson, J., Bohuski, K., and Karl, A. 1986. Changes in Desert Tortoise populations at the Desert Tortoise Research Natural Area between 1979 and 1985. Desert Tortoise Council Symposium Proceedings 1986:100–123.

Berry, K.H., Hoover, F.G., and Walker, M. 1996. The effects of poaching Desert Tortoises in the western Mojave Desert: evaluation of landscape and local impacts. Desert Tortoise Council Symposium Proceedings 1996:45, http://www.deserttortoise.org.

Berry, K.H., Spangenberg, E.K., Homer, B.L., and Jacobson, E.R. 2002. Deaths of Desert Tortoises following periods of drought and research manipulations. Chelonian Conservation and Biology 4:436–448.

Berry, K.H., Bailey, T.Y., and Anderson, K.M. 2006. Attributes of Desert Tortoise populations at the National Training Center, Central Mojave Desert, California, USA. Journal of Arid Environments 67 (Supplement):165–191.

Berry, K.H., Keith, K., and Bailey, T. 2008. Status of the Desert Tortoise in Red Rock Canyon State Park. California Fish and

Game 94:98–118.

Berry, K.H., Yee, J.L., Coble, A.A., Perry, W.M., and Shields, T.A. 2013. Multiple factors affect a population of Agassiz's Desert Tortoise (*Gopherus agassizii*) in the northwestern Mojave Desert. Herpetological Monographs 27:87–109.

Berry, K.H., Lyren, L.L., Yee, J.L., and Bailey, T.Y. 2014a. Protection benefits Desert Tortoise (*Gopherus agassizii*) abundance: the influence of three management strategies on a threatened species. Herpetological Monographs 28:66–92.

Berry, K.H., Gowan, T.A., Miller, D.M., and Brooks, M.L. 2014b. Models of invasion and establishment for African mustard (*Brassica tournefortii*). Invasive Plant Science and Management 7:599–616.

Berry, K.H., Coble, A.A., Yee, J.L., Mack, J.S., Perry, W.M., Anderson, K.M., and Brown, M.B. 2015a. Distance to human populations influences epidemiology of respiratory disease in Desert Tortoises. Journal of Wildlife Management 79:122–136.

Berry, K.H., Mack, J.S., Weigand, J.F., and Gowan, T.A. 2015b. Bidirectional recovery patterns of Mojave Desert vegetation in an aqueduct pipeline corridor after 36 years: II. Annual plants. Journal of Arid Environments 122:141–153.

Berry, K.H., Shields, T., and Jacobson, E.R. 2016a. *Gopherus agassizii* (Mohave Desert Tortoise). Probable Rattlesnake envenomation. Herpetological Review 47:652–653.

Berry, K.H., Weigand, J.F., Gowan, T.A., and Mack, J.S. 2016b. Bidirectional recovery patterns of Mojave Desert vegetation in an aqueduct pipeline corridor after 36 years: I. Perennial shrubs and grasses. Journal of Arid Environments 124:413–425.

Berry, K.H., Lyren, L.M., Mack, J.S., Brand, L.A., and Wood, D.A. 2016c. Desert Tortoise Annotated Bibliography, 1991–2015. U.S. Geological Survey Open File Report 2016-1023, http://dx.doi.org/10.3133/ofr20161023.

Beschta, R.L., Donahue, D.L., DellaSala, D.A., Rhodes, J.J., Karr, J.R., O'Brien, M.H., Fleischner, T.L., and Williams, C.D. 2013. Adapting to climate change on western public lands: addressing the ecological effects of domestic, wild, and feral ungulates. Environmental Management 41:474–491.

Bjurlin, C.D. and Bissonette, J.A. 2004. Survival during early life stages of the Desert Tortoise (*Gopherus agassizii*) in the south-central Mojave Desert. Journal of Herpetology 38:527–535.

Boarman, W.I. 1993. When a native predator becomes a pest: a case study. In: Majumdar, S.K., Miller, E.W., Baker, D.E., Brown, E.K., Pratt, J.R., and Schmalz, R.F (Eds.). Conservation and Resource Management. The Pennsylvania Academy of Science, pp. 191–206.

Boarman, W.I. and Berry, K.H. 1995. Common Ravens in the southwestern United States, 1968–92. In: LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J. (Eds.). Our Living Resources. A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service, pp. 73–75.

Boarman, W.I. and Sazaki, M. 2006. A highway's road-effect zone for Desert Tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94–101.

Boarman, W.I, Patten, M.A., Camp, R.J., and Collis, S.J. 2006. Ecology of a population of subsidized predators: Common Ravens in the central Mojave Desert, California. Journal of Arid Environments 67:248–261.

Bour, R. and Dubois, A. 1984. *Xerobates agassizii*, 1857, synonyme ancient de *Scaptochelys* Bramble, 1982 (Reptilia, Chelonii, Testudinidae). Bulletin Mensuel de la Société Linnéenne de Lyon 53:30–32.

Boyer, T.H. and Boyer, D.M. 2006. Turtles, tortoises, and terrapins. In: Mader, D.R. (Ed.). Reptile Medicine and Surgery, 2nd Ed. Saunders Elsevier Inc., USA, pp. 78–99.

Bramble, D.M. 1982. *Scaptochelys*: generic revision and evolution of Gopher Tortoises. Copeia 1982:852–867.

Bramble, D.M. and Hutchinson, J.H. 2014. Morphology, taxonomy, and distribution of North American tortoises. An evolutionary perspective. In: Rostal, D.C., McCoy, E.D., and Mushinsky, H.R. (Eds.). Biology and Conservation of North American Tortoises. Baltimore, MD: Johns Hopkins University Press, pp. 1–12.

Brand, L.A., Farnsworth, M.L., Meyers, J., Dickson, B.G., Grouios, C., Scheib, A.F., and Scherer, R.D. 2016. Mitigation-driven translocation effects on temperature, condition, growth, and mortality of Mojave Desert Tortoise (*Gopherus agassizii*) in the face of solar energy development. Biological Conservation 200:104–111.

Brattstrom, B.H. 1961. Some new fossil tortoises from Western North America with remarks on zoogeography and paleoecology of tortoises. Journal of Paleontology 35:543–560.

Brattstrom, B.H. 1965. Body temperatures of reptiles. American Midland Naturalist 73:376–422.

Brooks, M.L. 1995. Benefits of protective fencing to plant and rodent communities of the western Mojave Desert, California. Environmental Management 19:65–74.

Brooks, M.L. 1999. Alien annual grasses and fire in the Mojave Desert. Madroño 46:13–19.

Brooks, M.L. 2000. Competition between alien annual grasses and native annual plants in the Mojave Desert. American Midland Naturalist 144:92–108.

Brooks, M.L. 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. Journal of Applied Ecology 40:344–353.

Brooks, M.L. 2009. Spatial and temporal distribution of non-native plants in upland areas of the Mojave Desert. In: Webb, R.H., Fenstermaker, L.F., Heaton, J.S., Hughson, D.L., McDonald, E.V., and Miller, D.M. (Eds.). The Mojave Desert. Ecosystem Processes and Sustainability. Reno, NV: University of Nevada Press, pp. 101–124.

Brooks, M.L. and Berry, K.H. 2006. Dominance and environmental correlates of alien annual plants in the Mojave Desert, USA. Journal of Arid Environments 67:100–124.

Brooks, M.L. and Chambers, J.C. 2011. Resistance to invasion and resilience to fire in desert shrublands of North America. Rangeland Ecology and Management 64:431–438.

Brooks, M.L. and Esque, T.C. 2002. Alien plants and fire in Desert Tortoise (*Gopherus agassizii*) habitat of the Mojave and Colorado deserts. Chelonian Conservation and Biology 4:330–340.

Brooks, M.L. and Lair, B.M. 2009. Ecological effects of vehicular routes in a desert ecosystem. In: Webb, R.H., Fenstermaker, L.F., Heaton, J.S., Hughson, D.L., McDonald, E.V., and Miller, D.M. (Eds.). The Mojave Desert. Ecosystem Processes and Sustainability. Reno: University of Nevada Press, pp. 168–195.

Brooks, M.L. and Matchett, J.R. 2006. Spatial and temporal patterns of wildfires in the Mojave Desert, 1980–2004. Journal of Arid Environments 67 (Supplement):148–164.

Brooks, M.L., Matchett, J.R., and Berry, K.H. 2006. Effects of livestock watering sites on alien and native plants in the Mojave Desert, USA. Journal of Arid Environments 67 (Supplement):125–147.

Brown, M.B., Schumacher, I.M., Klein, P.A., Harris, K., Correll, T., and Jacobson, E.R. 1994. *Mycoplasma agassizii* causes upper respiratory tract disease in the Desert Tortoise. Infection and Immunity 62:4580–4586.

Brown, M.B., Berry, K.H., Schumacher, I.M., Nagy, K.A., Christopher, M.M., and Klein, P.A. 1999. Seroepidemiology of upper respiratory tract disease in the Desert Tortoise in the western Mojave Desert of California. Journal of Wildlife Diseases 35:716–727.

Buhlmann, K.A., Akre, T.S.B., Iverson, J.B., Karapatakis, D., Mittermeier, R.A., Georges, A., Rhodin, A.G.J., van Dijk, P.P., and Gibbons, J.W. 2009. A global analysis of tortoise and freshwater turtle distributions with identification of priority conservation areas. Chelonian Conservation and Biology 8:116–149.

Bulova, S.J. 1994. Pattern of burrow use by Desert Tortoises: gender differences and seasonal trends. Herpetological Monographs 7:133–143.

Bulova, S.J. 2002. How temperature, humidity, and burrow selection affect evaporative water loss in the Desert Tortoise. Journal of Thermal Biology 27:175–189.

Burge, B.L. 1977a. Daily and seasonal behavior, and areas utilized by the Desert Tortoise *Gopherus agassizi* in southern Nevada. Desert Tortoise Council Symposium Proceedings 1977:59–94.

Burge, B.L. 1977b. Movements and behavior of the Desert Tortoise (*Gopherus agassizii*). M.S. Thesis, University of Nevada, Las Vegas.

Burge, B.L. 1978. Physical characteristics and patterns of utilization of cover sites used by *Gopherus agassizi* in southern Nevada. Desert Tortoise Council Symposium Proceedings 1978:80–111.

Burge, B.L. and Bradley, W.G. 1976. Population density, structure and feeding habits of the Desert Tortoise, *Gopherus agassizi*, in a low desert study area in southern Nevada. Desert Tortoise Council Symposium Proceedings 1976:51–74.

Bury, R.B. and Luckenbach, R.A. 2002. Comparison of Desert Tortoise (*Gopherus agassizii*) populations in an unused and off-road vehicle area in the Mojave Desert. Chelonian Conservation and Biology 4:457–463.

Bury, R.B. and Marlow, R.W. 1973. The Desert Tortoise: will it survive? National Parks and Conservation Magazine 47:9–12.

California Department of Fish and Game Code. 1939–1981. Legislative history and regulations, Sections 200–203.1, 206, 2078, 208–210, 5000–5002, 5060, 5061. Sacramento, CA: California Fish and Game Code.

California Department of Fish and Wildlife. 2016. State and federally listed Endangered and Threatened animals of California. Sacramento, CA: California Department of Fish and Wildlife. Biogeographic Data Branch, California Natural Diversity Database, https://www.wildlife.ca.gov/data/cnddb. accessed 28 Sep 2016.

Camp, C.L. 1916. Notes on local distribution and habits of amphibians and reptiles of southeastern California in the vicinity of Turtle Mountains. University of California Publications in Zoology 12:503–544.

Camp, R.J., Knight, R.L, Knight, H.A.L., Sherman, M.W., and Kawashima, J.Y. 1993. Food habits of nesting Common Ravens in the eastern Mojave Desert. Southwestern Naturalist 38:163–165.

Campbell, T. 1983. Some natural history observations of Desert Tortoises and other species on and near the Desert Tortoise Natural Area, Kern County, California. Desert Tortoise Council Symposium Proceedings 1983:80–88.

Chaffee, M.A. and Berry, K.H. 2006. Abundance and distribution of selected elements in soils, stream sediments, and selected forage plants from Desert Tortoise habitats in the Mojave and Colorado deserts, USA. Journal of Arid Environments 67:35–87.

Christopher, M.M. 1999. Physical and biochemical abnormalities associated with prolonged entrapment in a Desert Tortoise. Journal of Wildlife Diseases 35:361–366.

Christopher, M.M., Berry, K.H., Wallis, I.R., Nagy, K.A., Henen, B.T., and Peterson, C.C. 1999. Reference intervals and physiologic alterations in hematologic and biochemical values of free-ranging Desert Tortoises in the Mojave Desert. Journal of Wildlife Diseases 35:212–238.

Christopher, M.M., Berry, K.H., Henen, B.T., and Nagy, K.A. 2003. Clinical disease and laboratory abnormalities in free-ranging Desert Tortoises in California (1990–1995). Journal of Wildlife Diseases 39:35–56.

CITES [Convention on International Trade in Endangered Species of Wild Fauna and Flora]. 2017. Appendices I, II and III. Valid from 4 October 2017. https://www.cites.org/eng/app/appendices.php. accessed 31 July 2018.

Cooper, J.G. 1861. New Californian animals. Proceedings of the California Academy of Sciences (ser. 1) 2:18–123.

Cope, E.D. 1875. Check-list of North American Batrachia and Reptilia. Bulletin of the U.S. National Museum 1:1–104.

Curtin, A.J., Zug, G.R., and Spotila, J.R. 2009. Longevity and growth strategies of the Desert Tortoise (*Gopherus agassizii*) in two American deserts. Journal of Arid Environments 73:463–471.

Cypher, B.L., Kelly, E.C., Westall, T.L., and Van Horn Job, C.L. 2018. Coyote diet patterns in the Mojave Desert: implications for threatened Desert Tortoises. Pacific Conservation Biology 24:44–54.

D'Antonio, C.M. and Vitousek, P.M. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Reviews in Ecology and Systematics 23:63–87.

Davy, C.M., Edwards, T., Lathrop, A., Bratton, M., Hagan, M., Henen, B., Nagy, K.A., Stone, J., Hillard, L.S., and Murphy, R.W. 2011. Polyandry and multiple paternities in the threatened Agassiz's Desert Tortoise, *Gopherus agassizii*. Conservation Genetics 12:1313–1322.

Dickinson, V.M., Duck, T., Schwalbe, C.R., Jarchow, J.L., and Trueblood, M.H. 2001. Nasal and cloacal bacteria in free-ranging Desert Tortoises from the western United States. Journal of Wildlife Diseases 37:252–257.

Donoghue, S. 2006. Nutrition. In: Mader, D.R. (Ed.). Reptile Medicine and Surgery. Saunders Elsevier, Inc., USA, pp. 251–298.

Drake, K.K., Medica, P.A., Esque, T.C., and Nussear, K.E. 2012. *Gopherus agassizii* (Agassiz's Desert Tortoise). Scute dysecdysis/scute sloughing. Herpetological Review 43:473–474.

Drake, K.K., Esque, T.C., Nussear, K.E., DeFalco, L.A., Scoles-Sciulla, S.J., Modlin, A.T., and Medica, P.A. 2015. Desert Tortoise use of burned habitat in the eastern Mojave Desert. Journal of Wildlife Management 79:618–629.

Drake, K.K., Bowen, L, Nussear, K.E., Esque, T.C., Berger, A.J., Custer, N.A., Waters, S.C., Johnson, J.D., Miles, A.K., and Lewison, R.L. 2016. Negative impacts of invasive plants on conservation of sensitive desert wildlife. Ecosphere 7(10):e01531.

Drake, K.K., Bowen, L., Lewison, R.L., Esque, T.C., Nussear, K.E., Braun, J., Waters, S.C., and Miles, A.K. 2017. Coupling gene-based and classic veterinary diagnostics improves interpretation of health and immune function in the Agassiz's Desert Tortoise (*Gopherus agassizii*). Conservation Physiology 5:1-17.

Duda, J.J., Krzysik, A.J., and Freilich, J.E. 1999. Effects of drought on Desert Tortoise movement and activity. Journal of Wildlife Management 63:1181–1192.

Edwards, T. and Berry, K.H. 2013. Are captive tortoises a reservoir for conservation? An assessment of genealogical affiliation of captive *Gopherus agassizii* to local, wild populations. Conservation Genetics 14:649–659.

Edwards, T., Jarchow, C.J., Jones, C.A., and Bonine, K.E. 2010.

Tracing genetic lineages of captive Desert Tortoises in Arizona. Journal of Wildlife Management 74:801–807.

Edwards, T., Berry, K.H., Inman, R.D., Esque, T.C., Nussear, K.E., Jones, C.A., and Culver, M. 2015. Testing taxon tenacity of tortoises: evidence for a geographic selection gradient at a secondary contact zone. Ecology and Evolution 5:2095–2114.

Edwards, T., Karl, A.E., Vaughn, M., Rosen, P.C., Melendez Torres, C., and Murphy, R.W. 2016a. The Desert Tortoise trichotomy: Mexico hosts a third, new sister-species of tortoise in the *Gopherus morafkai–G. agassizii* group. ZooKeys 562:131–158.

Edwards, T., Tollis, M., Hsieh, P., Gutenkunst, R.N., Liu, Z., Kusumi, K., Culver, M., and Murphy, R.W. 2016b. Assessing models of speciation under different biogeographic scenario; an empirical study using multi-locus and RNA-seq analyses. Ecology and Evolution 6:379–396.

Edwards, T., Vaughn, M., Rosen, P.C., Melendez Torres, C., Karl, A.E., Culver, M., and Murphy, R.W. 2016c. Shaping species with ephemeral boundaries: the distribution and genetic structure of the Desert Tortoise (*Gopherus morafkai*) in the Sonoran Desert region. Journal of Biogeography 43:484–497.

Egan, T.B., Parker, R.E., and Patrovsky, E.B. 2012. A view from the road: route designation in the western Mojave Desert. Designated Vehicle Network Field Review 2012. A report from Alliance for Responsible Recreation, 141 pp.

Emblidge, P.G., Nussear, K.E., Esque, T.C., Aiello, C.M., and Walde, A.D. 2015. Severe mortality of a population of threatened Agassiz's Desert Tortoises: the American Badger as a potential predator. Endangered Species Research 28:109–116.

Ennen, J.R., Lovich, J.E., Meyer, K.P., Bjurlin, C.D., and Arundel, T.R. 2012. Nesting ecology of a population of *Gopherus agassizii* at a utility-scale wind energy facility in southern California. Copeia 2012:222–228.

Esque, T.C., Schwalbe, C.R., DeFalco, L.A., Duncan, R.B., and Hughes, T.J. 2003. Effects of desert wildfires on Desert Tortoise (*Gopherus agassizii*) and other small vertebrates. Southwestern Naturalist 48:103–111.

Esque, T.C., Nussear, K.E., Drake, K.K., Walde, A.D., Berry, K.H., Averill-Murray, R.C., Woodman, A.P., Boarman, W.I., Medica, P.A., Mack, J., and Heaton, J.S. 2010a. Effects of subsidized predators, resource variability, and human population density on Desert Tortoise populations in the Mojave Desert, USA. Endangered Species Research 12:167–177.

Esque, T.C., Young, J.A., and Tracy, C.R. 2010b. Short-term effects of experimental fires on a Mojave Desert seed bank. Journal of Arid Environments 74:1302–1308.

Fagan, W.F. and Homes, E.E. 2006. Quantifying the extinction vortex. Ecology Letters 9:51–60.

Farnsworth, M.L., Dickson, B.G., Zachmann, L.J., Hegeman, E.E., Cangelosi, A.R., Jackson, T.G., Jr., and Scheib, A.F. 2015. Short-term space-use patterns of translocated Mojave Desert Tortoise in Southern California. PLoS ONE 10, e0134250.

Farrell, J. 1989. Some natural history observations of Raven behavior and predation on Desert Tortoise. Compilation of papers and abstracts from Symposia of the Desert Tortoise Council, 1987 through 1991:168.

Fedriani, J.M., Fuller, T.K., and Sauvajot, R.M. 2001. Does availability of anthropogenic food enhance densities of omnivorous mammals? An example. Coyotes in southern California. Ecography 24:325–331.

Field, K.J., Tracy, C.R., Medica, P.A., Marlow, R.W., and Corn, P.S. 2007. Return to the wild: translocation as a tool in conservation of the Desert Tortoise (*Gopherus agassizii*). Biological Conservation 136:232–245.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8:629–644.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R., Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T., and Winter, T.C. 2003. Road Ecology, Science and Solutions. Washington, DC: Island Press.

Foster, A.L., Berry, K, Jacobson, E.R., and Rytuba, J.J. 2009. American Geophysical Union. Fall Meeting 2009. Abstract B32B-04.

Franks, B.R., Avery, H.W., and Spotila, J.R. 2011. Home range and movement of Desert Tortoises *Gopherus agassizii* in the Mojave Desert of California, USA. Endangered Species Research 13:191–201.

Freilich, J.E., Burnham, K.P., Collins, C.M., and Garry, C.A. 2000. Factors affecting population assessments of Desert Tortoises. Conservation Biology 14:1479–1489.

Garfin, G., Franco, G., Blanco, H., Comrie, A., Gonzalez, P., Piechota, T., Smyth, R., and Waskom, R. 2014. Southwest. In: Melillo, J.M., Richmond, T.C., and Yohe, G.W. (Eds.). Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, pp. 462–486, doi:10.7930/JO8G8HMN.

Germano, D.J. 1993. Shell morphology of North American tortoises. American Midland Naturalist 129:319–335.

Germano, J. and Perry, L. 2012. Natural history notes. *Gopherus agassizii* (Desert Tortoise). Cohabitation with American Badger. Herpetological Review 43:127.

Germano, J., Van Zerr, V.E., Esque, T.C., Nussear, K.E., and Lamberski, N. 2014. Impacts of upper respiratory tract disease on olfactory behavior of the Mojave Desert Tortoise. Journal of Wildlife Diseases 50:354–358.

Gienger, C.M. and Tracy, C.R. 2008. Ecological interactions between Gila Monsters (*Heloderma suspectum*) and Desert Tortoises (*Gopherus agassizii*). Southwestern Naturalist 53:265–268.

Gilpin, M.E. and Soulé, M.E. 1986. Minimum viable populations: processes of extinction. In: Soulé, M.E. (Ed.). Conservation Biology: The Science of Scarcity and Diversity. Sunderland, MA: Sinauer Associates, pp. 19–34.

Goodlett, G.O. and Goodlett, G.C. 1992. Studies of unauthorized off-highway vehicle activity in the Rand Mountains and Fremont Valley, Kern County, California. Desert Tortoise Council Symposium Proceedings 1992:163–187.

Goolsby, D. 2016. Huge non-native tortoise found wandering Coachella Valley. The Desert Sun, 21 Oct 2016.

Grandmaison, D.D. and Frary, V.J. 2012. Estimating the probability of illegal Desert Tortoise collection in the Sonoran Desert. Journal of Wildlife Management 76:262–268.

Grant, C. 1936. The southwestern Desert Tortoise, *Gopherus agassizii*. Zoologica 21:225–229.

Grover, M.C. and DeFalco, L.A. 1995. Desert Tortoise (*Gopherus agassizii*): status of knowledge outline with references. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-GTR-316.

Hagerty, B.E. and Tracy, C.R. 2010. Defining population structure for the Mojave Desert Tortoise. Conservation Genetics 11:1795–1807.

Hagerty, B.E., Nussear, K.E., Esque, T.C., and Tracy, C.R. 2011. Making molehills out of mountains: landscape genetics of the Mojave Desert Tortoise. Landscape Ecology 26:267–280.

Hardy, R. 1976. The Utah population – a look in the 1970's. Desert

Tortoise Council Symposium Proceedings 1976: 84–88.

Harless, M.L., Walde, A.D., Delaney, D.K., Pater, L.L., and Hayes, W.K. 2009. Home range, spatial overlap, and burrow use of the Desert Tortoise in the west Mojave Desert. Copeia 2009:378–389.

Harless, M.L., Walde, A.D., Delaney, D.K., Pater, L.L., and Hayes, W.K. 2010. Sampling considerations for improving home range estimates of Desert Tortoise: effects of estimator, sampling regime, and sex. Herpetological Conservation and Biology 5:374–387.

Hazard, L.C., Shemanski, D.R., and Nagy, K.A. 2009. Nutritional quality of natural foods of juvenile Desert Tortoises (*Gopherus agassizii*): energy, nitrogen, and fiber digestibility. Journal of Herpetology 43:38–48.

Hazard, L.C., Shemanski, D.R., and Nagy, K.A. 2010. Nutritional quality of natural foods of juvenile and adult Desert Tortoises (*Gopherus agassizii*): calcium, phosphorus, and magnesium digestibility. Journal of Herpetology 44:135–147.

Hazard, L.C., Morafka, D.J., and Hillard, S. 2015. Post-release dispersal and predation of head-started juvenile Desert Tortoises (*Gopherus agassizii*): effect of release site distance on homing behavior. Herpetological Conservation and Biology 10:504–515.

Henen, B.T. 1997. Seasonal and annual energy budgets of female Desert Tortoises (*Gopherus agassizii*). Ecology 78:283–296.

Henen, B.T. 1999. Maternal behavior in Desert Tortoise (*Gopherus agassizii*) at Goffs, California. Desert Tortoise Council Symposium Proceedings 1999:25–27.

Henen, B.T. 2002a. Energy and water balance, diet, and reproduction of female desert tortoises (*Gopherus agassizii*). Chelonian Conservation and Biology 4:319–329.

Henen, B.T. 2002b. Reproductive effort and reproductive nutrition of female Desert Tortoises: essential field methods. Integrative and Comparative Biology 42:43–50.

Henen, B.T. 2004. Capital and income breeding in two species of desert tortoise. Transactions of the Royal Society of South Africa 59:65–71.

Henen, B.T. 2018. The 2017 tortoise translocation by the Marine Corps Air Ground Combat Center (Combat Center). Abstract, 43rd Symposium of the Desert Tortoise Council, 2018, http://www.deserttortoise.org.

Henen, B.T., Peterson, C.C., Wallis, I.R., Berry, K.H., and Nagy, K.A. 1998. Effects of climatic variation on field metabolism and water relations of Desert Tortoises. Oecologia 117:365–373.

Hessing, M.B. and Johnson, C.D. 1982. Disturbance and revegetation of Sonoran Desert vegetation in an Arizona powerline corridor. Journal of Range Management 35:254–258.

Hinderle, D., Lewison, R.L., Walde, A.D., Deutschman, D., and Boarman, W.I. 2015. The effects of homing and movement behaviors on translocation: Desert Tortoises in the western Mojave Desert. Journal of Wildlife Management 79:137–147.

Homer, B.L., Berry, K.H., Brown, M.B., Ellis, G., and Jacobson, E.R. 1998. Pathology of diseases in wild Desert Tortoises from California. Journal of Wildlife Diseases 34:508–523.

Hoover, F.G. 1995. An investigation of Desert Tortoise mortality in upland game guzzlers in the deserts of southern California. Desert Tortoise Council Symposium Proceedings 1996:36–43.

Hughson, D.L. 2009. Human population in the Mojave Desert: resources and sustainability. In: Webb, R.H., Fenstermaker, L.F., Heaton, J.S., Hughson, D.L., McDonald, E.V., and Miller, D.M. (Eds.). The Mojave Desert. Reno, NV: University of Nevada Press, pp. 57–77.

Hughson, D.L. and Darby, N. 2013. Desert Tortoise road mortality in Mojave National Preserve, California. California Fish and Game 99:222–232.

Hunter, R. 1991. *Bromus* invasions on the Nevada Test Site: present status of *B. rubens* and *B. tectorum* with notes on their relationship to disturbance and altitude. Great Basin Naturalist 51:176–182.

Inman, R., Fotheringham, A.S., Franklin, J., Esque, T., Edwards, T., and Nussear, K. 2019. Local niche differences predict genotype associations in sister taxa of Desert Tortoise. Diversity and Distributions 00:1–16, doi:10.111/ddi.12927.

IUCN. 2019. Red List of Threatened Species. https://www.iucnredlist.org/.

Iverson, J.B. 1992. A Revised Checklist with Distribution Maps of the Turtles of the World. Richmond, IN: Privately Printed, 363 pp.

Jacobson, E.R. 1994. Causes of mortality and diseases in tortoises: a review. Journal of Zoo and Wildlife Medicine 25:2–17.

Jacobson, E.R. and Berry, K.H. 2012. *Mycoplasma testudineum* in free-ranging Desert Tortoises, *Gopherus agassizii*. Journal of Wildlife Diseases 48:1063–1068.

Jacobson, E.R., Gaskin, J.M., Brown, M.B., Harris, R.K., Gardiner, C.H., LaPointe, J.L., Adams, H.P., and Reggiardo, C. 1991. Chronic upper respiratory tract disease of free-ranging Desert Tortoises (*Xerobates agassizii*). Journal of Wildlife Diseases 27:296–316.

Jacobson, E.R., Wronski, T.J., Schumacher, J., Reggiardo, C., and Berry, K.H. 1994. Cutaneous dyskeratosis in free-ranging Desert Tortoises, *Gopherus agassizii*, in the Colorado Desert of southern California. Journal of Zoo and Wildlife Medicine 25:68-81.

Jacobson, E.R., Berry, K.H., Stacy, B., Huzella, L.M., Kalasinsky, V.F., Fleetwood, M.L., and Mense, M.G. 2009. Oxalosis in wild Desert Tortoises, *Gopherus agassizii*. Journal of Wildlife Diseases 45:982–988.

Jacobson, E.R., Berry, K.H., Wellehan, J.F.X., Jr., Origgi, F., Childress, A.L., Braun, J., Schrenzel, M., Yee, J., and Rideout, B. 2012. Serologic and molecular evidence for testudinid herpesvirus 2 infection in wild Agassiz's Desert Tortoises, *Gopherus agassizii*. Journal of Wildlife Diseases 48:747–757.

Jacobson, E.R., Heard, D., and Berry, K.H. 2013. Necropsies of a Russian Tortoise (*Testudo horsfieldii*) and Agassiz's Desert Tortoise (*Gopherus agassizii*) from California. Report to the U.S. Geological Survey, Riverside, California.

Jacobson, E.R., Brown, M.B., Wendland, L.D., Brown, D.R., Klein, P.A., Christopher, M.M., and Berry, K.H. 2014. Mycoplasmosis and upper respiratory tract disease of tortoises: a review and update. Veterinary Journal 201:257–264.

Jaeger, E.C. 1922. Denizens of the Desert. Boston, MA: Houghton Mifflin Co.

Jaeger, E.C. 1950. Our Desert Neighbors. Stanford, CA: Stanford University Press.

James, G.W. 1906. The Wonders of the Colorado Desert. Vol. I. Boston, MA: Little Brown and Co.

Jennings, W.B. and Berry, K.H. 2015. Desert Tortoises (*Gopherus agassizii*) are selective herbivores that track the flowering phenology of their preferred food plants. PLoS ONE 10(1):e0116716.

Jepson Flora Project (eds.) 2018. Jepson eFlora, 6th Revision. http://ucjeps.berkeley.edu/eflora/, accessed 9 November 2018.

Johnson, H.B., Vasek, F.C., and Yonkers, T. 1975. Productivity, diversity and stability relationships in Mojave Desert roadside vegetation. Bulletin of the Torrey Botanical Club 102:106–115.

Johnson, A.J., Morafka, D.J., and Jacobson, E.R. 2006. Seroprevalence of *Mycoplasma agassizii* and tortoise herpesvirus in captive Desert Tortoises (*Gopherus agassizii*) from the Greater Barstow Area, Mojave Desert, California. Journal of

Arid Environments 67:192–201.

Johnston, F.J. 1987. The Bradshaw Trail. Revised edition. Riverside, CA: Historical Commission Press.

Keith, K., Berry, K.H., and Weigand, J. 2008. When Desert Tortoises are rare: testing a new protocol for assessing status. California Fish and Game 94:75–97.

Kelly, E.C., Cypher, B.L., and Germano, D.J. 2019. Temporal variation in foraging patterns of Desert Kit Foxes (*Vulpes macrotis arsipus*) in the Mojave Desert, California, USA. Journal of Arid Environments 167:1–7.

Kemp, P.R. and Brooks, M.L. 1998. Exotic species of California deserts. Fremontia 26:30–34.

Kim, C.S., Stack, D.H., and Rytuba, J.J. 2012. Fluvial transport and surface enrichment of arsenic in semi-arid mining regions: examples from the Mojave Desert, California. Journal of Environmental Monitoring 14:1798–1813.

Kim, C.S., Anthony, T.L., Goldstein, D., and Rytuba, J.J. 2014. Windborne transport and surface enrichment of arsenic in semi-arid mining regions: examples from the Mojave Desert, California. Aeolian Research 14:85–96.

Knight, R.L. and Kawashima, J.Y. 1993. Responses of Raven and Red-tailed Hawk populations to linear right-of-ways. Journal of Wildlife Management 57:266–271.

Knight, R.L., Knight, H.A.L., and Camp, R.J. 1993. Raven populations and land-use patterns in the Mojave Desert, California. Wildlife Society Bulletin 21:469–471.

Knight, R.L., Camp, R.J., and Knight, H.A.L. 1998. Ravens, Cowbirds, and Starlings at springs and stock tanks, Mojave National Preserve, California. Great Basin Naturalist 58:393–395.

Knight, R.L., Camp, R.J., Boarman, W.I., and Knight, H.A.L. 1999. Predatory bird populations in the east Mojave Desert, California. Great Basin Naturalist 59:331–338.

Kristan, W.B., III and Boarman, W.I. 2003. Spatial pattern of risk of Common Raven predation on Desert Tortoises. Ecology 84:2432–2443.

Kristan, W.B., III and Boarman, W.I. 2007. Effects of anthropogenic developments on Common Raven nesting biology in the west Mojave Desert. Ecological Applications 17:1703–1713.

Kristan, W.B., III, Boarman, W.I., and Crayon, J.J. 2004. Diet composition of Common Ravens across the urban-wildland interface of the west Mojave Desert. Wildlife Society Bulletin 32:244–253.

Krzysik, A.J. 2002. A landscape sampling protocol for estimating distribution and density patterns of Desert Tortoises at multiple spatial scales. Chelonian Conservation and Biology 4:366–379.

Lamb, T., Avise, J.C., and Gibbons, J.W. 1989. Phylogeographic patterns in mitochondrial DNA of the Desert Tortoise (*Xerobates agassizii*), and evolutionary relationships among the North American Gopher Tortoises. Evolution 43:76–87.

Lance, V.A. and Rostal, D.C. 2002. The annual reproductive cycle of the male and female Desert Tortoise: physiology and endocrinology. Chelonian Conservation and Biology 4:302–312.

Latch, E.K., Boarman, W.I., Walde, A., and Fleischer, R.C. 2011. Fine-scale analysis reveals cryptic landscape genetic structure in Desert Tortoises. PLoS ONE 6:e27794, doi:10.1371/journal.pone.0027794.

Lathrop, E.W. and Archbold, E.F. 1980a. Plant response to Los Angeles aqueduct construction in the Mojave Desert. Environmental Management 4:137–148.

Lathrop, E.W. and Archbold, E.F. 1980b. Plant response to utility right of way construction in the Mojave Desert. Environmental Management 4:215–226.

Lei, S.A. 2009. Rates of soil compaction by multiple land use practices in southern Nevada. In: Webb, R.H., Fenstermaker, L.F., Heaton, J.S., Hughson, D.L., McDonald, E.V., and Miller, D.M. (Eds.). The Mojave Desert. Ecosystem Processes and Sustainability. Reno: University of Nevada Press, pp. 159–167.

Leu, M., Hanser, S.E., and Knick, S.T. 2008. The human footprint in the West: a large-scale analysis of anthropogenic impacts. Ecological Applications 18:1119–1139.

Longshore, K.M., Jaeger, J.R., and Sappington, J.M. 2003. Desert Tortoise (*Gopherus agassizii*) survival at two eastern Mojave Desert sites: death by short-term drought? Journal of Herpetology 37:169–177.

Loughran, C.L., Ennen, J.R., and Lovich, J.E. 2011. *Gopherus agassizii* (Desert Tortoise). Burrow Collapse. Herpetological Review 42:593.

Lovich, J.E. 2011. Natural history notes. *Gopherus agassizii* (Desert Tortoise) and *Crotalus ruber* (Red Diamond Rattlesnake). Burrow co-occupancy. Herpetological Review 42:421.

Lovich, J.E. and Daniels, R. 2000. Environmental characteristics of Desert Tortoise (*Gopherus agassizii*) burrow locations in an altered industrial landscape. Chelonian Conservation and Biology 3:714–721.

Lovich, J.E., Ennen, J.R., Madrak, S., Meyer, K., Loughran, C., Bjurlin, C., Arundel, T.R., Turner, W., Jones, C., and Groenendaal, G.M. 2011a. Effects of wind energy production on growth, demography, and survivorship of a Desert Tortoise (*Gopherus agassizii*) population in southern California with comparisons to natural populations. Herpetological Conservation and Biology 6:161–174.

Lovich, J.E., Ennen, J.R., Madrak, S., and Grover, B. 2011b. Turtles, culverts, and alternative energy development: an unreported but potentially significant mortality threat to the Desert Tortoise (*Gopherus agassizii*). Chelonian Conservation and Biology 10:124–129.

Lovich, J.E., Ennen, J.R., Madrak, S.V., Loughran, C.L., Meyer, K.P., Arundel, T.R., and Bjurlin, C.D. 2011c. Long-term post-fire effects on spatial ecology and reproductive output of female Agassiz's desert tortoises (*Gopherus agassizii*) at a wind energy facility near Palm Springs, California, USA. Fire Ecology 7: doi:10.4996/fireecology.0703075.

Lovich, J.E., Agha, M., Meulblok, M., Meyer, K., Ennen, J.R., Loughran, C., Madrak, S., and Bjurlin, C. 2012. Climatic variation affects clutch phenology in Agassiz's Desert Tortoise *Gopherus agassizii*. Endangered Species Research 19:63–74.

Lovich, J.E., Agha, M., Yackulic, C.B., Meyer-Wilkins, K., Bjurlin, C., Ennen, J.R., Arundel, T.R., and Austin, M. 2014a. Nest site characteristics, nesting movements, and lack of long-term nest site fidelity in Agassiz's Desert Tortoises at a wind energy facility in southern California. California Fish and Game 100:404–416.

Lovich, J.E., Yackulic, C.B., Freilich, J.E., Agha, M., Austin, M., Meyer, K.P., Arundel, T.R., Hansen, J., Vamstad, M.S., and Root, S.A. 2014b. Climatic variation and tortoise survival: has a desert species met its match? Biological Conservation 169:214–224.

Lovich, J.E., Ennen, J.R., Yackulic, C.B., Meyer-Wilkins, K., Agha, M., Loughran, C., Bjurlin, C., Austin, M., and Madrak, S. 2015. Not putting all their eggs in one basket: bet-hedging despite extraordinary annual reproductive output of Desert Tortoises. Biological Journal of the Linnean Society 115:399–410.

Lovich, J.E., Agha, M., Ennen, J.R., Arundel, T.R., and Austin, M. 2018a. Agassiz's Desert Tortoise (*Gopherus agassizii*) activity areas are little changed after wind turbine-induced fires in California. International Journal of Wildland Fire 27:851–856.

Lovich, J.E., Puffer, S.R., Agha, M., Ennen, J.R., Meyer-Wilkins, K., Tennant, L.A., Smith, A.L., Arundel, T.R., Brundige, K.D., and Vamstad, M.S. 2018b. Reproductive output and clutch phenology of female Agassiz's Desert Tortoises (*Gopherus agassizii*) in the Sonoran Desert region of Joshua Tree National Park. Current Herpetology 37:40–57.

Mack, J.S., Berry, K.H., Miller, D.M, and Carlson, A.S. 2015. Factors affecting the thermal environment of Agassiz's Desert Tortoise (*Gopherus agassizii*) cover sites in the central Mojave Desert during periods of temperature extremes. Journal of Herpetology 49:405–414.

Mack, J.S., Schneider, H.E., and Berry, K.H. 2018. Crowding affects health, growth, and behavior in headstart pens for Agassiz's Desert Tortoise. Chelonian Conservation and Biology 17:14–26.

Marlow, R.W. and Tollestrup, K. 1982. Mining and exploitation of natural mineral deposits by the Desert Tortoise, *Gopherus agassizii*. Animal Behaviour 30:475–478.

Marushia, R.G., Brooks, M.L., and Holt, J.S. 2012. Phenology, growth, and fecundity as determinants of distribution in closely related nonnative taxa. Invasive Plant Science and Management 5:217–229.

McGinnis, S.M. and Voigt, W.G. 1971. Thermoregulation in the Desert Tortoise, *Gopherus agassizii*. Comparative Biochemistry and Physiology A 40:119–126.

McLuckie, A.M. and Fridell, R.A. 2002. Reproduction in a Desert Tortoise (*Gopherus agassizii*) population on the Beaver Dam Slope, Washington County, Utah. Chelonian Conservation and Biology 4:288–294.

McLuckie, A.M., Harstad, D.L., Marr, J.W., and Fridell, R.A. 2002. Regional Desert Tortoise monitoring in the Upper Virgin River Recovery Unit, Washington County, Utah. Chelonian Conservation and Biology 4:380–386.

Medica, P.A. and Eckert, S.E. 2007. *Gopherus agassizii* (Desert Tortoise). Food/mechanical injury. Herpetological Review 38: 445–447.

Medica, P.A. and Greger, P.D. 2009. *Gopherus agassizii* (Desert Tortoise). Predation by Mountain Lion. Herpetological Review 40:75–77.

Medica, P.A., Bury, R.B., and Luckenbach, R.A. 1980. Drinking and construction of water catchments by the Desert Tortoise, *Gopherus agassizii*, in the Mojave Desert. Herpetologica 36:301–304.

Medica, P.A., Nussear, K.E., Esque, T.C., and Saethre, M.B. 2012. Long-term growth of Desert Tortoises (*Gopherus agassizii*) in a southern Nevada population. Journal of Herpetology 46:213–220.

Mertens, R. and Wermuth, H. 1955. Die rezenten Schildkröten, Krokodile und Brückenechsen. Eine kritische Liste der heute lebenden Arten und Rassen. Zoologische Jahrbücher 83:323–440.

Miller, L. 1932. Notes on the Desert Tortoise (*Testudo agassizii*). Transactions of the San Diego Society of Natural History 10:399–402.

Miller, R.D. 1938. Saga of the walking rock. Desert Magazine 1:22–23.

Minnich, R.A. 2008. California's Fading Wildflowers: Lost Legacy and Biological Invasions. University of California Press.

Minnich, R.A. and Sanders, A.C. 2000. *Brassica tournefortii* Gouan. In: Bossard, C.C., Randall, J.M., and Hoshovsky, M.C. (Eds.). Invasive Plants of California's Wildlands. Berkeley, CA: University of California Press, pp. 68–72.

Morafka, D.J. and Berry, K.H. 2002. Is *Gopherus agassizii* a desert-adapted tortoise, or an exaptive opportunist? Implications for tortoise conservation. Chelonian Conservation and Biology 4:263–287.

Morafka, D.J., Berry, K.H, and Spangenberg, E.K. 1997. Predator-proof field enclosures for enhancing hatching success and survivorship of juvenile tortoises: a critical evaluation. In: Van Abbema, J. (Ed.). Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference. New York, NY: New York Turtle and Tortoise Society and the WCS Turtle Recovery Program, pp. 147–165.

Mueller, J.M., Sharp, K.R., Zander, K.K., Rakestraw, D.L., Rautenstrauch, K.R., and Lederle, P.E. 1998. Size-specific fecundity of the Desert Tortoise (*Gopherus agassizii*). Journal of Herpetology 32:313–319.

Mulder, K.P., Walde, A.D., Boarman, W.I., Woodman, A.P., Latch, E.K., and Fleischer, R.C. 2017. No paternal genetic integration in Desert Tortoises (*Gopherus agassizii*) following translocation into an existing population. Biological Conservation 210:318–324.

Munson, S.M., Long, A.L., Wallace, C.S.A., and Webb, R.H. 2016. Cumulative drought and land-use impacts on perennial vegetation across a North American dryland region. Applied Vegetation Science 19:430–441.

Murphy, R.W. 2014. Systematics of extant North American tortoises. In: Rostal, D.C., McCoy, E.D., and Mushinsky, H.R. (Eds.). Biology and Conservation of North American Tortoises. Baltimore, MD: Johns Hopkins University Press, pp. 25–29.

Murphy, R.W., Berry, K.H., Edwards, T., and McLuckie, A.M. 2007. A genetic assessment of the recovery units for the Mojave population of the Desert Tortoise, *Gopherus agassizii*. Chelonian Conservation and Biology 6:229–251.

Murphy, R.W., Berry, K.H., Edwards, T., Leviton, A.E., Lathrop, A., and Riedle, J.D. 2011. The dazed and confused identity of Agassiz's land tortoise, *Gopherus agassizii* (Testudines, Testudinidae) with the description of a new species, and its consequences for conservation. ZooKeys 113:39–71.

Nafus, M.G., Tuberville, T.D., Buhlmann, K.A., and Todd, B.D. 2013. Relative abundance and demographic structure of Agassiz's Desert Tortoise (*Gopherus agassizii*) along roads of varying size and traffic volume. Biological Conservation 162:100–106.

Nafus, M.G., Esque, T.C., Averill-Murray, R.C., Nussear, K.E., and Swaisgood, R.R. 2016. Habitat drives dispersal and survival of translocated juvenile Desert Tortoises. Journal of Applied Ecology 54:430–438. doi: 10.1111/1365-2664.12774.

Nagy, K.A. and Medica, P.A. 1986. Physiological ecology of Desert Tortoises in southern Nevada. Herpetologica 42:73–92.

Nagy, K.A., Henen, B.T., and Vyas, D.B. 1998. Nutritional quality of native and introduced food plants of wild Desert Tortoises. Journal of Herpetology 32:260–267.

Nagy, K.A., Hillard, L.S., Dickson, S., and Morafka, D.J. 2015a. Effects of artificial rain on survivorship, body condition and growth of head-started hatchlings, and on survivorship of head-started Desert Tortoises (*Gopherus agassizii*) released to open desert. Herpetological Conservation and Biology 10:535–549.

Nagy, K.A., Hillard, L.S., Tuma, M.W., and Morafka, D.J. 2015b. Head-started Desert Tortoises (*Gopherus agassizii*): movements, survivorship and mortality causes following their release. Herpetological Conservation and Biology 10:203–215.

Nagy, K.A., Kuchling, G., Hillard, L.S., and Henen B.T. 2016. Weather and sex ratios of head-started Agassiz's Desert Tortoise *Gopherus agassizii* juveniles hatched in natural habitat enclosures. Endangered Species Research 30:145–155.

Nelson, B. 2010. Huge 100-pound African tortoise found roaming Arizona desert. Mother Nature Network, 21 December 2010. https://www.mnn.com/.

Nicholson, L. and Humphreys, K. 1981. Sheep grazing at the Kramer study plot, San Bernardino County, California. Desert Tortoise Council Symposium Proceedings 1981:163–190.

Norris, F. 1982. On beyond reason: homesteading in the California Desert, 1885–1940. Southern California Quarterly—Historical Society of Southern California 64:297–312.

Nussear, K.E., Esque, T.C., Haines, D.F., and Tracy, C.R. 2007. Desert Tortoise hibernation: temperatures, timing, and environment. Copeia 2007:378–386.

Nussear, K.E., Esque, T.C., Inman, R.D., Gass, L., Thomas, K.A., Wallace, C.S.A., Blainey, J.B., Miller, D.M., and Webb, R.H. 2009. Modeling habitat of the Desert Tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran deserts of California, Nevada, Utah, and Arizona. U.S. Geological Survey. Open-File Report 2009–1102.

Nussear, K.E., Tracy, C.R., Medica, P.A., Wilson, D.S., Marlow, R.W., and Cohn, P.S. 2012. Translocation as a conservation tool for Agassiz's Desert Tortoises: survivorship, reproduction, and movements. Journal of Wildlife Management 767:1341–1353.

O'Connor, M.P., Zimmerman, L.C., Ruby, D.E., Bulova, S.J., and Spotila, J.R. 1994. Home range size and movements by Desert Tortoises, *Gopherus agassizii*, in the eastern Mojave Desert. Herpetological Monographs 8:60–71.

Ofteoal, O.T. 2002. Nutritional ecology of the Desert Tortoise in the Mojave and Sonoran deserts. In: Van Devender, T.R. (Ed.). The Sonoran Desert Tortoise: Natural History, Biology and Conservation. Tucson, AZ: The University of Arizona Press and the Arizona-Sonora Desert Museum, pp. 194–241.

Oftedal, O.T., Hillard, S., and Morafka, D.J. 2002. Selective spring foraging by juvenile Desert Tortoises (*Gopherus agassizii*) in the Mojave Desert: evidence of an adaptive nutritional strategy. Chelonian Conservation and Biology 4:341–352.

Ottley, J.R. and Velázques Solis, V.M. 1989. An extant, indigenous tortoise population in Baja California Sur, Mexico, with the description of a new species of *Xerobates* (Testudines: Testudinidae). Great Basin Naturalist 49:496–502.

Palmer, K.S., Rostal, D.C., Grumbles, J.S., and Mulvey, M. 1998. Long-term sperm storage in the Desert Tortoise (*Gopherus agassizii*). Copeia 1998:702–705.

Peterson, C.C. 1994. Different rates and causes of high mortality in two populations of the threatened Desert Tortoise *Gopherus agassizii*. Biological Conservation 70:101–108.

Peterson, C.C. 1996. Anhomeostasis: seasonal water and solute relations in two populations of the Desert Tortoise (*Gopherus agassizii*) during chronic drought. Physiological Zoology 69:1324–1358.

Piechowski, C. 2015. Analysis and results of off-road vehicle use violation monitoring and law enforcement actions in the West Mojave Planning Area of the California Desert Conservation Area by the Bureau of Land Management. Report from Defenders of Wildlife, California Program Office, Sacramento, California.

Prose, D.V. 1985. Persisting effects of armored military maneuvers on some soils of the Mojave Desert. Environmental Geology and Water Sciences 7:163–170.

Prose, D.V. 1986. Map of areas showing visible land disturbances caused by two military training exercises in the Mojave Desert, California. Reston, VA: U.S. Geological Survey Miscellaneous Field Studies, Map MF-1855.

Prose, D.V. and Wilshire, H.G. 2000. The lasting effects of tank maneuvers on desert soils and intershrub flora. U.S. Geological Survey, Open-File Reprt OF 00-512.

Prose, D.V., Metzger, S.K., and Wilshire, H.G. 1987. Effects of substrate disturbance on secondary plant succession: Mojave Desert, California. Journal of Applied Ecology 24:305–313.

Ragsdale, S. 1939. My friend, the tortoise. Desert Magazine 2:21–22.

Rao, L.E. and Allen, E.B. 2010. Combined effects of precipitation and nitrogen deposition on native and invasive winter annual production in California deserts. Oecologia 162:1035–1046.

Rao, L.E., Steers, R.J., and Allen, E.B. 2011. Effects of natural and anthropogenic gradients on native and exotic winter annuals in a southern California desert. Plant Ecology 212:1079–1089.

Rautenstrauch, K.R. and O'Farrell, T.P. 1998. Abundance of Desert Tortoises on the Nevada Test Site. Southwestern Naturalist 43:407–411.

Rautenstrauch, K.R., Rakestraw, D.L, Brown, G.A., Boone, J.L., and Lederle, P.E. 2002. Patterns of burrow use by Desert Tortoises (*Gopherus agassizii*) in southcentral Nevada. Chelonian Conservation and Biology 4:398–405.

Rhodin, A.G.J., Stanford, C.B., van Dijk, P.P., Eisemberg, C., Luiselli, L., Mittermeier, R.A., Hudson, R., Horne, B.D., Goode, E.V., Kuchling, G., Walde, A., Baard, E.H.W., Berry, K.H., Bertolero, A., Blanck, T.E.G., Bour, R., Buhlmann, K.A., Cayot, L.J., Collett, S., Currylow, A., Das, I., Diagne, T., Ennen, J.R., Forero-Medina, G., Frankel, M.G., Fritz, U., García, G., Gibbons, J.W., Gibbons, P.M., Gong, S., Guntoro, J., Hofmeyr, M.D., Iverson, J.B., Kiester, A.R., Lau, M., Lawson, D.P., Lovich, J.E., Moll, E.O., Páez, V.P., Palomo-Ramos, R., Platt, K., Platt, S.G., Pritchard, P.C.H., Quinn, H.R., Rahman, S.C., Randrianjafizanaka, S.T., Schaffer, J., Selman, W., Shaffer, H.B., Sharma, D.S.K., Shi, H., Singh, S., Spencer, R., Stannard, K., Sutcliffe, S., Thomson, S., and Vogt, R.C. 2018. Global conservation status of turtles and tortoises (Order Testudines). Chelonian Conservation and Biology 17:135–161.

Rico, Y., Edwards, T., Berry, K.H., Karl, A.E., Henen, B.T., and Murphy, R.W. 2015. Re-evaluating the spatial genetic structure of Agassiz's Desert Tortoise using landscape genetic simulations. Abstract. 40th Symposium of the Desert Tortoise Council, 2015, http://www.deserttortoise.org.

Roberson, J.B., Burge, B.L., and Hayden, P. 1985. Nesting observations of free-living Desert Tortoises (*Gopherus agassizii*) and hatching success of eggs protected from predators. Desert Tortoise Council Symposium Proceedings 1985:91–99.

Rostal, D.C., Lance, V.A., Grumbles, J.S., and Alberts, A.C. 1994. Seasonal reproductive cycle of the Desert Tortoise (*Gopherus agassizii*) in the eastern Mojave Desert. Herpetological Monographs 8:72–82.

Rostal, D.C., Wibbels, T., Grumbles, J.S., Lance, V.A., and Spotila, J.R. 2002. Chronology of sex determination in the Desert Tortoise. Chelonian Conservation and Biology 2002:313–318.

Rowlands, P.G., Johnson, H., Ritter, E., and Endo, A. 1982. The Mojave Desert. In: Bender, G.L. (Ed.). Reference Handbook on the Deserts of North America. Westport, CT: Greenwood Press, pp. 103–162.

Sánchez-Ramírez, S., Rico, Y., Berry, K.H, Edwards, T., Karl, A.E., Henen, B.T., and Murphy, R.W. 2018. Landscape limits gene flow and drives population structure in Agassiz's Desert Tortoise (*Gopherus agassizii*). Scientific Reports, https://www.nature.com/articles/s41598-018-29395-6.

Sarhadi, A., Ausín, M.C., Wiper, M.P., Touma, D., and Diffenbaugh, N.S. 2018. Multidimensional risk in a nonstationary climate: joint probability of increasingly severe warm and dry conditions. Science Advances 4:eaau3487.

Schneider, J.S. and Everson, G.D. 1989. The Desert Tortoise (*Xerobates agassizii*) in the prehistory of the southwestern Great Basin and adjacent areas. Journal of California and Great Basin Anthropology 11:175–202.

Schneider, H.E. and Allen, E.B. 2012. Effects of elevated nitrogen and exotic plant invasion on soil seed bank composition in Joshua Tree National Park. Plant Ecology 213:1277–1287.

Seager, R., Ting, M., Held, I., Kushnir, Y., Lu, J., Vecchi, G., Huang, H., Harnik, N., Leetmaa, A., Lau, N., Li, C., Velez, J., and Naik, N. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. Science, New Series 316:1181–1184.

Selzer, M.D. and Berry, K.H. 2005. Laser ablation ICP-MS profiling and semiquantitative determination of trace element concentrations in Desert Tortoise shells: documenting the uptake of elemental toxicants. Science of the Total Environment 339:253–265.

Sieg, A.E., Gambone, M.M., Wallace, B.P., Clusella-Trullas, S., Spotila, J.R., and Avery, H.W. 2015. Mojave Desert Tortoise (*Gopherus agassizii*) thermal ecology and reproductive success along a rainfall cline. Integrative Zoology 10:282–294.

Smith, S.D., Huxman, T.E., Zitzer, S.F., Charlet, T.N., Housman, D.C., Coleman, J.S., Fenstermaker, L.K., Seemann, J.R., and Nowak, R.S. 2000. Elevated CO_2 increases productivity and invasive species success in an arid ecosystem. Nature 408:79–82.

Spears, J.R. 1892. Illustrated Sketches of Death Valley and other Borax Deserts of the Pacific Coast. Chicago and New York: Rand, McNally & Co. [Reprint 1977. San Fernando, CA: Sagebrush Press.]

Stebbins, R.C. 1966. A Field Guide to Reptiles and Amphibians in the Western United States. Boston: Houghton-Mifflin Co.

Spenceley, A., Mack, J., and Berry, K.H. 2015. *Gopherus agassizii* (Agassiz's Desert Tortoise). Attempted predation. Herpetological Review 46:422–423.

Steiger, N.J., Smerdon, J.E., Cook, B.I., Seager, R., Williams, A.P., and Cook, E.R. 2019. Oceanic and radiative forcing of medieval megadroughts in the American Southwest. Science Advances 5:eax0087.

Stejneger, L. 1893. Annotated list of the reptiles and batrachians collected by the Death Valley Expedition in 1891, with descriptions of new species. North American Fauna 7:159–228.

Stephens, F. 1914. Arid California and its animal life. Biennial Report of the California Fish and Game Commission 23:127–135.

Stone, K.J. 1989. Foxsong. 100 Years of Cow Ranching in the San Bernardino Mountains/Mojave Desert. Memorial Edition. Morongo Valley, CA: Sagebrush Press.

Suazo, A.A., Spencer, J.E., Engel, E.C., and Abella, S.R. 2012. Responses of native and non-native Mojave Desert winter annuals to soil disturbance and water additions. Biological Invasions 14:215–227.

Syphard, A.D., Keeley, J.E., and Abatzoglou, J.T. 2017. Trends and drivers of fire activity vary across California aridland ecosystems. Journal of Arid Environments 144:110–122.

Todd, B.D., Halstead, B.J., Chiquoine, L.P., Peaden, J.M., Buhlmann, K.A., Tuberville, T.D., and Nafus, M.G. 2016. Habitat selection by juvenile Mojave Desert Tortoises. Journal of Wildlife Management 80:720–728.

Tollis, M., DeNardo, D.F., Cornelius, J.A., Dolby, G.A., Edwards, T., Henen, B.T., Karl, A.E., Murphy, R.W., and Kusumi, K. 2017. The Agassiz's Desert Tortoise genome provides a resource for the conservation of a threatened species. PLoS ONE 12(5):e0177708.

Trader, M.R., Brooks, M.L., and Draper, J.V. 2006. Seed production by the non-native *Brassica tournefortii* (Sahara mustard) along desert roadsides. Madroño 53:313–320.

TTWG [Turtle Taxonomy Working Group: Rhodin, A.G.J., Iverson, J.B., Bour, R., Fritz, U., Georges, A., Shaffer, H.B., and van Dijk, P.P.]. 2017. Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (8th Ed.). Chelonian Research Monographs 7:1–292.

Tuma, M.W., Millington, C., Schumaker, N., and Burnett, P. 2016. Modeling Agassiz's Desert Tortoise population response to anthropogenic stressors. Journal of Wildlife Management 80:414–429.

Turner, F.B., Medica, P.A., and Lyons, C.L. 1984. Reproduction and survival of the Desert Tortoise (*Scaptochelys agassizii*) in Ivanpah Valley, California. Copeia 1984:811–820.

Turner, F.B., Hayden, P., Burge, B.L., and Roberson, J.B. 1986. Egg production by the Desert Tortoise (*Gopherus agassizii*) in California. Herpetologica 42:93–104.

Turner, F.B., Berry, K.H., Randall, D.C., and White, G.C. 1987. Population ecology of the Desert Tortoise at Goffs, California, 1983–1986. Report to the Southern California Edison Company. Research and Development Series 87-RD-81.

Turtle Conservation Coalition [Stanford, C.B., Rhodin, A.G.J., van Dijk, P.P., Horne, B.D., Blanck, T.B.D., Goode, E.V., Hudson, R., Mittermeier, R.A., Currylow, A., Eisemberg, C., Frankel, M., Georges, A., Gibbons, P.M., Juvik, J.O., Kuchling, G., Luiselli, L., Shi, H., Singh, S., and Walde W. (Eds).]. 2018. Turtles in Trouble: the World's 25+ Most Endangered Tortoises and Freshwater Turtles – 2018. Ojai, CA: IUCN SSC Tortoise and Freshwater Turtle Specialist Group, Turtle Conservancy, Turtle Survival Alliance, Turtle Conservation Fund, Chelonian Research Foundation, Conservation International, Wildlife Conservation Society, and Global Wildlife Conservation, 80 pp.

USBLM [U.S. Bureau of Land Management]. 1973. Interim Critical Management Plan for Recreational Vehicle Use in the California Desert. Sacramento, CA: Department of the Interior, Bureau of Land Management.

USBLM [U.S. Bureau of Land Management]. 1980. The California Desert Conservation Area Plan, 1980. Sacramento, CA: Department of the Interior, Bureau of Land Management.

USBLM [U.S. Bureau of Land Management]. 2016. Desert Renewable Energy Conservation Plan. Record of Decision for the Land Use Plan Amendment to the California Desert Conservation Area Plan, Bishop Resource Management Plan, and Bakersfield Resource Management Plan. U.S. Dept. of Interior, Bureau of Land Management. BLM/CA/PL-2016/03+1793+8321.

USBLM [U.S. Bureau of Land Management]. 2019. West Mojave Route Network Project. Final Supplemental Environmental Impact Statement for the California Desert District. Moreno Valley, California. BLM/CA/DOI-BLM-CA-D080-2018-0008-EIS.

USDC [U.S. District Court]. 2009. Order summary judgment motions. Case 3:06-cv-04884-SI. Center for Biological Diversity, et al., Plaintiffs v. BLM. United States District Court for the Northern District of California, USA. Available at http://www.biologicaldiversity.org/programs/public_lands/deserts/california_desert_conservation_area/pdfs/WEMO_NECO_case_order_9_28_09.pdf.

USDC [U.S. District Court]. 2011. Order re: remedy. Case 3:06-cv-04884-SI. Center for Biological Diversity, et al., Plaintiffs v. BLM. United States District Court for the Northern District of California, USA.

USDD [U.S. Dept. of Defense, Dept. of the Navy]. 2017. Record of Decision on the Supplemental environmental impact statement for land acquisition and airspace establishment to support large-scale Marine Air Ground Task Force live-fire and maneuver training at Marine Corps Air Ground Combat Center, Twentynine Palms, California, 10 February 2017.

USDI [U.S. Dept. of the Interior]. 1990. Endangered and Threatened wildlife and plants: determination of Threatened status for the Mojave population of the Desert Tortoise. Federal Register 55:12178–12191.

USFWS [U.S. Fish and Wildlife Service]. 1980. Endangered and Threatened wildlife and plants: listing as Threatened with critical habitat for the Beaver Dam Slope population of the Desert Tortoise in Utah. Federal Register 45:55654–55666.

USFWS [U.S. Fish and Wildlife Service]. 1994. Desert Tortoise (Mojave population) Recovery Plan. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service.

USFWS [U.S. Fish and Wildlife Service]. 2008. Environmental assessment to implement a Desert Tortoise Recovery Plan task: reduce Common Raven predation on the Desert Tortoise. Final. Ventura, CA: U.S. Department of the Interior, Fish and Wildlife Service.

USFWS [U.S. Fish and Wildlife Service]. 2010. Mojave Population of the Desert Tortoise (*Gopherus agassizii*). 5-Year Review: Summary and Evaluation. Reno, NV: Desert Tortoise Recovery Office, U.S. Department of the Interior, Fish and Wildlife Service.

USFWS [U.S. Fish and Wildlife Service]. 2011. Revised recovery plan for the Mojave population of the Desert Tortoise (*Gopherus agassizii*). Reno, NV: U.S. Department of the Interior, Fish and Wildlife Service.

USFWS [U.S. Fish and Wildlife Service]. 2015. Range-wide Monitoring of the Mojave Desert Tortoise (*Gopherus agassizii*): 2013 and 2014. Annual Report. Reno, NV: U.S. Department of the Interior, Fish and Wildlife Service.

USGCRP [U.S. Global Change Research Program]. 2017. Climate Science Special Report: Fourth National Climate Assessment, Volume I. Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., Dokken, D.J., Stewart, B.C., and Maycock, T.K. (Eds.). Washington, DC: U.S. Global Change Research Program, 470 pp.

Uptain, C. 1983. Activities and their impacts on the Desert Tortoise Natural Area, Kern County, California. Report to California Department of Fish and Game, Inland Fisheries Branch, Rancho Cordova, California.

van Dijk, P.P., Stuart, B.L., and Rhodin, A.G.J. (Eds.). 2000. Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Chelonian Research Monographs No. 2, 164 pp.

Vasek, F.C. 1979. Early successional stages in Mojave Desert scrub vegetation. Israel Journal of Botany 23:133–148.

Vasek, F.C. 1980. Creosote bush: long-lived clones in the Mojave Desert. American Journal of Botany 67:246–255.

Vasek, F.C. 1983. Plant succession in the Mojave Desert. Crossosoma 9:1–23.

Vasek, F.C., Johnson, H.B., and Eslinger, D.H. 1975a. Effects of pipeline construction on creosote bush scrub vegetation of the Mojave Desert. Madroño 23:1–12.

Vasek, F.C., Johnson, H.B., and Brum, G.D. 1975b. Effects of power transmission lines on vegetation of the Mojave Desert. Madroño 23:114–129.

von Seckendorff Hoff, K. and Marlow, R.W. 2002. Impacts of vehicle road traffic on Desert Tortoise populations with consideration of conservation of tortoise habitat in southern Nevada. Chelonian Conservation and Biology 4:449–456.

Vredenburg, L.M., Shumway, G.L., and Hartill, R.D. 1981. Desert Fever: An Overview of Mining in the California Desert. Living West Press.

Walde, A.D. and Currylow, A. 2015. *Gopherus agassizii* (Mojave Desert Tortoise) and *Coleonyx variegatus variegatus* (Desert Banded Gecko). Spring burrow cohabitation. Herpetology Notes 8:501–502.

Walde, A.D., Delaney, D.K., Harless, M.L., and Pater, L.L. 2007a. Osteophagy by the Desert Tortoise (*Gopherus agassizii*). Southwestern Naturalist 52:147–149.

Walde, A.D., Harless, M.L., Delaney, D., and Pater, L.L. 2007b. Anthropogenic threat to the Desert Tortoise (*Gopherus agassizii*): litter in the Mojave Desert. Western North American Naturalist 67:147–149.

Walde, A.D., Walde, A.M., and Delany, D.K. 2008. *Gopherus agassizii* (Desert Tortoise). Predation. Herpetological Review 39:214.

Walde, A.D, Walde, A.M., Delaney, D.K., and Pater, L.L. 2009. Burrows of Desert Tortoises (*Gopherus agassizii*) as thermal refugia for Horned Larks (*Eremophila alpestris*) in the Mojave Desert. Southwestern Naturalist 54:375–381.

Walde, A.M., Walde, A.D., and Jones, C. 2014. *Gopherus agassizii* (Mohave Desert Tortoise) and *Crotalus mitchellii* (Speckled Rattlesnake). Burrow associate. Herpetological Review 45:688.

Walde, A.D., Currylow, A., and Walde, A.M. 2015. Discovery of a new burrow associate of the Desert Tortoise (*Gopherus agassizii*), the Long-nosed Leopard Lizard (*Gambelia wislizenii*). Herpetology Notes 8:107–109.

Wallis, I.R., Henen, B.T., and Nagy, K.A. 1999. Egg size and annual egg production by female Desert Tortoises (*Gopherus agassizii*): the importance of food abundance, body size, and date of egg shelling. Journal of Herpetology 33:394–408.

Webb, R.H. and Stielstra, S.S. 1979. Sheep grazing effects on Mojave Desert vegetation and soils. Environmental Management 3:517–529.

Webb, R.H. and Wilshire, H.G. (Eds.). 1983. Environmental Effects of Off-Road Vehicles. New York: Springer Verlag.

Webb, W.C., Boarman, W.I., and Rotenberry, J.T. 2004. Common Raven juvenile survival in a human-augmented landscape. The Condor 106:517–528.

Webb, W.C., Boarman, W.I., and Rotenberry, J.T. 2009. Movements of juvenile Common Ravens in an arid landscape. Journal of Wildlife Management 73:72–81.

Weinstein, M.N. 1989. Modeling Desert Tortoise habitat: can a useful management tool be developed from existing transect data? Ph.D. Dissertation, University of California, Los Angeles.

Weinstein, M.N. and Berry, K.H. 1989. Morphometric analysis of Desert Tortoise populations. Riverside, CA: U.S. Department of the Interior, Bureau of Land Management.

Weitzman, C.L., Sandmeier, F., and Tracy, R. 2017. Prevalence and diversity of the upper respiratory pathogen *Mycoplasma agassizii* in Mojave Desert Tortoises (*Gopherus agassizii*). Herpetologica 73:113–120.

Weitzman, C.L., Tillett, R.L., Sandmeier, F.C., Tracy, C.R., and Alvarez-Ponce, D. 2018. High quality draft genome sequence of *Mycoplasma testudineum* strain BH29^T, isolated from the respiratory tract of a Desert Tortoise. Standards in Genomic Sciences 13:9.

Wentworth, E.N. 1948. America's Sheep Trails. Iowa State College Press.

Wilshire, H.G. and Nakata, J.K. 1976. Off-road vehicle effects on California's Mojave Desert. California Geology 29:123–132.

Wilson, D.S., Tracy, C.R., Nagy, K., and Morafka, D.J. 1999a. Physical and microhabitat characteristics of burrows used by juvenile Desert Tortoises (*Gopherus agassizii*). Chelonian Conservation and Biology 3:448–453.

Wilson, D.S., Morafka, D.J., Tracy, C.R., and Nagy, K.A. 1999b. Winter activity of juvenile Desert Tortoises (*Gopherus agassizii*) in the Mojave Desert. Journal of Herpetology 33:496–501.

Wilson, D.S., Nagy, K.A., Tracy, C.R., Morafka, D.J., and Yates, R.A. 2001. Water balance in neonate and juvenile Desert Tortoises, *Gopherus agassizii*. Herpetological Monographs 15:158–170.

Woodbury, A.M. and Hardy, R. 1948. Studies of the Desert Tortoise, *Gopherus agassizii*. Ecological Monographs 18:145–200.

Woodman, A.P., Walde, A.D., and Boarman, W.I. 2013. Predation of adult Agassiz's Desert Tortoise by Common Ravens in the central Mojave Desert. Abstract. 38th Annual Desert Tortoise Council Symposium, 2013, http://deserttortoise.org.

Wyneken, J., Mader, D.R., Weber, E.S., III, and Merigo, C. 2006. Medical care of sea turtles. In: Mader, D.R. (Ed.). Reptile Medicine and Surgery. Saunders Elsevier, Inc. USA, pp. 972–1007.

Zimmerman, L.C., O'Connor, M.P., Bulova, S.J., Spotila, J.R., Kemp, S.J., and Salice, C.J. 1994. Thermal ecology of Desert Tortoises in the eastern Mojave Desert: seasonal patterns of operative and body temperatures, and microhabitat utilization. Herpetological Monographs 7:45–59.

Citation Format for this Account:

Berry, K.H. and Murphy, R.W. 2019. *Gopherus agassizii* (Cooper 1861) – Mojave Desert Tortoise, Agassiz's Desert Tortoise. In: Rhodin, A.G.J., Iverson, J.B., van Dijk, P.P., Stanford, C.B., Goode, E.V., Buhlmann, K.A., Pritchard, P.C.H., and Mittermeier, R.A. (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs 5(13):109.1–45. doi: 10.3854/crm.5.109.agassizii.v1.2019; www.iucn-tftsg.org/cbftt/.

Herpetological Conservation and Biology 13(2):433–452.
Submitted: 19 February 2018; Accepted: 24 June 2018; Published: 31 August 2018.

Population Trends in Mojave Desert Tortoises (*Gopherus agassizii*)

Linda J. Allison[1,3] *and Ann M. McLuckie*[2]

[1]*Desert Tortoise Recovery Office, U.S. Fish and Wildlife Service, Reno, Nevada 89502, USA*
[2]*Utah Division of Wildlife Resources, Washington County Field Office, 451 N SR-318, Hurricane, Utah 84737, USA*
[3]*Corresponding author, email: linda_allison@fws.gov*

***Abstract*.—Populations of the Mojave Desert Tortoise (*Gopherus agassizii*) experienced severe declines in abundance in the decades leading up to 1990, when the species was listed as threatened under the U.S. Endangered Species Act. Population responses to recovery efforts have not been well documented because of the difficulties of studying this low-density, cryptic species over a time period appropriate to its long generation time. We used line distance sampling to estimate annual adult densities since 1999 in Utah and since 2004 elsewhere in the range of Mojave Desert Tortoises. We used generalized least squares regression on log-transformed adult tortoise densities to estimate annual percentage change through 2014 in each of 17 Tortoise Conservation Areas (TCAs) in the five recovery units. We report annual proportional increases in density of adults in the Northeastern Mojave Recovery Unit, but declines in the other four recovery units. Adjusting these densities and trends for the area of potential habitat in each recovery unit, we estimated that in 2004 there were 336,393 adult tortoises (standard error [SE] = 51,596), with an overall loss of 124,050 adult tortoises (SE = 36,062) by 2014. The proportion of juveniles in our surveys has been decreasing in all five recovery units since 2007. Prevailing declines in the abundance of adults overall and in four of the five recovery units indicate the need for more aggressive implementation of recovery actions and more critical evaluation of the suite of future activities and projects in tortoise habitat that may exacerbate ongoing population declines.**

Key Words.—Colorado Desert; distance sampling; information theory; long-term monitoring; Mojave Desert; species recovery

Introduction

Turtles around the world face the highest level of endangerment of any vertebrate lineage today (Stanford et al. 2018). Historical extinctions and recent crises have characterized species on islands or with relatively localized and easily exploitable populations (Stanford et al. 2018). However, turtles as a group are vulnerable in part due to their shared life histories based on high adult survival, delayed age at first reproduction, and low rates of juvenile recruitment (Congdon et al. 1993; Stanford et al. 2018). Even tortoises with relatively large historical ranges are susceptible to threats with relatively small effects, in combination and acting over long generation times, and this life-history strategy also diminishes their ability to recovery quickly from population losses.

Populations of the Desert Tortoise (*Gopherus agassizii*, *sensu stricto*) experienced severe declines in abundance in the decades leading up to 1990, when populations in the Mojave and Colorado deserts west and north of the Colorado River were listed as Threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service [USFWS]1990). Murphy et al. (2011) split the full species into two: the Mojave Desert Tortoise (*Gopherus agassizii*) occupying the range north and west of the Colorado River (the same area listed as Threatened above and retaining this listing) and the Sonoran Desert Tortoise (*G. morafkai*) south and east of the Colorado River. Population responses to recovery efforts for *G. agassizii* have not been well documented, in part, because of the difficulties of studying this low-density, long-lived species. The current recovery plan (USFWS 2011) designates five recovery units for *G. agassizii* that are intended to conserve genetic, behavioral, and morphological diversity necessary for the long-term recovery of the entire listed species (Fig. 1). The recovery plan also defines criteria that form the basis for decisions about continued listing status. For instance, rates of population change of *G. agassizii* should be increasing for at least one tortoise generation (25 y) in all recovery units to warrant delisting (USFWS 2011).

Whereas *G. agassizii* (*sensu stricto*) were initially protected on the basis of population declines estimated on a limited number of small, selectively located mark-recapture study plots, over the longer term, status descriptions should be based on more extensive and rigorous population estimates (Tracy, R.C., R. Averill-Murray, W.I. Boarman, D. Delehanty, J. Heaton, E. McCoy, D. Morafka, K. Nussear, B. Hagerty, and

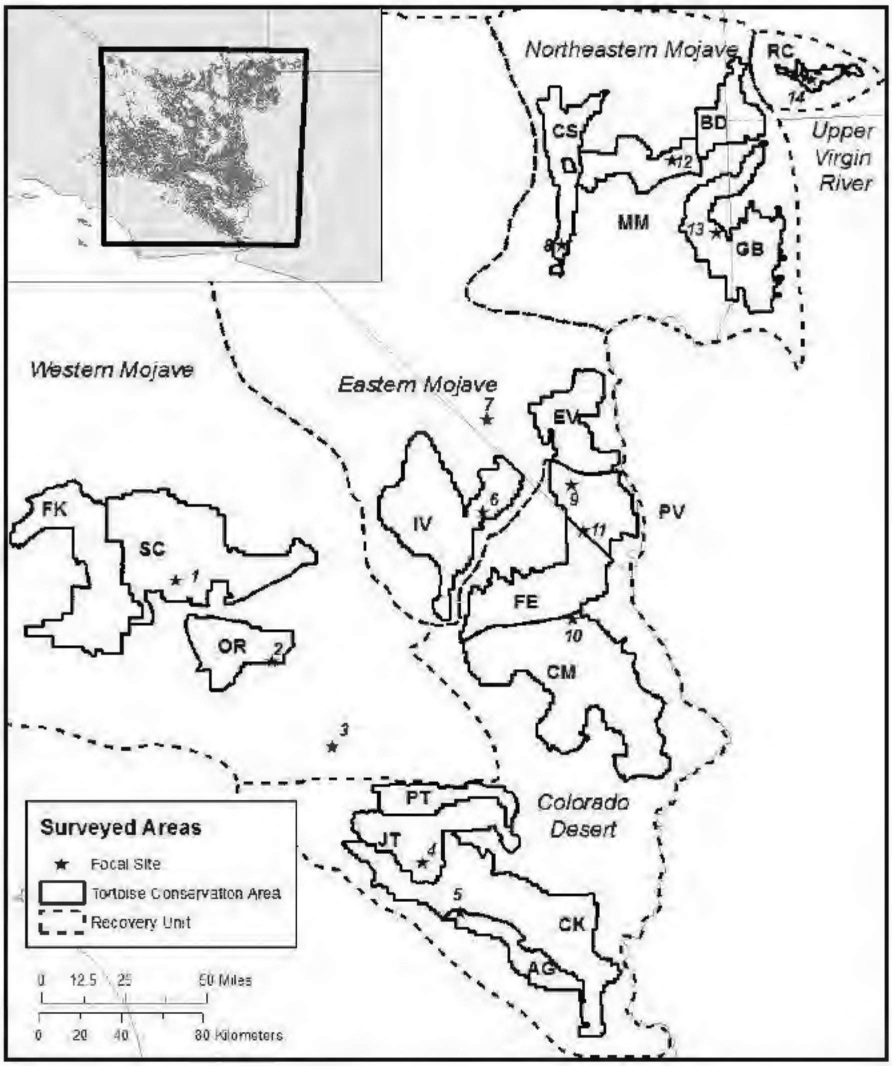


FIGURE 1. Tortoise Conservation Areas (TCAs, n = 17) for Mojave Desert Tortoises (*Gopherus agassizii*) that were monitored in the Mojave and Colorado deserts, USA. Sites were monitored through 2014 and began in 2004 except in the Red Cliffs Desert Reserve, where surveys started in 1999. TCAs and their codes are Chocolate Mountains Aerial Gunnery Range (AG), Beaver Dam Slope (BD), Chuckwalla (CK), Chemehuevi (CM), Coyote Springs Valley (CS), Eldorado Valley (EV), Fenner (FE), Fremont-Kramer (FK), Gold Butte-Pakoon (GB), Ivanpah (IV), Joshua Tree (JT), Mormon Mesa (MM), Ord-Rodman (OR), Pinto Mountains (PT), Piute Valley (PV), Red Cliffs (RC), Superior-Cronese (SC). Observations to estimate visibility were made of transmittered tortoises at the numbered focal sites: 1) Superior-Cronese, 2) Ord-Rodman, 3) Twentynine Palms, 4) Joshua Tree, 5) Chuckwalla, 6) Ivanpah, 7) Jean, 8) Indian Springs, 9) Piute Valley 1, 10) Chemehuevi, 11) Piute Valley 2, 12) Halfway Wash, 13) Gold Butte, 14) Red Cliffs. Potential habitat as defined in the text is overlain on the southwestern United States in the extent indicator.

P. Medica. 2004. Desert Tortoise Recovery Plan Assessment. Report to the U.S, Fish and Wildlife Service, Reno, Nevada. Available from http://www.fws.gov/nevada/desert_tortoise/documents/dtrpac/dtrpac_report.pdf [Accessed 15 August 2018]). In 1999, agencies cooperating on recovery of *G. agassizii* adopted distance sampling (Buckland et al. 2001) for estimating population density at large spatial scales. Surveyors use distance sampling to account for the proportion of the population that is not observed at increasing distances from the observers. We conducted distance sampling surveys for *G. agassizii* throughout Tortoise Conservation Areas (TCAs; Fig. 1), which include federally designated critical habitat for the species (USFWS 1994), as well as in contiguous areas with conservation designations and suitable tortoise habitat (Nussear et al. 2009). Most recovery units (USFWS 1994, 2011) contained more than one TCA (Fig. 1). Ongoing monitoring for *G. agassizii* based on distance sampling has been conducted since 1997 in the Upper

Virgin River Recovery Unit by the Utah Division of Wildlife Resources and by the USFWS in the remaining four recovery units starting in 2001.

In this paper, we start by developing annual density estimates for each TCA based on distance sampling. These efforts are typically collaboratively funded with each agency requiring annual reports that include annual population estimates. Our second and primary goal herein was to use these annual estimates to describe adult *G. agassizii* population trends for each TCA and recovery unit. These trends must account for precision of annual estimates that is often low, variable, and correlated between TCAs within years. Although we cannot fully evaluate the recovery criterion that requires increasing population numbers in each recovery unit until at least 25 y of surveys have been completed (USFWS 2011), this monitoring program is part of the adaptive management strategy for recovering *G. agassizii*. Our third goal was to use the interim regional population trends to evaluate the effectiveness of the recovery program. Our fourth goal was to characterize future trajectories for these populations based on changing patterns of relative abundance of juveniles.

Materials and Methods

Study areas.—*Gopherus agassizii* occur throughout large, continuous regions of the Mojave and Colorado deserts of North America (Fig. 1). They occupy a broad elevational range (sea level to 2,225 m) from valley bottoms and bajada slopes at lower elevations to upper alluvial and mountain slopes at higher elevations (Luckenbach 1982). Typical habitat for *G. agassizii* is Creosote Bush (*Larrea tridentata*) scrub in association with White Bursage (*Ambrosia dumosa*) but they are also found in Joshua Tree (*Yucca brevifolia*) woodland, Blackbrush (*Coleogyne ramosissima*) scrub, microphyll woodlands, Shadscale (*Atriplex confertifolia*) scrub, saltbush (*Atriplex* spp.) scrub, cactus scrub, and warm season grassland (Germano et al. 1994; Nussear et al. 2009). Throughout their range, tortoises inhabit areas that include deeply incised washes, sandstone outcrops, rugged rocky canyons, and basalt-capped ridges interspersed with sandy valleys (Bury et al. 1994). However, tortoises most commonly occur in areas with gentle slopes, sufficient shrub cover, and friable soils to allow burrow construction (Bury et al. 1994).

Starting in 1997 in Upper Virgin River Recovery Unit and in 2001 elsewhere, we surveyed 17 TCAs across the five recovery units (Fig. 1). We did not survey every TCA every year, but the total area of 29,127 km^2 comprises the long-term monitoring frame (Table 1). The TCAs named for Red Cliffs Desert Reserve (RC) and Joshua Tree National Park (JT) exclude portions of these jurisdictions that were not potential tortoise habitat (USFWS 1994); RC also excluded a portion that was used for translocations of wild tortoises displaced by development. Each year we made behavioral observations on tortoises at up to 11 of the 14 focal sites within the overall study area (Fig. 1) to estimate the proportion of tortoises that were potentially visible to transect surveyors.

Data collection.—Initially, we placed transects randomly within each TCA. In RC, these were permanent transect locations from the beginning of the program, and we surveyed the 153 transects annually between 1999 and 2001, then every other year. Between 2001 and 2003 in the rest of the range, there was restricted sampling based on various environmental criteria (USFWS 2006), so for comparability we only used data collected starting in 2004 when transects were sited at random throughout TCAs. Beginning in 2007 in these areas outside RC, we shifted from strictly random placement to random selection from a set of systematically placed transects that covered each TCA. Both of these methods result in transects that were located at random with respect to the location of tortoises, so the resulting annual density estimates are unbiased. Each year, available funding determined the number of transects assigned in each TCA.

Sampling methods we used adhered to study design considerations for distance sampling (Anderson, D.R., and K.P. Burnham. 1996. A monitoring program for the desert tortoise. Report to the Desert Tortoise Management Oversight Group. Available from https://www.fws.gov/nevada/desert_tortoise/documents/reports/Anderson-Burnham.1996 monitoringplan.pdf. [Accessed 15 August 2018]). We based initial transect and overall survey length on preliminary estimates of encounter rate and associated effort required to estimate density with a coefficient of variation (CV) of 0.10–0.15. We modified the number and length of transects as specified in Buckland et al. (2001) during earlier years of the surveys and based on updated information about encounter rates.

We completed surveys between mid-March and the end of May each year, when preferred food plants flower and *G. agassizii* are generally active outside of burrows. We started transects early enough so surveys would be completed before the hottest time of the day, scheduling survey dates in specific TCAs to correspond to peak daily tortoise activity based on past experience as well as observation of tortoises outfitted with radio-transmitters (see below). Surveys generally started around 0800 during March but started as early as sunrise by the beginning of May.

Generally, each two-person team walked one transect each day, using a compass and pre-specified bearings. Standard transects were 12 km long, walked in a

Table 1. Tortoise Conservation Areas within each Recovery Unit including total area (km²) and total effort (km) by year. Tortoise Conservation Areas (with acronym; Acr) are grouped under corresponding larger recovery units. Red Cliffs Desert Reserve was also surveyed in 1999 (307 km), 2000 (302 km), 2001 (314 km) and 2003 (309 km).

Tortoise Conservation Area	Acr	Area (km²)	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
Colorado Desert		13,530	3,319	3,984	2,007	1,348	1,375	2,383	1,316	1,403		
Chocolate Mtn Aerial Gunnery Range	AG	755	331	228	404	158	378	378		363	413	554
Chuckwalla	CK	3,509	1,083	866	747	112		613	280	213		
Chemehuevi	CM	4,038	836	1,129	180	84	119	458	354	176		
Fenner	FE	1,841	410	288	178	108	121	246	179	168		
Joshua Tree	JT	1,567	278	601	135	102	240	227	147	183		
Pinto Mountains	PT	751	56	155	131	72	162	213	118	140		
Piute Valley	PV	1,070	325	717	231	713	355	249	239	159		
Eastern Mojave		3,720	876	620	368	714	548	578	746	639		
Eldorado Valley	EV	1,153	361	452	188	594	427	212	331	320		
Ivanpah	IV	2,567	515	168	180	120	120	365	416	318		
Northeastern Mojave		4,889	1,037	1,489	2,304	1,485	4,154	4,265	3,984	4,184		
Beaver Dam Slope	BD	828		421	478	2578	631	662	751	819	683	
Coyote Springs Valley	CS	1,117	365	237	906	1,592	1,504	1,046	967	996		
Gold Butte-Pakoon	GB	1,977	361	432	300		733	1,258	1,039	1,116	923	
Mormon Mesa	MM	968	311	398	621	691	1,286	1,298	1,227	1,253		
Western Mojave		6,873	1,534	1,979	896	599	1,351	2,144	1,257	876		2,095
Fremont-Kramer	FK	2,417	463	661	300	216	361	566	264	193		815
Ord-Rodman	OR	1,124	381	310	141	102	197	270	174	158		472
Superior-Cronese	SC	3,332	690	1,009	456	281	793	1,307	820	525		808
Upper Virgin River		115		305	308		310		310		314	
Red Cliffs Desert Reserve	RC	115		305	308		310		310		314	

square that was 3 km on each side. Where relatively open creosote-bursage alluvial slopes dominated the landscape, we found that repeated searching near the centerline did not improve encounter rates or detection on the line (USFWS 2006), so we did not mark the transect centerline for additional search effort. Instead, the leader surveyed along a straight path with a 25-m cord trailing behind. The second observer followed at the end of the moving cord and searched independently. The cord served as the transect centerline when taking distance measurements, and we calculated the walked length of these transects as the straight-line distance between GPS point coordinates that were recorded approximately 500 m apart along the transect.

In RC, where terrain rendered tortoises less visible, surveyors used a three-pass survey to effectively search on and near the marked transect centerline. One crew member, Observer A, dragged the end of the 50-m surveyor tape, following the transect bearing to its intended location. Observer A then walked in a sinusoidal pattern back toward the beginning of the tape searching for tortoises on one side of the tape while the other crew member walked in a similar sinusoidal pattern on the opposite side. Observer A then searched directly along the tape back to the end. The process repeated itself, with the roles of the two surveyors reversing each time. This intensive searching and the rugged terrain limited transects to 2 km per team each day.

We measured the distance and bearing of the tortoise to the observer on the center line in order to calculate the perpendicular distance of the tortoise to the transect center line. We measured distances with 30-m fiberglass or 50-m surveyor tapes, and we measured bearings with compasses. We used all observations of tortoises > 180 mm carapace length (CL) to develop detection curves and density estimates, whether tortoises were in burrows, in the open, or under vegetation. When tortoises were on the surface or could be easily extracted from burrows, we recorded CL and sex. Without suggesting that there is a single size threshold for reproduction within or between populations (Germano 1994), we refer hereafter to tortoises that are at least 180 mm CL as adults and smaller tortoises as juveniles.

Because we placed transects at random with respect to terrain and human infrastructure, and because standard transects were 3 km on each side, it was not unusual for the surveyed path to cross through varied terrain or be blocked by an obstacle such as a highway.

The rules for modifying transects in these situations involved reflecting or elongating transects to avoid obstacles associated with human infrastructure (large roads, private inholdings, etc.), or shortening transects in rugged terrain. The sampling frame therefore represented the walkable area of each TCA. Transects that were partially outside TCA boundaries were initially completed without regard for these jurisdictional changes, but where the boundary was impassable, we reflected transect segments into TCAs as needed (Buckland et al. 2001) or pivoted shorter transects in RC on their northeastern corner to fit inside the TCA. By 2010 we reflected transects so that all paths were inside TCAs.

We used behavioral observations of tortoises carrying radio transmitters (Boarman et al. 1998) to estimate the proportion of individuals available to be seen above ground or in burrows during transect surveys, G_0 (Anderson and Burnham, *op. cit.*). Telemetry technicians used a VHF radio receiver and directional antenna to locate radio-equipped tortoises (n = 5–30) at each focal site (Fig. 1) during the same daily time period when field crews were walking transects in that region of the desert. Observers completed a survey circuit of all transmittered animals as many times as possible (range, 0–5 times per day) during the allotted time, recording each time whether the tortoise was visible.

Estimation of annual tortoise density in each TCA.—We used distance sampling (Buckland et al. 2001) to develop density estimates based on encounter rates in each TCA adjusted for imperfect detection of animals farther from the transect centerline. Estimates were developed each year separately for reporting to sponsoring agencies. We used Program DISTANCE, 6.2 (Thomas et al. 2010), to estimate P_a, the proportion of adult *G. agassizii* detected within w meters of the transect centerline. We truncated observations by distance from the centerline to improve model fit as judged by the simplicity of the resulting detection function (Buckland et al. 2001). Truncation typically reduced the number of observations overall by 5% or fewer, improving estimates of detection probability but reducing the number of observations to estimate encounter rate in each TCA. Sample size considerations also contributed to our decision to rely on pooling robustness (Buckland et al. 2001) rather than using covariates to model detection function estimates (Marques et al. 2007). Detection function estimation is robust in the face of pooling data from different observers, on different days, and in different areas (Buckland et al. 2001) as long as factors that cause variability in detection probability are represented proportionately (Marques et al. 2007). Such factors include vegetation that differentially obscures vision with distance and different detection patterns characteristic of individual crews (pairs). Crews on the same team walked the same number of transects although crews on different teams might not. For these reasons, we placed transects at random in each TCA and developed separate detection curves each year for each field team, pooling data from all TCAs surveyed by that team. Teams also correspond to regions of the desert, and years are correlated with precipitation conditions that affect spring vegetation height and cover, so detection curves that are created separately for teams and years also indirectly address additional factors that affect detection. In years when a team surveyed both in the Mojave and the Sonoran deserts, where the vegetation types may affect tortoise detection differentially, we used two separate detection curves if the sum of their AIC values was less than the AIC value for the single detection curve for the team. In RC, where the same transects were walked each year, we used a single detection curve for all years of the study. Although we pooled observations from multiple TCAs (or from multiple years in RC) for each detection curve, we estimated adult tortoise encounter rates (n/L) and the variance of n separately for each TCA each year.

The distance to which observations were truncated, w, determined the reported area searched in each TCA, $2wL$, where L is the total length in kilometers walked. We applied Akaike's Information Criterion (AIC) to select among detection-function models (uniform, half normal, and hazard-rate) and key function/series expansions recommended in Buckland et al. (2001). Where more than one model were strongly supported by the data, we selected on the basis of Chi-square goodness-of-fit statistics near the transect centerline.

If there is imperfect detection on the transect centerline, a further correction factor must be applied to estimate the true density of tortoises. Because transects in RC used a three-pass method to search the centerline, we assumed that all tortoises at the transect centerline were detected. Elsewhere, detections by two observers walking the centerline one after the other allowed estimation of the detection probability for tortoises within increasing distances from the transect centerline as for a two-pass removal estimator (White et al. 1982); this provides a test of the assumption that all tortoises on the transect centerline are recorded ($g(0) = 1$).

We used a final correction factor, G_0, to adjust the density estimate to account for tortoises hidden in burrows in addition to those that were visible. Each bootstrapped estimate of G_0 was based on one randomly selected visibility record for each tortoise outfitted with a radio transmitter on each day it was located. We generated 1,000 bootstrap samples in PASW Statistics (release 18.0.2, SPSS, Inc. Chicago, Illinois, USA) to estimate G_0 and its standard error by site.

Annual density in each TCA was estimated as:

$$D = \frac{n}{2wLP_a G_0 g(0)}$$

Whereas n and L were estimated separately for each TCA, observations from multiple TCAs were used to generate a single estimate of P_a. We also applied estimates of G_0 to more than one TCA, and we based estimates of *g(0)* on all observations from the two-pass surveys. This pooling of information can lead to covariance between TCA estimates in a given year (see below). Although two of the correction factors have similar symbols, when the parameter symbol involves a capital letter (G_0), we are referring to the proportion visible; the lower-case letter refers to the probability of detection of visible tortoises at the centerline.

Describing trends in adult tortoise densities.—We used R 3.4.1 (R Core Team 2017) to develop marginal models (Pinheiro et al. 2017) describing the natural log of tortoise density per km^2 as a function of year and location. Logarithmic transformations have a special interpretation when modelling trends; a modest linear trend in a logarithmic quantity represents a proportional change rather than a linear one (Keene 1995). A slope of 0.05 for ln(density) regressed on years, for instance, would be interpreted as a 5% increase per year. Our models included TCA, Year, and Year^2. Year was centered before modeling (Schielzeth 2010). Year^2 was included to capture any curvilinear population responses, and we anticipate modeling additional polynomial terms in the future when we are considering a longer time period. The full model also included two-way interactions between TCA and the linear and quadratic time factors. We used generalized least squares regression to also weight annual density estimates based on their variance and to add covariance structure to account for sets of density estimates that were inherently correlated because they shared correction factors of P_a or G_0 (Pekar and Brabec 2016). This second level of analysis therefore incorporated information about the first-level (annual density) variances and covariances.

We used a model based on the full suite of fixed effects to select among different variance weighting and covariance structures (Zuur et al. 2009). We used model selection procedures based on second-order AIC (AIC$_c$, Burnham and Anderson 2002; Mazerolle 2015) to decide whether to weight the analysis by the variance or CV of the annual density estimates. We also considered whether to model correlations among residuals for density estimates from the same Year, or due to use of pooled G_0 and P_a estimates for multiple TCA density estimates (see above). For all subsequent tests of potential fixed-effects models, we selected a covariance structure to account for within-Year correlation of residuals and weighted optimization procedures as a function of the CV of annual density estimates.

With the final variance weighting and correlation structures in place, we used AIC$_c$ for selection among alternative models and examined the fit of the best model using marginal r^2 (Nagelkerke 1991). We used ANCOVA to examine whether slopes and intercepts of TCAs in each recovery unit described the same pattern (Zar 1996). To apply tortoise densities from the TCAs to entire recovery units, we estimated the area of potential habitat in each of the five recovery units based on Nussear et al. (2009). We only considered 1-km^2 grid cells assigned a probability of occupancy > 0.5 as potential habitat (Liu et al. 2005) after removing any area identified as an impervious surface (Fry et al. 2011).

Describing trends in representation of juvenile size class.—During surveys, we noted all observed tortoises of any size; however, smaller tortoises were less detectable than adults and there were too few observations of smaller tortoises to make density estimates based on distance sampling. Instead, to complement our analysis of changes in the abundance of adult tortoises, we used mixed effects logistic regression (Bates et al. 2015) to evaluate the relative proportion of juvenile tortoises detected in each recovery unit, fitting the observations to models including Year, Year^2, Recovery Unit, and two-way interactions between Recovery Unit and the time factors as predictors. We also included the categorical form of Year as a random factor to account for any enforced correlation across the recovery units in proportion of juveniles present due to annual conditions. Because we observed many fewer juvenile tortoises than adults, we report results at the larger spatial scale of the recovery unit rather than for each TCA. Tortoises that could not be extracted from burrows were often classified as unknown rather than as adults or juveniles, especially earlier in the study period. We conservatively assumed all unclassified tortoises were adults, so that estimates of the proportion of juvenile observations earlier in the time series were not inflated. Lacking information on detectability of juveniles to correct our raw data, the relative proportion of juveniles that we examined reflected their representation among detected animals, not the actual proportion of juveniles in the population. We used AIC for model selection, weighting, and averaging (Barton 2015). Note that because the continuous input variable Year was standardized to a mean of zero and divided by two standard deviations before model development (Schielzeth 2010), we could consider models with the quadratic form of this variable even if the linear form was not present in the model; this is equivalent to assuming opposing trends at the start and end of the study period

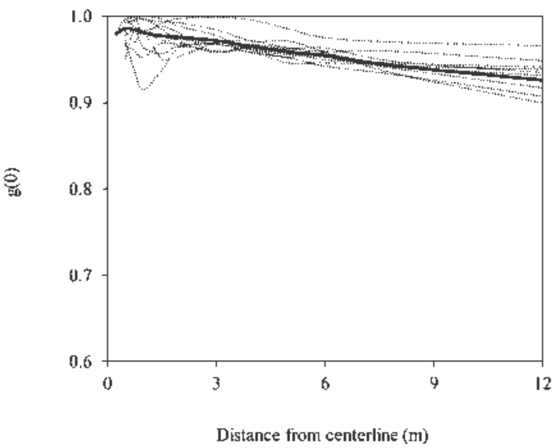


Figure 2. Detection of Mojave Desert Tortoises (*Gopherus agassizii*) at the transect centerline (*g(0)*) based on all two-pass survey observations as remote as x meters from the transect centerline. Dotted lines are annual curves; solid line is overall pattern across years from 2004 through 2014 (no surveys conducted in 2006). Note the convergence of *g(0)* on 1.0 as x goes to 0.

but no average trend overall. This standardization also allowed us to use model averaging on interaction terms (Schielzeth 2010). For models describing Year^2 effects, the inflection point at which trends shifted between increases and decreases in the odds of encountering juveniles on surveys was estimated as $-\beta_{Year}/2\beta_{Year}^{2}$.

Results

Adult densities and trends.—Annual probability of detection within 2 m of the transect centerline varied from 0.95 to 1.00, and converged on *g(0)* = 1.0 (Fig. 2), so we added no *g(0)* correction to annual density estimates. In contrast, although estimated tortoise visibility (G_0) was generally greater than 0.80, it was estimated as low as 0.35 at Chemehuevi in 2012 (Fig. 3, Appendix A), illustrating the degree of bias possible if tortoise density estimates do not include corrections for tortoises unavailable for detection. Some of our focal sites were consistently characterized by more above-ground activity than others (Fig. 3). The half-strip width, w, was generally between 12 and 22 m (Appendix B). Detection rate, P_a, was 0.64 in RC and averaged 0.45 in the other TCAs, where two-pass surveys were implemented; however, whether two- or three-pass sampling was used, the detection shoulder near the centerline consistently indicated nearly complete detection out to 2 m (10% of w) as recommended by Buckland et al. (2001).

Annual density estimates ranged from 0.2 adult tortoises/km^2 (SE = 0.2) in GB in 2005 to 28.0/ km^2 (SE = 4.0) in RC in 2000 (Table 2). During the first years reported here (2004 and 2005), TCAs in the Northeastern Mojave Recovery Unit had lower mean densities (< 5.0/

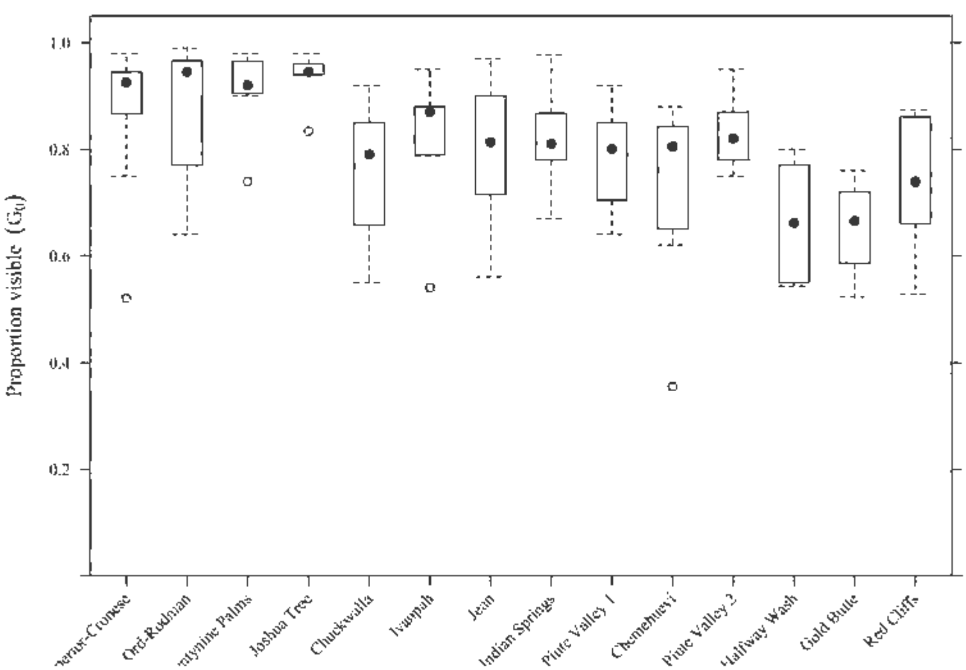


Figure 3. Box and whisker plots indicating the proportion of adult Mojave Desert Tortoises (*Gopherus agassizii*) visible (G_0) at each of 14 focal sites shown in Fig. 1 during transect surveys from 1999 through 2014. Boxes represent the interquartile range (values from the 25th – 75th percentile), crossed by a heavy bar at the median. Dotted-line whiskers indicate the extent of the 12.5–87.5 percentile, with any values outside this range shown as hollow dots below some whiskers. Sites are ordered from west on the left to east. Not all focal sites were used to correct density estimates each year. For instance, only Red Cliffs was monitored before 2004, and Jean was used in only one year of observation.

Table 2. Densities (n/km^2) of adult Mojave Desert Tortoises (*Gopherus agassizii*) and corresponding standard errors (SEs) in each Tortoise Conservation Area (TCA) from 2004 to 2014. Acronyms for TCAs are given in Table 1. RC was also surveyed earlier: 1999 (34.3, SE = 11.32), 2000 (25.7, SE = 5.61), 2001 (24.4, SE = 5.69), 2003 (14.0, SE = 2.79).

TCA within Recovery Unit	Year									
	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
Colorado Desert										
AG	11.4 (3.55)	13.4 (4.31)	6.5 (1.50)	4.5 (2.56)	7.5 (2.74)	13.8 (3.52)		6.0 (1.84)	7.3 (1.96)	8.4 (2.09)
CK	4.9 (1.49)	6.0 (1.77)	4.3 (1.19)	4.2 (2.84)		3.7 (1.14)	3.9 (1.37)	3.9 (1.62)		
CM	6.7 (1.27)	10.3 (3.10)	3.9 (1.71)	4.8 (3.07)	9.4 (5.98)	4.2 (1.40)	4.0 (1.51)	0.8 (0.90)		
FE	8.2 (1.94)	13.5 (2.80)	6.2 (2.37)	6.6 (3.05)	8.3 (4.01)	6.9 (2.49)	6.8 (2.78)	0.9 (0.95)		
JT	1.9 (0.53)	2.7 (0.79)	3.0 (1.94)	2.3 (1.75)	2.3 (1.56)	2.8 (1.56)	3.5 (1.33)	3.4 (1.63)		
PT	2.2 (2.12)	9.9 (3.58)	1.9 (0.98)	3.3 (3.53)	4.3 (2.38)	3.4 (1.85)	3.3 (1.39)	3.7 (1.57)		
PV	2.9 (1.13)	3.7 (0.90)	4.1 (1.88)	4.1 (1.28)	3.6 (1.64)	3.8 (1.37)	6.6 (2.62)	1.9 (1.46)		
Eastern Mojave										
EV	2.6 (0.94)	5.0 (1.25)	4.1 (1.69)	1.8 (0.85)	3.8 (1.56)	1.0 (0.62)	2.8 (1.13)	0.9 (0.74)		
IV	4.4 (1.19)	4.4 (2.46)	5.6 (1.95)	5.1 (2.92)	4.1 (1.86)	1.0 (0.48)	4.5 (1.72)	2.8 (1.79)		
Northeastern Mojave										
BD		0.9 (0.49)	1.1 (0.57)	1.1 (0.59)	3.2 (1.61)	3.3 (0.93)	3.3 (1.22)	5.4 (1.60)	2.6 (1.06)	
CS	1.3 (0.54)	3.3 (1.23)	1.4 (0.47)	1.2 (0.37)	2.0 (0.74)	3.6 (0.87)	4.0 (0.88)	2.9 (0.66)		
GB	0.6 (0.34)	0.2 (0.18)	1.1 (0.58)		2.2 (1.14)	1.7 (0.61)	1.6 (0.58)	2.3 (0.74)	1.7 (0.68)	
MM	2.4 (0.88)	4.9 (1.37)	3.0 (0.93)	1.9 (0.73)	7.3 (2.83)	5.5 (1.15)	6.3 (2.10)	4.3 (1.30)		
Upper Virgin River										
RC		22.5 (4.59)	22.1 (10.76)		15.5 (3.74)		19.3 (4.14)		18.3 (5.58)	
Western Mojave										
FK	8.4 (2.31)	5.3 (1.28)	3.0 (1.46)	0.5 (0.51)	3.3 (1.13)	2.4 (0.60)	3.5 (1.11)	2.2 (1.07)		4.7 (1.05)
OR	7.3 (2.25)	7.7 (1.80)	7.1 (3.26)	5.0 (5.34)	7.2 (2.65)	7.5 (1.85)	3.2 (1.18)	4.6 (2.14)		3.5 (0.88)
SC	6.3 (1.84)	6.3 (1.32)	5.9 (2.28)	1.9 (1.19)	4.6 (1.12)	2.6 (0.49)	3.4 (0.79)	4.3 (1.41)		2.5 (0.60)

km^2) than TCAs in other recovery units. Each year we surveyed RC, it consistently had the highest densities of adult tortoises.

The best model to describe variation in adult tortoise densities supported the hypothesis that densities changed proportionally over time, with different linear trends in each TCA (Table 3). Models based on linear trends had strong support (cumulative model weights = $\sum w$ = 0.9996; Table 3), whereas those including quadratic effects of time had essentially no support ($\sum w < 0.0001$). We report tortoise trend estimates based only on the best-performing model, with $w > 0.999$ and describing a large amount of variation in $\log_e$(Density). Estimates of r^2 (marginal r^2 = 0.84, Nagelkerke's modified r^2 = 0.92) indicated that after weighting to address variance heterogeneity and building in covariance structure, there was considerable variance in adult densities that could be explained by the effects of Year, TCA, and their interaction. Covariance between TCA density estimates from the same year accounted for 17.0% of the total

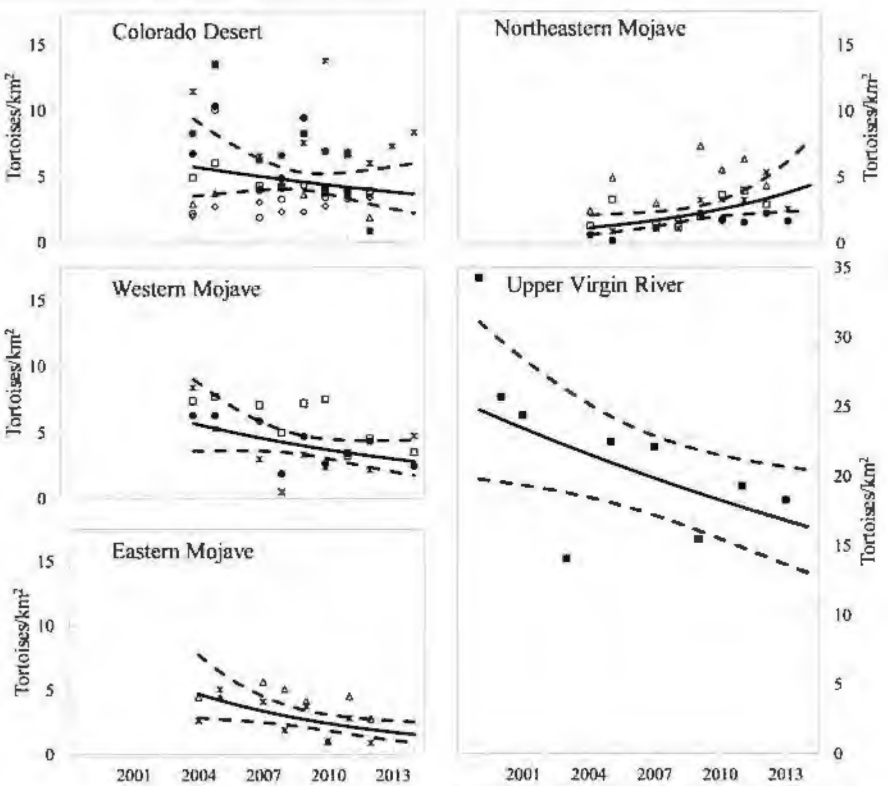


Figure 4. Trends in density (tortoises/km^2) of adult Mojave Desert Tortoises (*Gopherus agassizii*) in each recovery unit through 2014: since 1999 for Upper Virgin River Recovery Unit and for all others since 2004. Separate markers are used for annual density estimates for each tortoise conservation area within the recovery unit. The modeled change in density is the bold line and its 90% CI is shown with the dashed line, reflecting the Type I error specified in U.S. Fish and Wildlife Service (2011).

variance. Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality.

Densities of adult *G. agassizii* were declining, on average, in every recovery unit except the Northeastern Mojave (Table 4, Fig. 4). Average density of adult tortoises increased in the Northeastern Mojave Recovery Unit at 13.1%/y (SE = 4.3%) since 2004, with especially large rates of increase (> 13%/y) estimated in BD and GB. Adult densities in the other four recovery units have declined at different annual rates: Colorado Desert (-4.5%, SE = 2.8%), Upper Virgin River (-3.2%, SE = 2.0%), Eastern Mojave (-11.2%, SE = 5.0%), and Western Mojave (-7.1%, SE = 3.3%). Based on analysis of covariance, three of the four recovery units with more than one TCA could be characterized by common regression slopes (Eastern Mojave: $F_{1,12}$ = 0.305, P = 0.591; Western Mojave: $F_{2,21}$ = 0.094, P = 0.910; Northeastern Mojave: $F_{3,24}$ = 1.206, P = 0.317; Colorado Desert: $F_{6,43}$ = 2.391, P = 0.044), but intercepts indicate different initial densities in two of the recovery units (Eastern Mojave: $F_{1,13}$ = 2.560, P = 0.134; Western Mojave: $F_{2,23}$ = 3.326, P = 0.054; Northeastern Mojave: $F_{3,27}$ = 11.073, P < 0.001; Colorado Desert: $F_{6,49}$ = 5.090, P < 0.001). The estimates we report above and in Table 4 are therefore total regression results for the Colorado Desert and Northeastern Mojave recovery units to characterize this greater within-recovery unit variation in slopes and/or intercepts, but common regression results for the other recovery units. Slopes differed between recovery units ($F_{4,119}$ = 9.422, P < 0.001).

We applied estimated recovery unit densities based on TCAs to all potential habitat in each recovery unit, developing a high-end estimate of abundance for each recovery unit in 2004 and 2014 (Table 5). Despite the increasing population trend of adults in the Northeastern Mojave, its small area and low starting density resulted in a relatively small overall increase in the number of adult tortoises by 2014. In contrast, the much larger areas of the Eastern and Western Mojave and Colorado Desert recovery units, plus the higher estimated initial densities in these areas, explain much of the estimated total loss of adults since 2004. We estimate there were 124,050 fewer adult tortoises (SE = 36,062) range-wide in 2014 compared to the 336,393 tortoises (SE = 51,596) present in 2004.

Changes in representation of juvenile size class.— The full model of spatial and temporal effects describing the proportion of juveniles among observed tortoises

Table 3. Model selection table for all models fit to log-transformed annual densities of adult Mojave Desert Tortoises (*Gopherus agassizii*) through 2014 for all Tortoise Conservation Areas (TCAs), starting in 1999 for Red Cliffs Desert Reserve and in 2004 for the remaining 16 TCAs. Model weights (*w*) express the relative support for each model given the data and are based on relative scores for the second order Akaike's Information Criterion (AIC_c).

Model	Log likelihood	AIC_c	ΔAIC_c	*w*
TCA + Year + TCA×Year	-42 2	186 0	0 0	0 9996
TCA + Year	-76 7	203 2	17 2	0 0002
TCA	-78 4	203 9	17 9	0 0001
TCA + Year + Year^2	-76 0	204 7	18 7	0 0001
TCA + Year + Year^2 + TCA×Year + TCA×Year^2	-25 6	229 2	43 2	0 0000
Year + Year^2	-150 0	312 7	126 7	0 0000
Year	-155 3	321 1	135 1	0 0000
Random effects only	-160 3	329 0	143 0	0 0000

reduced the unexplained variance by 30.6% compared to the model of an overall average proportion, accounting for intra-year correlated proportions. Although the model with only Recovery Unit as a fixed effect had the lowest AIC, there was considerable support for models other than the top-ranking one (Table 6). The next five ranked models added Year or Year^2 effects and were within five AIC units of the best model; the cumulative weight of the top six models was > 0.95. As expected based on the ranked models, model-averaged parameter estimates indicated that the odds of finding a juvenile tortoise differed primarily between recovery units, with a weaker pattern of change over time (Table 7). This analysis approach does not allow us to estimate the true proportion of juveniles in the population, and indeed the higher proportion of juveniles found in the Upper Virgin River Recovery Unit is undoubtedly a product of the three-pass search technique used there in contrast to two-passes elsewhere. Of the four recovery units in which we used two-pass surveys, the probability of encountering a juvenile was consistently lowest in the Western Mojave Recovery Unit. The model-averaged Year parameter estimate indicated the average pattern over all years (1999 through 2014) because we standardized the input variable Year (mean = 2007.0, SD = 4.1). The model-averaged Year parameter for each recovery unit is close to zero, indicating similar proportions at the beginning and end of the survey period, with slightly fewer juveniles in the Northeastern and Western Mojave recovery units, and slightly more elsewhere. However, the negative sign of the Recovery Unit X Year^2 parameter estimates indicated that between the beginning and end of the survey period, there were increased odds of encountering juveniles (Schielzeth 2010); the proportion of juveniles was increasing when surveys began in 1999 but peaked in 2007 and have been declining in all recovery units since then.

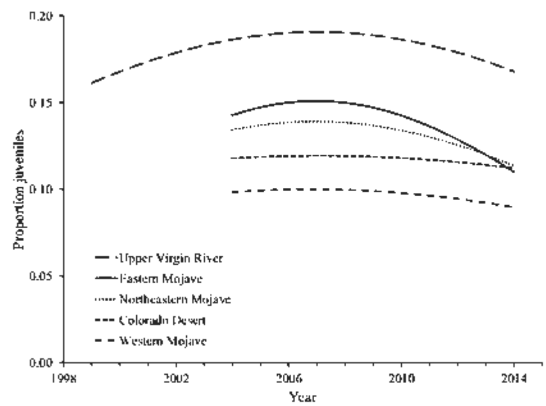


Figure 5. Relative proportion of juvenile Mojave Desert Tortoises (*Gopherus agassizii*) in each recovery unit through 2014: since 1999 for Upper Virgin River Recovery Unit and for all others since 2004.

The linear and quadratic time effects indicate that in all recovery units the odds of encountering a juvenile have declined since 2007 (Table 7, Fig. 5), which is most of the period of surveys for four of the five recovery units. The magnitude of the Recovery Unit X Year^2 effects indicates this trend was strongest in the Eastern and Northeastern Mojave recovery units, so that in 2014 there were 23% fewer (Eastern Mojave) and 15% fewer (Northeastern Mojave) juveniles compared to 2004. In 2007, the year when the proportion of juveniles was estimated to be highest in all recovery units, $P(\text{juvenile}_{2007UpperVirginRiver}) = 0.189$, CV = 0.057 and, in contrast, $P(\text{juvenile}_{2007Western\ Mojave}) = 0.099$, CV = 0.067. The probability that an encountered tortoise was a juvenile was also consistently low in the Colorado Desert ($P[\text{juvenile}_{2007Colorado\ Desert}] = 0.119$, CV = 0.131) and lower than in the remaining two recovery units ($P[\text{juvenile}_{2007Eastern\ Mojave}] = 0.149$, CV = 0.187; $P[\text{juvenile}_{2007Northeastern\ Mojave}] = 0.140$, CV = 0.085).

Discussion

Our analyses provide the first estimates of regional and range-wide population trends for *G. agassizii*. Overall this threatened species is experiencing large, ongoing population declines, and adult tortoise numbers have decreased by over 50% in some recovery units since 2004. Although TCAs within the same recovery unit had very different initial densities, trends were more similar within recovery units than between them. Only one of the five recovery units (Northeastern Mojave) exhibited population increases across all TCAs; this recovery unit also had the lowest densities at the start of our study period in 2004.

Maximum annual population growth rate projected in the eastern Mojave Desert during optimum forage conditions on a 2.59-km^2 study plot was 2% (Turner et al. 1987, unpubl. report), while Nussear and Tracy (2007) simulated annual population growth rates as

Table 4. Parameter estimates and standard errors (SEs) from the best-fitting model describing $\log_e$ transformed density/km^2 of adult Mojave Desert Tortoises (*Gopherus agassizii*). The model applies for the period through 2014 for all recovery units, starting in 1999 in Upper Virgin River and in 2004 for the remaining four recovery units.

Recovery unit / Tortoise Conservation Area	Intercept (SE)	Slope (SE)
Western Mojave	-3 174(0 102)	-0 071(0 033)
Fremont-Kramer (FK)	-3 195(0 103)	-0 068(0 030)
Ord-Rodman (OR)	-2 801(0 104)	-0 082(0 031)
Superior-Cronese (SC)	-3 149(0 092)	-0 093(0 029)
Colorado Desert	-3 051(0 078)	-0 045(0 028)
Chocolate Mtn Aerial Gunnery Range (AG)	-2 395(0 115)	-0 033(0 033)
Chuckwalla (CK)	-3 093(0 119)	-0 041(0 042)
Chemehuevi (CM)	-2 966(0 131)	-0 108(0 047)
Fenner (FE)	-2 574(0 127)	-0 073(0 048)
Joshua Tree (JT)	-3 553(0 132)	0 062(0 044)
Pinto Mountains (PT)	-3 144(0 149)	-0 083(0 058)
Piute Valley (PV)	-3 193(0 120)	0 044(0 049)
Northeastern Mojave	-3 870(0 119)	0 131(0 043)
Beaver Dam Slope (BD)	-3 975(0 143)	0 222(0 052)
Coyote Springs Valley (CS)	-3 750(0 100)	0 102(0 041)
Gold Butte-Pakoon (GB)	-4 365(0 148)	0 144(0 048)
Mormon Mesa (MM)	-3 148(0 101)	0 082(0 041)
Eastern Mojave	-3 544(0 132)	-0 112(0 050)
Eldorado Valley (EV)	-3 589(0 131)	-0 092(0 051)
Ivanpah (IV)	-3 273(0 126)	-0 074(0 048)
Upper Virgin River	-1 654(0 093)	-0 032(0 021)
Red Cliffs Desert Reserve (RC)	-1 654(0 093)	-0 032(0 021)

high as 5%. We describe regional population increases in some TCAs much larger than this, possibly indicating that optimal environmental conditions alone do not explain these increases. Several unpaved roads in these TCAs have been closed by the BLM and legal protections since the early 1990s may have reduced the number of tortoises purposely killed or removed from the wild. Nonetheless, the 3.7-fold increase in adults since 2004 that is described here would be unexpected even under much more active management. The large variance associated with these estimates of population trend probably factors into the magnitude of the estimate. Large variances that describe the best estimates of trends in adult density indicate that more modest increases are almost as strongly supported by the data.

Encounter rates make the largest contribution to variance in the annual TCA density estimates, reflecting the non-random pattern of tortoises on the landscape. High between-transect variability in encounter rate means that within-year encounter rate variance will be high, as will between-year variance unless the same transects are surveyed each year. This is the case only in RC, the only TCA where encounter rate variance was never the primary contributor to the density variance (more about variance considerations below).

Based on the rapid increase in the number of adults, juveniles in the Northeastern Mojave Recovery Unit must also be increasing in absolute terms despite the -0.021 change in their relative number since 2004. Locally focused demographic studies are required to describe the roles of increasing adult survivorship and/or recruitment into adult size classes; these studies could also further our understanding of the survivorship of the more cryptic juveniles (USFWS 2011). Population trends of the future (over more than a generation) will provide a measure of reproduction and juvenile survivorship since 2004 in the Northeastern Mojave TCAs.

Declining adult densities through 2014 have left the Western Mojave adult numbers at 49% and in the Eastern Mojave at 33% of their 2004 levels. Such steep declines in the density of adults are only sustainable if there were suitably large improvements in reproduction and juvenile growth and survival. However, the proportion of juveniles has not increased anywhere since 2007, and in these two recovery units the proportion of juveniles in 2014 has declined to 91% and 77% of their representation in 2004, respectively. This may be a continuation of ongoing population declines for at least part of the Western Mojave (Berry et al. 2013).

Reductions in the number of juvenile tortoises may reflect reduced reproduction and/or increased mortality of smaller tortoises. Drought indices for the deserts of the southwestern United States have increased in recent decades (USFWS 2006, Guida et al. 2014), with speculation that female tortoises consequently reduce annual reproductive effort (Henen 1997, 2002) or that hatchlings may be at increased risk of emerging to find too little moisture and related forage (Morafka 1994; Nagy and Medica 1986; Nagy et al. 1997; Wilson et al. 2001). Many other sources of mortality to smaller desert tortoises have been identified (Darst et al. 2013), but recent attention has focused especially on increased predation risk in the Western Mojave, Eastern Mojave, and Colorado Desert recovery units due to prey-switching during droughts by Coyotes (*Canus latrans*; Esque et al. 2010) and especially by increasing abundance of Common Ravens (*Corvus corax*), which typically prey on smaller tortoises rather than on adults (Boarman and Berry 1995; Kristan and Boarman 2003).

Ultimately, trends in adult and juvenile densities reflect the impact of numerous unquantified threats to *G. agassizii* populations over the period of the study (Tracy et al., *op. cit.*; Darst et al. 2013). With few exceptions, the multitude of threats, acting over the long lives of these animals, prevents more rapid and direct identification of specific agents responsible for *G. agassizii* population

Table 5. Estimated change in abundance of adult Mojave Desert Tortoises (*Gopherus agassizii*) in each recovery unit between 2004 and 2014, including standard error (SE) of abundance estimates. Abundance estimates are based on recovery unit densities calculated from the model in Table 4 and applied to all areas of the associated recovery unit meeting criteria as modeled habitat, whether inside or outside TCAs.

Recovery Unit	Modeled Habitat (km^2)	2004 Abundance (SE)	2014 Abundance (SE)	Δ Abundance (SE)
Western Mojave	23,139	131,540 (35,415)	64,871 (17,465)	-66,668 (17,949)
Colorado Desert	18,024	103,675 (30,366)	66,097 (19,359)	-37,578 (11,006)
Northeastern Mojave	10,664	12,610 (4,304)	46,701 (15,940)	34,091 (11,636)
Eastern Mojave	16,061	75,342 (21,589)	24,664 (7,067)	-50,679 (14,522)
Upper Virgin River	613	13,226 (1,115)	10,010 (1,234)	-3,216 (340)
Total	68,501	336,393 (51,596)	212,343 (31,391)	-124,050 (36,062)

increases or declines. Local conditions in each TCA also determine whether the same threat will act with similar severity. For instance, although wildfires in 2005 in RC were associated with high tortoise mortality (McLuckie et al. 2014), similarly large fires that year in GB are believed to have impacted areas of poor tortoise habitat quality due to earlier overgrazing. These areas supported lower densities of tortoises at the time of the wildfire, so the impact of the fires was much less in GB than in RC (Tuma et al. 2016).

Techniques appropriate for describing survivorship and reproduction have characterized tortoise population dynamics in a handful of small, unrepresentative areas, while surveys in larger, more typical low-density areas are difficult to associate with specific local human activities. The trends we describe are consistent with published observations within some TCAs. As mentioned above in the Upper Virgin River Recovery Unit, RC experienced catastrophic wildfire as well as a drought-related die-off of tortoises during the period of this study (McLuckie et al. 2014). The vulnerability of this smaller recovery unit in the face of such large-scale impacts remains of paramount concern. In the Western Mojave Recovery Unit, decreasing population trends in the decades before 2004 were described based on multiple widespread but local mark-recapture plots (Doak et al. 1994; Berry and Medica 1995; Tracy et al., *op. cit.*); other evidence of population declines came from comparison of the frequency of live and dead tortoise sightings in the Western Mojave TCAs (Tracy et al., *op. cit.*). During the period covered by our study, Esque et al. (2010) also noted increased rates of predation by coyotes in the Western Mojave and linked this to decreases in their mammal prey base following drought.

In other parts of the desert, earlier research on local plots sometimes described population trajectories that differ from declines reported by us, such as static adult tortoise numbers on 2.59- km^2 plots in the IV TCA in the Eastern Mojave Recovery Unit, and in PV and FE in the Colorado Desert Recovery Unit (Berry and Medica 1995). The data in these cases were for earlier decades and describe patterns on single local plots that were not

Table 6. Model selection table for mixed model logistic regression describing the proportion of observations that were juvenile Mojave Desert Tortoises (*Gopherus agassizii*) from 2004 through 2014 for all recovery units (starting in 1999 for Upper Virgin River Recovery Unit). Year was also used as a categorical variable to capture the random effects of annual conditions. Model weights (w) express the relative support for each model given the data and are based on relative scores for Akaike's Information Criterion (AIC). Models with ΔAIC < 5 are shown (these model weights cumulatively account for > 0.95 of model support) as well as the top model for describing patterns in adult densities (Table 3) and the null model.

Model	Log likel.	AIC	ΔAIC	w
RU	-1967.8	3947.5	0.0	0.324
RU + Year2	-1966.8	3947.6	0.1	0.309
RU + Year	-1967.7	3949.5	2.0	0.119
RU + Year + Year2	-1966.8	3949.6	2.1	0.114
RU + Year2 + RU×Year2	-1964.1	3950.2	2.7	0.084
RU + Year + Year2 + RU×Year2	-1964.0	3951.9	4.4	0.036
RU + Year + RU×Year	-1965.9	3953.8	6.3	0.014
Random factors only	-1982.0	3968.1	20.6	0.000

Table 7. Parameter estimates (standard errors) for changes in the relative proportion of juveniles observed on surveys for adult Mojave Desert Tortoises (*Gopherus agassizii*) from 2004 through 2014 in four of the five recovery units and since 1999 in Upper Virgin River Recovery Unit. Estimates are model-averaged with shrinkage across the top six models in Table 6. For interpreting inflection points, the input variable Year was standardized based on mean = 2007.0 and standard deviation = 4.1.

Recovery Unit	Intercept	Year	Year^2
Colorado Desert	-1.999 (0.133)	0.003 (0.088)	-0.097 (0.380)
Eastern Mojave	-1.729 (0.206)	0.003 (0.106)	-0.484 (1.262)
Northeastern Mojave	-1.822 (0.107)	-0.001 (0.095)	-0.307 (0.534)
Upper Virgin River	-1.445 (0.066)	0.003 (0.003)	-0.212 (0.045)
Western Mojave	-2.198 (0.071)	-0.005 (0.105)	-0.154 (0.330)

selected to be representative of the larger TCA (Corn 1994; Anderson et al. 2001; Tracy et al., *op. cit.*). For instance, ongoing and long-term declines on a 2.59-km^2 plot in the JT TCA of the Colorado Desert Recovery Unit (Lovich et al. 2014) may reflect drought impacts they describe, in addition to consequences from the unimproved road that bisects the plot, and predator impacts reported elsewhere in a low relief site (Berry et al. 2013). These characteristics of the plot differ from large areas of the TCA, which are in more rugged terrain and where we characterize populations as increasing.

Throughout our assessment, we describe tortoise status based on adult densities, which is useful for comparison of areas of different sizes. However, if the area available to tortoises is decreasing, then trends in tortoise density no longer capture the magnitude of decreases in abundance. Some of the area of potential habitat (68,501 km^2) has certainly been modified in a way that decreases the number of tortoises present. We used area estimates that removed impervious surfaces created by development as cities in the desert expanded. However, we did not address degradation and loss of habitat from recent expansion of military operations (753.4 km^2 so far on Fort Irwin and the Marine Corps Air Ground Command Center), from intense large scale fires such as those that burned 576.2 km^2 in critical habitat alone in 2005, or from development of utility-scale solar facilities in the desert that have been permitted on 194 km^2 to date (USFWS 2016). The impact of the many smaller land use conversions (habitat loss) have not been compiled, but this and the small scale of habitat restoration projects (habitat gain) have been dwarfed by the scale of habitat conversion from military exercises, renewable energy facilities, and catastrophic fire. Due to loss and degradation of potential habitat, the recovery unit abundance estimates in Table 5 are maximum estimates. Habitat loss would also disrupt the prevailing population structure of this widely distributed species with geographically limited dispersal (isolation by distance; Murphy et al. 2007; Hagerty and Tracy 2010). Demographic connection with nearby local populations has enabled repopulation of at least one area after a local die-off of tortoises (Germano and Joyner 1988). We therefore anticipate an additional impact of this habitat loss is decreasing resilience of local tortoise populations by reducing demographic connections to neighboring populations (Fahrig 2007). Military and commercial operations and infrastructure projects that reduce tortoise habitat in the desert are anticipated to continue.

The high variability of population estimates and the serious consequences of hypothesis testing that fails to detect a true population decline are ongoing topics in conservation biology (Johnson 1989; Taylor and Gerrodette 1993; Taylor et al. 2007; Gerrodette 2011). Conventional hypothesis testing involves comparison of observed trend estimates to a null model of static population size; this unnecessarily restricts the scope and usefulness of monitoring programs to acquiring enough information to rule out no-action (Wade 2000; Gerrodette 2011). Instead, we used an information-theoretic approach in which the data are applied to each competing model; we drew conclusions based on the relative support for each model given the data (Burnham and Anderson 2002). In this case, regional trend models best described the data in hand. Our current analysis strongly concludes that there are similar population trends within recovery units, with different trends between recovery units.

The range-wide scope of our analysis also uses the power of replication in space to underline regional trends rather than attempting to describe one local trend in isolation (see Freilich et al. 2005; Inman et al. 2009). We would have reached less definitive conclusions if the monitoring effort had continued exclusively in a few dozen 2.59-km^2 study plots that had been initiated in the 1970s or if fewer TCAs had been surveyed, perhaps in a less coordinated effort. Instead, the current range-wide distance sampling program provides fairly coarse but clear summaries of patterns in tortoise density and abundance, definitive because they sample regionally and range-wide.

Although our results demonstrate the power of this monitoring program to detect large positive and negative trends over a 10–15-y period, large SEs for density trends we found reflect two important sources of imprecision in the population growth estimates. First, long-term monitoring programs spread over a large area are describing multiple underlying local phenomena. This can be seen in the consistent but TCA-specific within-recovery-unit trends. The same phenomenon is expected within TCAs. For example, each end of a valley may be experiencing different population dynamics, or lowland habitat may offer different population growth potential from upland habitat. It is also to be expected that there is some variation in the degree of population growth supported by year-to-year environmental conditions. These sources of variability in TCA- or recovery-unit-level population dynamics are reflected in the SE of our population trend estimates. By modeling intra-year covariation in TCA density estimates, we accounted for some of the process variation due to annual conditions.

Sampling error of the density estimate is a composite of the errors from the encounter rate estimates as well as from both correction factors that are applied. Estimation of P_a consistently contributes about 10% to the variance in the annual density estimates (e.g., McLuckie et al. 2002), and many more observations are needed to develop a detection curve than to estimate encounter rate. Detection curves based on 60 observations might be minimally acceptable (Buckland et al. 2001), whereas encounter rate estimates based on the same number of detections would be robust. This issue underlies the simulations by Freilich et al. (2005), which led them to reject distance sampling as a viable method for such sparsely distributed animals. The current monitoring program always applied much greater survey effort to estimate TCA-specific encounter rates than anticipated by Freilich et al. (2005); also, to avoid poor detection estimates, we pooled detection distances across all TCAs completed by a given team of surveyors. A certain amount of precision is also lost to the annual density estimates by correcting for G_0. However, this quantity can vary considerably between years, so failure to correct population estimates adequately would add bias to annual density estimates (Freilich et al. 2000).

Encounter rate estimation is consistently the largest variance component in all TCA density estimates (e.g., McLuckie et al. 2002). Most encounter rate variance is inherent to the distribution of tortoises on the landscape (Krzysik 2002), reflecting topographic and vegetation differences between transects with additional sampling variance reflecting relative survey effort. The planned and sustained effort in RC has resulted in much larger sample sizes than in other TCAs and more precision for annual population density estimates (CV = SE/density consistently between 0.12 and 0.15), contributing to lower between-year sampling error. Sampling error is also reduced because we survey the same transects in RC each year. The declining trend in abundance was therefore discernible even though RC was only monitored every other year, an approach that has not been pursued in the rest of the range where survey effort has fluctuated at a generally suboptimal level based on inconsistent funding.

Turtles and tortoises world-wide are as threatened with extinction as any other vertebrate lineage (Stanford et al. 2018). The crisis in turtle survival stems from ongoing direct exploitation that targets turtles for consumption or captivity as well as from indirect or untargeted harm such as mortality on roadways or non-lethal degradation of the habitat they need to survive. Most extinct turtle taxa in the past hundreds of years were extirpated from constrained areas (mostly giant tortoises endemic to islands), whereas the turtle species that are currently most endangered are primarily threatened by habitat alteration and collection for the pet trade or food market (Stanford et al. 2018). *Gopherus agassizii* is one of six North American species of *Gopherus*, part of all of which have protected status under U.S. or Mexican regulations or both. *Gopherus flavomarginatus* is listed among the top 25 threatened freshwater and terrestrial turtle species (Stanford et al. 2018), and populations have been decimated by habitat loss and ongoing collection for consumption. The remaining *Gopherus* species are widespread, which is not characteristic of turtles that have faced the first waves of extinction and local extirpation of the modern era. Population losses have nonetheless been documented in these *Gopherus* species (Bury et al. 1988; McCoy et al. 2006; Allison and McCoy 2014), and *G. agassizii* is now included in the list of the top 50 turtle and tortoise species at greatest risk (Stanford et al. 2018). Unlike earlier groups of turtle and tortoise species at risk of extinction, declines in *Gopherus* may instead reflect compounding impacts of threats that are not acutely lethal to individuals or populations (USFWS 2011). In common with other turtles and tortoises, their life history puts *G. agassizii* at greater risk from even slightly elevated adult mortality (Congdon et al. 1993; Doak et al. 1994) and recovery from population declines will require more than enhancing adult survivorship (Spencer et al. 2017). Currently, 60.8% of turtle species are designated Threatened on the International Union for Conservation of Nature (IUCN) Red List (IUCN 2017), including all *Gopherus* species except *G. berlandieri*. Although populations comprising *G. morafkai* and *G. evgoodei* were classified as conspecifics of *G. agassizii* at the time of the most recent IUCN status assessment, they are now recognized as distinct species, and are considered Vulnerable by the Tortoise and Freshwater Turtle Specialist Group, which officially consults to update the IUCN Red List (Rhodin et al. 2017).

The negative population trends in most of the TCAs for Mojave Desert Tortoises indicate that this species is on the path to extinction under current conditions. This may reflect inadequate recovery action implementation, slow response by tortoises and their habitat to implemented actions, or new and ongoing human activities in the desert that have not been mitigated appropriately. It may also be a result of stochastic or directional climatic events that impact large expanses of tortoise habitat (e.g., drought, fire, climate change) and are largely beyond the realm of local land management activities. Our results are a call to action to remove ongoing threats to tortoises from TCAs, and possibly to contemplate the role of human activities outside TCAs and their impact on tortoise populations inside them.

Long-term monitoring is an essential component of evidence-based management (Lindenmayer and Likens 2010). It determines whether the composite management efforts over ecologically meaningful time periods have been effective. For G. agassizii, the reinvigoration of the interagency management oversight group tasked with implementing recovery activities based on their predicted effectiveness has the potential to translate results from this monitoring program into decisions about maintaining or altering contemporary management activities. Monitoring of declining populations should be deeply integrated in conservation and recovery programs. Recovery plans under the U.S.

Endangered Species Act always stipulate population thresholds that would trigger removal of federal protection, but adaptive-management triggers based on monitoring results that show population declines are absent from most recovery planning (Lindenmayer et al. 2013) and have not yet been integrated into the management for *G. agassizii*.

Although these surveys were designed to provide a 25-y description of population growth, it is clear that this single purpose would be an underutilization of the program that can certainly address interim management questions (Nichols and Williams 2006). For long-lived *G. agassizii*, monitoring of the reproductive portion of the population also captures the effects of management on the population segment that must be the basis for recovery. Population recovery will necessitate accelerated, prioritized recovery activities (Darst et al. 2013). Targeted, local effectiveness monitoring (Lyons et al. 2008; Lindenmayer et al. 2011), where possible, would complement our larger population monitoring program. Both types of monitoring will be needed to characterize the effectiveness of recovery activities where the list of threats is so large and varied.

Acknowledgments.—This monitoring program was developed and adapted around recommendations provided by David Anderson and Kenneth Burnham in 1996. P. Steven Corn, Clarence Everly, Richard Fridell, Jill Heaton, Ronald Marlow, Philip Medica, Kenneth Nussear, and C. Richard Tracy contributed to the early development of the program. Over the years, hundreds of surveyors collected field data, led over multiple years by Terry Christopher, Imogen Daly, Nathan Gregory, Deborah Harstad, and Peter Woodman. Melissa Brenneman, Rohit Patil, Clarence Everly, and Jill Heaton contributed to database development, quality control, and data management protocols. Reviews by Roy Averill-Murray, Catherine Darst, Kimberleigh Field, Katherine Ralls, J. Michael Reed, and Robert Steidl improved this manuscript considerably. Funding for various years of this study was provided by Arizona Strip Field Office, BLM; California Desert District, BLM; Clark County Desert Conservation Program; Edwards Air Force Base; Parashant National Monument, National Park Service; Joshua Tree National Park; Marine Corps Air Station, Yuma; Mojave National Preserve; National Training Center, Ft. Irwin; Southern Nevada Field Office, BLM; Washington County Habitat Conservation Plan; Utah Division of Wildlife Resources; and State of Utah Endangered Species Mitigation Fund. These and other government land managers provided access to surveyed areas. We conducted these minimal tortoise handling activities as well as all transmitter attachment, maintenance, and removal procedures in compliance with U.S. Fish and Wildlife Service recovery permits TE-108507 and TE-038224, which set out terms and conditions that were also requirements for our associated state permits. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Literature Cited

Allison, L.J., and E.D. McCoy. 2014. North American tortoise abundance. Pp. 118–126 *In* Biology and Conservation of North American Tortoises. Rostal, D.C., E.D. McCoy, and H.R. Mushinsky (Eds.). Johns Hopkins University Press, Baltimore, Maryland, USA.

Anderson, D.R., K.P. Burnham, B.C. Lubow, L. Thomas, P.S. Corn, P.A. Medica, and R.W. Marlow. 2001. Field trials of line transect methods applied to estimation of desert tortoise abundance. Journal of Wildlife Management 65:583–597.

Barton, K. 2015. MuMIn: Multi-model Inference. R package version 1.15.1. R Foundation for Statistical Computing, Vienna, Austria. http://CRAN.R-project.org/package=MuMIn.

Bates D., M. Maechler, B. Bolker, and S. Walker. 2015. lme4: Linear Mixed-effects Models using Eigen and S4. R package version 1.1–8. R Foundation for Statistical Computing, Vienna, Austria. http://CRAN.R-project.org/package=lme4.

Berry, K.H., and P.A. Medica. 1995. Desert Tortoises in the Mojave and Colorado deserts. Pp. 135–137 *In* Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (Eds.). U.S. Department of the Interior, National Biological Service, Washington, D.C., USA.

Berry, K.H., J.L. Yee, A.A. Coble, W.M. Perry, and T.A. Shields. 2013. Multiple factors affect a population of Agassiz's Desert Tortoise (*Gopherus agassizii*) in the northwestern Mojave Desert. Herpetological Monographs 27:87–109.

Boarman, W.I., and K.H. Berry. 1995. Common Ravens in the southwestern United States, 1968–92. Pages 73–75 *In* Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (Eds.). U.S. Department of the Interior, National Biological Service, Washington, D.C., USA.

Boarman, W.I., T. Goodlett, G. Goodlett, and P. Hamilton. 1998. Review of radio transmitter attachment techniques for turtle research and recommendations for improvement. Herpetological Review 29:26–33.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001.

Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK.

Burnham, K.P., and D.R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-theoretic Approach. 2nd Edition. Springer, New York, New York, USA.

Bury, R.B., T.C. Esque, L.A. DeFalco, and P.A. Medica. 1994. Distribution, habitat use, and protection of the desert tortoise in the Eastern Mojave Desert. Pp. 57–72 *In* Biology of North American Tortoises. Bury, R.B., and D.J. Germano (Eds). National Biological Survey, Fish and Wildlife Research 13, Washington, D.C., USA.

Bury, R.B., D.J. Morafka, and C.J. McCoy. 1988. Distribution, abundance and status of the Bolsón Tortoise. Pp. 5–30 *In* The Ecogeography of the Mexican Bolsón Tortoise (*Gopherus flavomarginatus*): Derivation of its Endangered Status and Recommendations for its Conservation. Morafka, D.J. and C.J. McCoy (Eds). Annuals of the Carnegie Museum 57.

Congdon, J.D., A.E. Dunham, and R.C. van Loeben Sels. 1993. Delayed sexual maturity and demographics of Blanding's Turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. Conservation Biology 7:826–833.

Corn, P.S. 1994. Recent trends of Desert Tortoise populations in the Mojave Desert. Pp. 85–93 *In* Biology of North American Tortoises. Bury, R.B., and D.J. Germano (Eds). National Biological Survey, Fish and Wildlife Research 13, Washington, D.C., USA.

Darst C.R., P.J. Murphy, N.W. Strout, S.P. Campbell, K.J. Field, L. Allison, and R.C. Averill-Murray. 2013. A strategy for prioritizing threats and recovery actions for at-risk species. Environmental Management 51:786–800.

Doak, D., P. Karieva, and B. Klepetka.1994. Modeling population viability for the Desert Tortoise in the Western Mojave. Ecological Applications 4:446–460.

Esque, T.C., K.E. Nussear, K.K. Drake, A.D. Walde, K.H. Berry, R.C. Averill-Murray, A.P. Woodman, W.I. Boarman, P.A. Medica, J. Mack, and J.S. Heaton. 2010. Effects of subsidized predators, resource variability, and human population density on desert tortoise populations in the Mojave Desert, USA. Endangered Species Research 12:167–177.

Fahrig, L. 2007. Non-optimal animal movement in human-altered landscapes. Functional Ecology 21:1003–1015.

Freilich, J.E., K.P. Burnham, C.M. Collins, and C.A. Garry. 2000. Factors affecting population assessments of Desert Tortoises. Conservation Biology 14:1479–1489.

Freilich, J.E., R.J. Camp, J.J. Duda, and A.E. Karl. 2005. Problems with sampling Desert Tortoises: a simulation analysis based on field data. Journal of Wildlife Management 69:45–56.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the conterminous United States. Photogrammetric Engineering and Remote Sensing 77:858–864.

Germano, D.J. 1994. Comparative life histories of North American tortoises. Pp. 175–185 *In* Biology of North American Tortoises. Bury, R.B., and D.J. Germano (Eds.). National Biological Survey, Fish and Wildlife Research 13, Washington, D.C., USA.

Germano, D.J., R.B. Bury, T.C. Esque, T.H. Fritts, and P.A. Medica. 1994. Range and habitat of the Desert Tortoise. Pp. 57–72 *In* Biology of North American Tortoises. Bury, R.B., and D.J. Germano (Eds.). National Biological Survey, Fish and Wildlife Research 13, Washington, D.C., USA.

Germano, D.J., and M.A. Joyner. 1988. Changes in a Desert Tortoise (*Gopherus agassizii*) population after a period of high mortality. Pp. 190–198 *In* Management of Amphibians, Reptiles, and Small Mammals in North America: Proceedings of the Symposium. Szaro, R.C., K.E. Severson, and D.R. Patton (Technical Coordinators). U.S. Department of Agriculture, Forest Service General Technical Report RM-166, Fort Collins, Colorado, USA.

Gerrodette, T. 2011. Inference without significance: measuring support for hypotheses rather than rejecting them. Marine Ecology 32:404–418.

Guida, R. J, S. R. Abella, W. J. Smith, Jr., H. Stephen, and C. L. Roberts. 2014. Climatic change and desert vegetation distribution: assessing thirty years of change in Southern Nevada's Mojave Desert. The Professional Geographer 66:311–322.

Hagerty, B.E., and C.R. Tracy. 2010. Defining population structure for the Mojave Desert Tortoise. Conservation Genetics 11:1795–1807.

Henen, B.T. 1997. Seasonal and annual energy budgets of female Desert Tortoises (*Gopherus agassizii*). Ecology 78:283–296.

Henen, B.T. 2002. Reproductive effort and reproductive nutrition of female Desert Tortoises: essential field methods. Integrative and Comparative Biology 42:43–50.

Inman, R.D, K.E. Nussear, and C.R. Tracy. 2009. Detecting trends in Desert Tortoise population growth: elusive behavior inflates variance in estimates of population density. Endangered Species Research 10:295–304.

International Union for Conservation of Nature (IUCN). 2017. IUCN Red List of Threatened Species. Version 2017–3. http://www.iucnredlist.org.

Johnson, D.H. 1989. An empirical Bayes approach to analyzing recurring animal surveys. Ecology 70:945–952.

Keene, O.N. 1995. The log transformation is special. Statistics in Medicine 14:811–819.

Kristan, W.B., and W.I. Boarman. 2003. Spatial pattern of risk of Common Raven predation on Desert Tortoises. Ecology 84:2432–2443.

Krzysik, A.J. 2002. A landscape sampling protocol for estimating distribution and density patterns of Desert Tortoises at multiple spatial scales. Chelonian Conservation and Biology 4:366–379.

Lindenmayer, D.B., and G.E. Likens. 2010. The science and application of ecological monitoring. Biological Conservation 143:1317–1328.

Lindenmayer, D.B., G.E. Likens, A. Haywood, and L. Miezis. 2011. Adaptive monitoring in the real world: proof of concept. Trends in Ecology and Evolution 26:641–646.

Lindenmayer, D.B., M.P. Piggott, and B.A. Wintle. 2013. Counting the books while the library burns: why conservation monitoring programs need a plan for action. Frontiers in Ecology and the Environment 11:549–555.

Liu, C., P.M. Berry, T.P. Dawson, and R.G. Pearson. 2005. Selecting thresholds of occurrence in the prediction of species distributions. Ecography 28:385–393.

Lovich, J.E., C.B. Yackulic, J. Freilich, M. Agha, M. Austin, K.P. Meyer, T.R. Arundel, J. Hansen, M.S. Vamstad, and S.A. Root. 2014. Climatic variation and tortoise survival: has a desert species met its match? Biological Conservation 169:214–224.

Luckenbach, R.A. 1982. Ecology and management of the Desert Tortoise (*Gopherus agassizii*) in California. Pp. 1–37 *In* North America Tortoises: Conservation and Ecology. Bury, R.B. (Ed.). National Biological Survey, U.S. Fish and Wildlife Service, Wildlife Research Report 12, Washington, D.C., USA.

Lyons, J.E., M.C. Runge, H.P. Laskowski, and W.L. Kendall. 2008. Monitoring in the context of structured decision-making and adaptive management. Journal of Wildlife Management 72:1683–1692.

Marques, T.A., L. Thomas, S.G. Fancy, and S.T. Buckland. 2007. Improving estimates of bird density using multiple-covariate distance sampling. Auk 124:1229–1243.

Mazerolle, M.J. 2015. AICcmodavg: Model Selection and Multimodel Inference based on (Q)AIC(c). R package version 2.0-3. R Foundation for Statistical Computing, Vienna, Austria. http://CRAN.R-project.org/package=AICcmodavg.

McCoy, E.D., H.R. Mushinsky, and J. Lindzey. 2006. Declines of the Gopher Tortoise on protected lands. Biological Conservation 128:120–127.

McLuckie, A.M., D.L. Harstad, J.W. Marr, and R.A. Fridell. 2002. Regional Desert Tortoise monitoring in the Upper Virgin River Recovery Unit, Washington County, Utah. Chelonian Conservation and Biology 4:380–386.

McLuckie, A.M., E.T. Woodhouse, and R.A. Fridell. 2014. Regional Desert Tortoise monitoring in the Red Cliffs Desert Reserve, 2013. Utah Division of Wildlife Resources, Publication number 14-15. Salt Lake City, Utah, USA.

Morafka, D.J. 1994. Neonates: missing links in the life history of North American tortoises. Fish and Wildlife Service Research 13:161–173.

Murphy R.W., K.H. Berry, T. Edwards, A.E. Leviton, A. Lathrop, J.D. Riedle. 2011. The dazed and confused identity of Agassiz's land tortoise, *Gopherus agassizii* (Testudines, Testudinidae) with the description of a new species, and its consequences for conservation. ZooKeys 113:39–71.

Murphy, R.W., K.H. Berry, T. Edwards, and A.M. McLuckie. 2007. A genetic assessment of the recovery units for the Mojave population of the Desert Tortoise, *Gopherus agassizii*. Chelonian Conservation and Biology 6:229–251.

Nagelkerke, N.J.D. 1991. A note on a general definition of the coefficient of determination. Biometrika 78:691–692.

Nagy, K.A., and P.A. Medica. 1986. Physiological ecology of Desert Tortoises. Herpetologica 42:73–92.

Nagy, K. A., D. J. Morafka, and R. A. Yates. 1997. Young Desert Tortoise survival: energy, water, and food requirements in the field. Chelonian Conservation and Biology 2:396–404.

Nichols, J.D., and B.K. Williams. 2006. Monitoring for conservation. Trends in Ecology and Evolution 21:668–673.

Nussear, K.E., and C.R. Tracy. 2007. Can modeling improve estimation of Desert Tortoise population densities? Ecological Applications 17:579–586.

Nussear, K.E., T.C. Esque, R.D. Inman, L. Gass, K.A. Thomas, C.S.A. Wallace, J.B. Blainey, D.M. Miller, and R.H. Webb. 2009. Modeling habitat of the Desert Tortoise (*Gopherus agassizii*) in the Mojave and parts of the Sonoran deserts of California, Nevada, Utah, and Arizona. Open-file Report 2009–1102, U.S. Geological Survey, Reston, Virginia, USA.

Pekár, S., and M. Brabec 2016. Marginal models via GLS: a convenient yet neglected tool for the analysis of correlated data in the behavioural sciences. Ethology 122:621–631.

Pinheiro, J., D. Bates, S. DebRoy, D. Sarkar, and R Core Team. 2017. nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-131. R Foundation for Statistical Computing, Vienna, Austria. http://CRAN.R-project.org/package=nlme.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Rhodin, A.G.J., J.B. Iverson, R. Bour, U. Fritz, A. Georges, H.B. Shaffer, and P.P. van Dijk (Turtle Taxonomy Working Group). 2017. Turtles of the world: annotated checklist and atlas of taxonomy, synonymy, distribution, and conservation status. Pp. 1–292 *In* Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the International Union for Conservation of Nature (SSC Tortoise and Freshwater Turtle Specialist Group). Rhodin, A.G.J., J.B. Iverson, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, P.C.H. Pritchard, and R.A. Mittermeier (Eds.). Chelonian Research Monographs 7, Lunenburg, Massachusetts, USA.

Schielzeth, H. 2010. Simple means to improve the interpretability of regression coefficients. Methods in Ecology and Evolution 1:103–113.

Spencer, R.-J., J.U. Van Dyke, and M.B. Thompson. 2017. Critically evaluating best management practices for preventing freshwater turtle extinctions. Conservation Biology 31:1340–1349.

Stanford, C.B., A.G.J. Rhodin, P.P. van Dijk, B. D. Horne, T. Blanck, E.V. Goode, R. Hudson, R. A. Mittermeier, A. Currylow, C. Eisemberg, et al. (Turtle Conservation Coalition). 2018. Turtles in Trouble: The World's 25+ Most Endangered Tortoises and Freshwater Turtles–2018. International Union for Conservation of Nature Tortoise and Freshwater Turtle Specialist Group, Turtle Conservancy, Turtle Survival Alliance, Turtle Conservation Fund, Conservation International, Chelonian Research Foundation, Wildlife Conservation Society, and Global Wildlife Conservation, Ojai, California, USA.

Taylor, B.L., and T. Gerrodette. 1993. The uses of statistical power in conservation biology: the Vaquita and Northern Spotted Owl. Conservation Biology 7:489–500.

Taylor, B.L., M. Martinez, T. Gerrodette, J. Barlow, and Y.N. Hrovat. 2007. Lessons from monitoring trends in abundance of marine mammals. Marine Mammal Science 23:157–175.

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B. Bishop, T.A. Marques, and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5–14.

Tuma, M.W., C. Millington, N. Schumaker, and P. Burnett. 2016. Modeling Agassizi's Desert Tortoise population response to anthropogenic stressors. Journal of Wildlife Management 80:414–429.

U.S. Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the Mojave population of the desert tortoise. Federal Register 55:12178–12191.

U.S. Fish and Wildlife Service. 1994. Desert Tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

U.S. Fish and Wildlife Service 2006. Range-wide Monitoring of the Mojave Population of the Desert Tortoise: 2001–2005 Summary Report. Report by the Desert Tortoise Recovery Office, U.S. Fish and Wildlife Service, Reno, Nevada, USA. 85 pp.

U.S. Fish and Wildlife Service. 2011. Revised Recovery Plan for the Mojave Population of the Desert Tortoise (*Gopherus agassizii*). U.S. Fish and Wildlife Service, California and Nevada Region, Sacramento, California, USA.

U.S. Fish and Wildlife Service. 2016. Biological Opinion on the Proposed Land Use Plan Amendment under the Desert Renewable Energy Plan. Memorandum to Deputy State Director, Bureau of Land Management, Sacramento, California. Dated August 16. From Field Supervisor, Carlsbad Fish and Wildlife Office. Carlsbad, California. 203 pp.

Wade, P.R. 2000. Bayesian methods in conservation biology. Conservation Biology 14:1308–1316.

White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Publication LA-87-87-NERP. Los Alamos National Laboratory, Los Alamos, New Mexico, USA.

Wilson, D.S., K.A. Nagy, C.R. Tracy, D.J. Morafka, and R.A. Yates. 2001. Water balance in neonate and juvenile desert tortoises, *Gopherus agassizii*. Herpetological Monographs 15:158–170.

Zar, J.H. 1996. Biostatistical Analysis. 3rd Edition. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Zuur, A.R., E.N. Ieno, N.J. Walker, A.A. Saveliev, G.M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York, New York, USA.

Linda J. Allison is an Ecologist with the Desert Tortoise Recovery Office of the U.S. Fish and Wildlife Service in Reno, Nevada, USA. One of her roles is coordination of a four-state line distance sampling effort to describe Mojave Desert Tortoise status and trends. Linda has degrees in Biology with an emphasis in ecology and evolution from the University of California, Berkeley, USA (B.S.), and from Arizona State University, Tempe, USA (M.S.). (Photographed by Rebecca Palush).

Ann M. McLuckie received her M.S. from University of Arizona, Tucson, USA, studying the genetics, morphology, and ecology of the Desert Tortoise in the Black Mountains in Mojave County, Arizona. Since 1997, she has worked as a Wildlife Biologist with the Utah Division of Wildlife Resources, USA, designing and implementing a Desert Tortoise monitoring program for the Red Cliffs Desert Reserve and Red Cliffs National Conservation Area, USA. (Photographed by Brian Bock).

Appendix A. Annual proportion visible, G_0 (standard error), at each focal site where we monitored transmittered adult Mojave Desert Tortoises (*Gopherus agassizii*). Sites are listed in order from the western-most to the eastern-most and their locations are indicated in Fig. 1. Red Cliffs was also surveyed earlier: 1999 (0.63, SE = 0.185), 2000 (0.86, SE = 0. 144), 2001 (0.86, SE = 0.167), 2003 (0.87, SE = 0. 135).

Site	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014
Superior-Cronese	0.95 (0.081)	0.92 (0.094)	0.96 (0.050)	0.75 (0.197)	0.90 (0.120)	0.98 (0.056)	0.94 (0.073)	0.94 (0.073)		0.91 (0.101)
Ord-Rodman	0.98 (0.035)	0.92 (0.083)	0.64 (0.213)	0.74 (0.130)	0.96 (0.054)	0.94 (0.072)	0.95 (0.062)	0.79 (0.156)		0.99 (0.030)
Twentynine Palms	0.98 (0.028)	0.90 (0.110)	0.97 (0.047)	0.74 (0.113)						
Chuckwalla	0.70 (0.183)	0.74 (0.153)	0.87 (0.060)	0.55 (0.105)	0.73 (0.175)	0.84 (0.125)	0.85 (0.108)	0.82 (0.075)	0.84 (0.058)	0.59 (0.087)
Ivanpah	0.95 (0.071)	0.87 (0.102)	0.94 (0.091)	0.79 (0.107)	0.79 (0.120)	0.88 (0.157)	0.87 (0.149)	0.54 (0.098)		
Jean	0.86 (0.142)									
Indian Springs			0.79 (0.140)	0.83 (0.153)	0.88 (0.118)	0.86 (0.130)	0.79 (0.093)	0.98 (0.049)		
Piute Valley 1	0.84 (0.148)	0.91 (0.118)	0.81 (0.178)	0.73 (0.127)		0.79 (0.218)	0.86 (0.141)	0.65 (0.148)		
Chemehuevi	0.88 (0.104)	0.65 (0.174)	0.62 (0.118)	0.80 (0.120)	0.84 (0.130)	0.81 (0.144)	0.80 (0.162)	0.35 (0.077)		
Piute Valley 2	0.80 (0.191)	0.87 (0.166)								
Halfway Wash					0.64 (0.167)	0.77 (0.200)	0.55 (0.152)	0.54 (0.116)	0.68 (0.136)	
Gold Butte						0.76 (0.141)	0.65 (0.155)	0.52 (0.118)	0.68 (0.123)	
Red Cliffs		0.86 (0.140)	0.53 (0.247)		0.68 (0.131)		0.74 (0.134)		0.66 (0.180)	

Appendix B. Detection statistics for field teams surveying separate Tortoise Conservation Areas (TCAs) each year. Teams walked *L* total km over *k* transects and detected n adult Mojave Desert Tortoises, which was P_a proportion of those available within *w* meters of the transect centerline. The coefficient of variation (CV) for P_a is also listed. Separate detection curves were built for each team each year, except in Red Cliffs Desert Reserve (RC), for which we report on the single composite detection curve. Other TCAs are abbreviated as Chocolate Mountains Aerial Gunnery Range (AG), Beaver Dam Slope (BD), Chuckwalla (CK), Chemehuevi (CM), Coyote Springs Valley (CS), Eldorado Valley (EV), Fenner (FE), Fremont-Kramer (FK), Gold Butte-Pakoon (GB), Ivanpah (IV), Joshua Tree (JT), Mormon Mesa (MM), Ord-Rodman (OR), Pinto Mountains (PT), Piute Valley (PV), and Superior-Cronese (SC).

Year	TCAs	k	L	w	n	P_a	CV(P_a)
1999 to 2013	RC	1,417	2,778	20	1,141	0.64	0.02
2004	AG, CK, CM, FE, IV, JT, PT	316	3,509	15	292	0.57	0.03
2004	FK, OR, SC	138	1,534	15	134	0.42	0.19
2004	BD, CS, EV, GB, MM, PV	175	1,723	22	57	0.47	0.10
2005	AG, CK, CM, FE, FK, IV, JT, OR, PT, SC	451	5,414	13	394	0.47	0.06
2005	BD, CS, EV, GB, MM, PV	267	2,852	18	108	0.40	0.10
2007	BD, CS, EV, GB, MM, PV	282	2,723	13	67	0.57	0.10
2007	AG, CK, CM, FE, FK, IV, JT, OR, PT, SC	271	3,174	16	155	0.39	0.09
2008	BD, CS, EV, MM, PM	566	5,705	18	127	0.41	0.10
2008	AG, CK, CM, FE, FK, IV, JT, OR, PT, SC	118	1,354	14	42	0.47	0.33
2009	BD, CS, EV, GB, MM, PV	568	5,525	15	109	0.25	0.23
2009	AG, CM, FE, FK, IV, JT, OR, PT, SC	225	2,492	14	103	0.35	0.10
2010	BD, CS, GB, MM	425	4,265	16	164	0.41	0.08
2010	CM, EV, FE, IV, PV	368	2,465	14	109	0.59	0.06
2010	FK, OR, SC	187	2,144	12	91	0.58	0.07
2010	AG, CK, JT, PT	140	1,431	8	85	0.67	0.10
2011	BD, CS, GB, MM	380	3,984	20	166	0.43	0.10
2011	CM, EV, FE, IV, PV	312	2,548	20	133	0.32	0.19
2011	CK, FK, JT, OR, PT, SC	160	1,802	16	100	0.53	0.08
2012	BD, CS, GB, MM	369	4,184	21	151	0.38	0.12
2012	CM, EV, FE, IV, PV	201	1,695	15	28	0.43	0.26
2012	AG, CK, FK, JT, OR, PT, SC	162	1,776	14	73	0.40	0.15
2013	AG, BD, GB	173	2,019	16	68	0.45	0.20
2014	AG, FK, OR, SC	230	2,649	10	118	0.61	0.06

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]

Wed 12/15/2021 7:41 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

We do not want this solar project as it can / will affect OHV riding areas and trails.

Signed,

[redacted]

[EXTERNAL] Attn: Rough Hat Clark County Solar Project Variance

Vegas Valley 4 Wheelers <info@vv4w.org>

Wed 12/15/2021 8:07 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Attn: Rough Hat Clark County Solar Project Variance

We do not want this solar project as it can / will affect OHV riding areas and trails

[redacted]
Vegas Valley Four Wheelers
Club President

[EXTERNAL] Solar

[redacted]

Wed 12/15/2021 9:21 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

To: Whom It May Concern,

I live in the Pahrump So Valley, community of Mountain Falls.
I want to let you know that I am totally opposed to any attempt to allow solar panel and farms in the deserts of this area. Vote NO please.

I am also appalled that you would even consider allowing foreign investors and out of state companies to build and take over our beautiful desert landscape and destroy wildlife and precious natural desert landscape.
More to the point, Why? we don't seem to have any advantage to our area, our water table is low, and why should you allow it to be used? We need it!

Nevada has vast desert space, why are you allowing and *picking* on this community? And we all know California has plenty of its own desert space they can use.

Tell them NO, we don't want out deserts destroyed and become a sea of black glass in this valley.

I would like to know whom of the BLM and Solar Companies have allowed these solar farms to be built in their back yards? Speak up please....

PLEASE say no to solar farms here in our Valley, WE DON'T WANT and Don't want the destruction.

I know you have heard from many of us at BLM and the commissioners hearings, including myself.
The people of this area are very passionate about our community and the *intrusive invasion of our quite, peace and enjoyment of this land.* Especially the land owners and families who will basically have the solar farms in their back yards that will be their view for the next 30 plus years,, *Is that what you will have at your home,* think about it please? Please walk in our shoes. WE moved here because of the natural landscape, peace and many of us are from the California area and wanted to get away from the destruction of a once beautiful state.

This is not why we bought our property. We want the open space. WE want to enjoy the desert landscape, wild life roaming horses, turtles, the little creepy crawling of the lizards, horny toads, coyotes, mountain lions, etc. Remember they were all here first, why should they be destroyed. *Was not BLM suppose to protect the desert ????? Then do it please.*

One last note for now. Maybe you can have solar farms put by Area 51, I bet all of those little green ones would love their little hind ends warmed up a bit. just a thought.

Thank you for your time and sincere consideration to Pahrump Valley and the voice of the wonderful people who live here. And I am sure you know our population is mostly retired seniors, our wonderful VETS, generational land owners
who all love this area, and want to continue to do so. HELP US PLEASE.

GOD BLESS America and the community of Pahrump Valley.

thank you.
[redacted]
Mountain Falls

[EXTERNAL] Oppose Large Solar Projects Near Pahrump Residents

[redacted]

Wed 12/15/2021 7:13 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

To BLM:

I oppose any and all large solar projects near Pahrump NV.

I am not against solar energy in general. I am against pu ng very large solar projects in or right next to town. There are thousands of square miles of wide open desert in Nevada far away from towns. The only reason to put projects near town is to make more money for the owners by being closer to exis ng infrastructure. It will hurt, not help, us residents. It will not help us financially, and it will cause lots of problems like dust, reduced property values, and spoiled desert views.

I pay federal taxes which fund your agency. I hope you will respect us residents and not just solar businesses when you make your plans. Please put large solar projects far out of town where they won't bother anyone, or put them on exis ng roofs.

[redacted]
Southern Pahrump Resident

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]

Wed 12/15/2021 8:04 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Attn: Rough Hat Clark County Solar Project Variance

We do not want this solar project as it can / will affect OHV riding areas and trails.

Signed
[redacted]

[EXTERNAL] Attn:Rough hat Clark County solar project variance

[redacted]

Wed 12/15/2021 8:36 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

We do not want this project as it interferes with off road use.
Signed
[redacted]

Sent from my T-Mobile 5G Device

Solar

From: [redacted]

To: blm_nv_snd_energyprojects@blm.gov

Date: Wednesday, December 15, 2021, 01:21 PM PST

To: Whom It May Concern,

I live in the Pahrump So Valley, community of Mountain Falls.
I want to let you know that I am totally opposed to any attempt to allow solar panel and farms in the deserts of this area. Vote NO please.

I am also appalled that you would even consider allowing foreign investors and out of state companies to build and take over our beautiful desert landscape and destroy wildlife and precious natural desert landscape.
More to the point, Why? we don't seem to have any advantage to our area, our water table is low, and why should you allow it to be used? We need it!

Nevada has vast desert space, why are you allowing and *picking* on this community? And we all know California has plenty of its own desert space they can use.

Tell them NO, we don't want out deserts destroyed and become a sea of black glass in this valley.

I would like to know whom of the BLM and Solar Companies have allowed these solar farms to be built in their back yards? Speak up please....

PLEASE say no to solar farms here in our Valley, WE DON'T WANT and Don't want the destruction.

I know you have heard from many of us at BLM and the commissioners hearings, including myself.
The people of this area are very passionate about our community and the *intrusive invasion of our quite, peace and enjoyment of this land*. Especially the land owners and families who will basically have the solar farms in their back yards that will be their view for the next 30 plus years,, *Is that what you will have at your home*, think about it please? Please walk in our shoes. WE moved here because of the natural landscape, peace and many of us are from the California area and wanted to get away from the destruction of a once beautiful state.

This is not why we bought our property. We want the open space. WE want to enjoy the desert landscape, wild life *roaming horses, turtles, the little creepy crawling of the lizards, horny toads, coyotes, mountain lions, etc.*
Remember they were all here first, why should they be destroyed. *Was not BLM suppose to protect the desert ????? Then do it please.*

One last note for now. Maybe you can have solar farms put by Area 51, I bet all of those little green ones would love their little hind ends warmed up a bit. just a thought.

Thank you for your time and sincere consideration to Pahrump Valley and the voice of the wonderful people who live here. And I am sure you know our population is mostly retired seniors, our wonderful VETS, generational land owners
who all love this area, and want to continue to do so. HELP US PLEASE.

GOD BLESS America and the community of Pahrump Valley.

thank you, [redacted]

[EXTERNAL] Solar and Wind Farms near Pahrump, NV

[redacted]

Thu 12/16/2021 9:37 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

To Whom it May Concern,

I am a long time resident of Pahrump, NV. I'm not against solar in general. I just don't like the federal government giving solar businesses a "good deal" by giving them land close to town. This saves the business money because it's closer to existing electrical infrastructure, but it hurts us residents. It will lead to disruption and dust, reduced property values, and spoiled desert views. It will not help us financially either (unless you invest in the company). BLM has thousands of square miles of open desert far away from town where they can place these projects. Our little town does not need or want solar farms going into our county. Please reconsider any and all contracts for nearby solar and wind farms in our area. Thank you.

[redacted]

[EXTERNAL] Pahrump solar projects

[redacted]

Thu 12/16/2021 7:08 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

I am against any solar projects close to Pahrump. BLM lands for these projects should be MILES from any city or town.
Sent from Mail for Windows

RE: Automatic reply: [EXTERNAL] Pahrump solar projects

[redacted]

Thu 12/16/2021 7:56 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Rough Hat project in Pahrump is too close to local proper es and businesses This solar proposal should be denied.

Sent from Mail for Windows

From: BLM_NV_SND_EnergyProjects
Sent: Thursday, December 16, 2021 2:09 PM
To: [redacted]
Subject: Automa c reply: [EXTERNAL] Pahrump solar projects

Thank you for your email. If you are providing public input or a question specific to a project, please provide the name of the project.

This email is monitored, if you are seeking additional information we will get back to you as quickly as possible. Thank you for your interest in public lands.

Energy & Infrastructure Team
Southern Nevada District
Bureau of Land Management

Private Well Owners Association
P.O. Box 2073
Pahrump, NV 89041
Website: www.privatewellowners.com
email: privatewellowners@outlook.com
Facebook: Private Well Owners Association

"Every Drop Counts"

December 16, 2021. Statement by [redacted] for the Private Well Owners Association.

Projects – **There are a total of 6 projects by the applicant that will affect Basin 162. In a combination of Nye and Clark Counties.**

1. Rough Hat – Nye County Solar – **500MW** (Power Technology

2. Rough Hat 2- Clark County Solar Project **400MW.**

3. Copper Rays – Clark County – 5,518 acres(?) – **700MW.**

4. Copper Rays – Nye County – 5,518 acres(?) – **700MW.**

5. Yellow Pine – Clark County –**500 MW** SOLAR PROJECT. Located 10 miles southeast of Pahrump. Study by SWCA Environmental Consultants, June 2016 states "Water Supply to be Determined". Page 23 states 4.1 line 9, "panel washing'. Page 24 4.2 line 5 states that Panel washing "the demand for water to wash the panels is approx. 50,000 gallons per day" – 4 times per year. – 200,000 gallons per year approx. **(YPSP – YELLOW PINE SOLAR PROJECT).**

Water Use 4.3 – "will be approx. 600-acre feet over 18 months period"(see attached).

To clean the PV modules four times per year is estimated to be about 25-acre feet per year, depending on site events and conditions.

"Based on the anticipated uses, the estimated quantity of water needed for operation of the YPSP will be approximately 25 AFY."

6. Sagittarius – Nye & Clark – 4,300 acres, **400 MW** -building right next to the approved Yellow Pine Sola Project all the way to the California Border.

ALL PROJECT DRAW WATER FROM PAHRUMPS BASIN 162 ONLY

Total megawatts all six project that would draw water from Basin 162.

Rough Hat - Nye County - 500 megawatts

Rough Hat 2 - Clark County - 400 megawatts

Copper Rays - Clark County- 700 megawatts

Copper Rays - Nye County - 700 megawatts

Yellow Stone -Clark County- 500 megawatts

Sagittarius - Nye & Clark County-400 megawatts

TOTAL 3,900 megawatts.

ifOTAL WATER USE FOR ALL PROJECTS OVER EACH 18 MONTHS, per project according to the - Yellow Pine Solar Plan of Development by SWCA Environmental Consultants June 16, 2016 "Water Use Page 24 states (see attached) "The total water usage during construction will be approximately 600-acre feet over an 18-month period."

Using figures estimated by the developer 600-acre feet (updated recently to 800-acre feet) times 6 projects would be 4,800-acre feet of water from Basin 162 over the construction of these projects, plus 25-acre feet per year for the life of the project to dean the PV Modules times 6 (150-acre feet) totaling 4,950-acre feet {if started in the same year, a single project would draw 825-acre feet in first year.)

It is estimated in the Pahrump Basin 162 Groundwater Management Plan version February 2018 Figure 3 "Adjustment of over allocation of recharge and over dedication of water rights is at a 6,600-acre feet deficit.

Basin 162 cannot withstand an additional 4,S00 acre feet withdrawal for the development of these 6 projects, and 150-acre feet annually for PV Module cleaning of these same 6 projects' life.

Therefore, the Private Well Owners Association requests that all these projects be denied due to the devastating impact they all would have on our Groundwater Basin '162.

PAHRUMPS ONLY WATER DRINKING SUPPLY (which includes not only private wells, but all utilities.) [redacted]

I request my statement be written into the recor d/ [redacted]

Yellow Pine Solar Plan of Development
Prepared for Yellow Pine Solar, LLC
Prepared by SWCA Environmental Consultants
June 2016

4.3 Water Use and Waste Management

4.3.1 Water Use

The Applicant is exploring options to buy commercial water or purchase or lease existing water rights and construct a new well.

Initial construction water usage will be in support of site preparation and grading activities. During earthwork for the grading of access roads, foundations, equipment pads, and YPSP components, the main use of water will be for compaction and dust control. Smaller quantities will be required for preparation of the concrete required for foundations and other minor uses. Subsequent to the earthwork activities, water usage will be in support of dust suppression and normal construction water requirements that are associated with construction of the building, substation, internal access roads, and solar arrays. The total water usage during construction will be approximately 600 acre feet over an 18-month period.

The PV technology proposed for the YPSP does not require water for the generation of electricity. During operations, water use will be limited primarily to PV array washing with the potential for periodic dust control and maintenance applications. Drinking (potable) water will be supplied for workers on-site, and is estimated to be approximately 300 gallons per month varying seasonally and by work activities.

The amount of water required to clean the PV modules four times per year is estimated to be about 8 million gallons per year, approximately 25 acre feet per year (AFY). Depending on site events and conditions, the cleaning frequency may be less. The water used for module cleaning is not anticipated to require disposal due to the extremely high evaporation rate at the site. Based on the anticipated uses, the estimated quantity of water needed for operation of the YPSP will be approximately 25 AFY. This assumes no generation of wastewater on-site that would require treatment.

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]

Thu 12/16/2021 7:27 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Respected Bureau of Land Management Planners,

I am writing to oppose the Rough Hat Clark County Solar Project. This project constitutes wholesale environmental destruction and is WRONG.

We should all agree that climate change necessitates a change in energy strategy. However, there are better ways to transition away from fossil fuels. Destroying the desert is NOT clean energy. Yes, solar energy is sorely needed, but NOT at the cost of an ecosystem!

We need to put solar on rooftops, in parking lots, and other urban locations where shade is actually desired, not destructive. Additionally, it is much more cost effective to put electricity generation near to where it is used. It is inefficient to transport electricity through wires long distances.

Hundreds of species have, over thousands of years evolved to create special and unique adaptations to live in this harsh environment. Deserts are sensitive ecosystems that take hundreds of years to create!

People unfamiliar with the desert environment assume that it is a wasteland. This is not true at all. The desert is full of life! Just a few of the many special living plant species you might find here are:

Fremont's Phacelia, Phacelia fremontii
Mojave Yucca, Yucca schidigera
Honey Mesquite, Prosopis glandulosa
Desert Globemallow, Sphaeralcea ambigua
Hairy Sand Verbena, Abronia villosa
White Bursage, Ambrosia dumosa
Cotton Top Cactus, Echinocactus polycephalus
Screwbean Mesquite, Prosopis pubescens
Brittlebush, Encelia farinosa
Shadscale, Atriplex canescens
Water Jacket, Lycium andersonii
Spiny Menodora, Menodora spinescens
Baltic Rush, Juncus balticus

Alkali Sacaton, Sporobolus airoides

(These are all plants that have been documented nearby in the same living conditions.)

Please protect this area.

Respectfully submitted,

[redacted]

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]
Thu 12/16/2021 3:12 AM
To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Hello,
We do not want this solar project as it can / will affect OHV riding areas and trails and my happiness.

Thank you,
[redacted]
24 year old Jeep girl who loves the outdoors and nature and being in it.

[EXTERNAL] solar farm

[redacted]
Thu 12/16/2021 4:24 PM
To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

I have been a resident of Pahrump Nevada since 1999. I am against the projected solar farm to be placed in the area of Pahrump on BLM land. While it seems like a good idea to build a huge farm in this area it isn't.

It would require the destruction of thousands of acres of desert to place it here.With no benefit to the residents of Pahrump. If California is in such a need for this facility then let them build it in California. We are having a lot of air quality issues with blowing sand now in our area.without destroying more landscape. Between the destruction of the desert we are having shortages of our water supply. Where is the water going to come from to maintain the large facility?

I am asking that this project is not approved due to it not being in our best interest.

[redacted]

[EXTERNAL] Rough Hat Solar Project, Pahrump,NV

[redacted]

Fri 12/17/2021 8:57 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

To Whom it Concerns
I am writing to express my disagreement with respect to the project to install a solar farm on 5000 acres too near to Pahrump, NV. This endeavor should not continue near Pahrump. There are thousands of NV acres that can accommodate this type of construction and disruption.
The land around Pahrump is used by many of us for hiking, camping, horseback riding and more. This project will disturb the fragile nature of desert soil, allow for dust from wind storms and be a blight on this well travelled portion of the desert.
Please relocate your solar project to a more remote piece of Nevada!
Sincerely,

[redacted]

[EXTERNAL] Attn: Rough Hat Clark County Solar Project Variance

[redacted]

Fri 12/17/2021 4:50 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

We do not want this solar project as it can / will affect OHV riding areas and trails.
Signed
[redacted]

Sent from my iPhone

[EXTERNAL] Pahrump solar project

[redacted]

Sun 12/19/2021 10:43 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

We are strongly opposed to a huge solar project in Pahrump NV. We already have rapidly decreasing water resources and a harmful dust pollution problem, not to mention excessive heat which a project like this will only add to. This proposed project will harm wildlife and our quality of life here. There is plenty of desert away from town for such things, please do NOT CHOOSE PAHRUMP!

[redacted]

[EXTERNAL] Solar projects in Nevada

[redacted]

Sun 12/19/2021 1:47 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Cc: rephorsford@mail8.housecommunications.gov <rephorsford@mail8.housecommunications.gov>; Senator Catherine Cortez Masto <Senator@cortezmasto.senate.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

I know we need solar projects & ASAP — we should have been doing them for 50 years already so now we're desperate to meet our increasing energy needs & reduce our dependence on fossil fuels. But can't we be smart, thoughtful, careful, & not barge ahead without considering impacts on human/animal/plant lives, on communities, on our environment? Can't we involve the communities & the people who live there in plans?

When there is so much land in NV that is not in or near towns — why ruin the beauty & health of places where people are living — where people have built their homes & lives, invested in their community? Instead, couldn't these facilities be placed away from communities?

NIMBY - is there a reason to install a huge solar farm right in & next to our town? Any town?

For me, it isn't just a matter of not wanting the solar project to destroy the beauty & health of my neighborhood, but also why aren't environmental & ecological concerns taken into account & accommodations made for healthy soil, natural habitats of plants & animals, remedies/prevention for stirring up dust/worsening blowing dust (creating health hazard)?

Why do our state's lands need to be destroyed for another state's needs?

I'm sure the circumstances are much more complex than what appears at the surface of this situation.

But why aren't these concerns addressed before moving ahead?

I'm retired & decided to move to Nevada 2 years ago because of the beauty & peacefulness of the desert. I am learning about the desert ecology here — the 600 year old Joshua trees, habitats of tortoises, etc. Now I find that these things are about to be destroyed. It is disheartening & disappointing.

I want to be proud of my state. I want my state & its residents to thrive. I want us all to reduce our carbon footprint. I try to do my part by driving less, eating "slower" (more local/less meat), recycling, growing plants & some of our own food, trying to live consciously & kindly. But that is not enough — we all need to work together if we are to prolong life on this planet for future generations.

Destroying ecological habitats seems counter to that goal.

I realize that not enough is being done to reduce our dependency on fossil fuels. But running roughshod is not the way to get everyone on board, it is not doing the right thing or the best thing. Can't we do better?

[EXTERNAL] Please STOP big solar projects close to towns like Pahrump

[redacted]

Sun 12/19/2021 2:51 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

To whom it may concern with The BLM:

Please cease considerations on allowing development of large scale solar projects on public lands near Pahrump, NV and ANYWHERE near towns and cities in Nevada.

There are massive immediate and unintended negative consequences in approving solar fields/farms, etc.

The thought of Rough Hat Nye, Copper Rays, and others progressing makes my stomach turn. It sickens almost every single resident I speak to about it.

Thank you,

[redacted]

[redacted]

[EXTERNAL] Rough Hat Clark County Solar Project Scoping Comments

Ed Larue <ed.larue@verizon.net>

Mon 12/20/2021 2:35 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Dear BLM,

Please find attached formal scoping comments on the above-referenced project.

Regards, and Happy Holidays,

Ed LaRue
Desert Tortoise Council
Ecosystems Advisory Committee

DESERT TORTOISE COUNCIL
4654 East Avenue S #257B
Palmdale, California 93552
www.deserttortoise.org
eac@deserttortoise.org

Via email only

20 December 2021

Attn: Rough Hat Clark County Solar Project Variance
Bureau of Land Management, Southern Nevada District Office
4701 N. Torrey Pines Drive
Las Vegas, NV 89130
BLM_NV_SND_EnergyProjects@blm.gov

RE: Rough Hat Clark County Solar Project Scoping Comments

Dear Bureau of Land Management,

The Desert Tortoise Council (Council) is a non-profit organization comprised of hundreds of professionals and laypersons who share a common concern for wild desert tortoises and a commitment to advancing the public's understanding of desert tortoise species. Established in 1975 to promote conservation of tortoises in the deserts of the southwestern United States and Mexico, the Council routinely provides information and other forms of assistance to individuals, organizations, and regulatory agencies on matters potentially affecting desert tortoises within their geographic ranges.

We appreciate this opportunity to provide comments on the above-referenced project. Given the location of the proposed project in habitats likely occupied by Mojave desert tortoise (*Gopherus agassizii*) (synonymous with Agassiz's desert tortoise), our comments pertain to enhancing protection of this species during activities authorized by the Bureau of Land Management (BLM), which we assume will be added to the Decision Record as needed. Please accept, carefully review, and include in the relevant project file the Council's following comments and attachments for the proposed project.

The purpose of scoping is to allow the public to participate in an "early and open process for determining the scope of issues to be addressed, and for identifying the significant issues related to a proposed action" (40 Code of Federal Regulations (CFR) 1501.7). The Draft Environmental Impact Statement (DEIS) should discuss how this proposed project fits within the management structure of the current land management plan for the area, which is the Las Vegas Resource Management Plan (BLM 1998). It should provide maps of critical habitat for the Mojave desert tortoise (USFWS 1994a), Areas of Critical Environmental Concern (ACECs), and other areas identified as necessary for special management by BLM [e.g., National Conservation Lands (NCLs)]; U.S. Fish and Wildlife Service (USFWS) (e.g., linkage habitats between desert tortoise populations); Nevada Department of Wildlife (NDOW); other federal, state, and local agencies; and tribal lands.

Project Description

Candela Renewables, LLC (proponent) has applied to the BLM Las Vegas Field Office for a right-of way grant to provide the necessary land and access for the construction and operation of a proposed solar facility and interconnection to the regional transmission system. Candela Renewables is proposing the construction, operation, and eventual decommissioning of the Rough Hat Clark County Solar Project (proposed project), a photovoltaic solar power project including a battery storage facility on BLM-managed public land designated as a solar variance area in Clark County. Rough Hat Clark County Solar Project includes up to a 400 MW alternating current (AC) solar photovoltaic power generating facility with energy storage on approximately 2,400 acres of BLM-managed public land located in the Pahrump Valley in Clark County immediately adjacent to the county line, southeast of the Town of Pahrump and approximately 38 miles west of Las Vegas. The collected electricity would be delivered to a proposed onsite substation, where it would then be transferred to the BLM-approved Trout Canyon Substation via a new 230 kV generation gen-tie transmission line.

Proposed Action and Alternatives Considered

The BLM is considering the construction and operation and maintenance of this utility solar-scale facility outside the solar energy zones (SEZs) that it identified and approved in an earlier environmental review process under the National Environmental Policy Act (NEPA) (BLM and DOE 2012). As such we insist that BLM comply with all applicable regulations, Executive Orders, and federal statutes. BLM should demonstrate in the DEIS that the proposed project meets all these requirements and the following variance factors with respect to the tortoise: We require documentation:

- that the proposed project will be in conformance with decisions in current land use plan(s) and the Federal Land Policy and Management Act with respect to sustainable yield;
- that the proposed project will be consistent with priority conservation, restoration, and/or adaptation objectives in the best available landscape-scale information (e.g., for tortoise population connectivity, etc.);
- that the applicant has coordinated with governments, including consideration of consistency with officially adopted plans and policies (e.g., recovery plans);

- that the proposed project is in an area with low or comparatively low resource conflicts and where conflicts can be resolved;
- that the proposed project will be located in, or adjacent to, previously contaminated or disturbed lands;
- that the proposed project will minimize adverse impacts on important fish and wildlife habitats and migration/movement corridors;
- that the proposed project will minimize impacts on lands with wilderness characteristics and the values associated with these lands;
- that the proposed project will not adversely affect lands donated or acquired for conservation purposes, or mitigation lands identified in previously approved projects such as translocation areas for desert tortoise;
- that significant cumulative impacts on resources of concern should not occur as a result of the proposed project (i.e., exceedance of an established threshold such population viability for the tortoise and connectivity of tortoise populations among recovery units); and,
- that BLM's analysis of its desert tortoise variance process (i.e., https://blmsolar.anl.gov/variance/process/factors/desert-tortoise/) to determine whether the data available and used in 2012 currently apply to the tortoise, as population numbers and densities have substantially declined in this recovery unit and the data/knowledge currently available on habitat linkages for the tortoise is greater than in 2012.

We have serious concerns about BLM's desert tortoise variance process:

- Any necessary mitigation will improve conditions within the connectivity area, and if these options do not exist, necessary mitigation will be applied toward the nearest tortoise conservation area (e.g., an ACEC for which tortoise had been identified in the Relevant and Important Criteria or critical habitat); and
- A plan is in place to effectively monitor desert tortoise impacts, including verification that desert tortoise connectivity corridors are functional. The required Federal Endangered Species Act (FESA) consultation will further define this monitoring plan.

Regarding the first bulleted action, we are not sure who determines what mitigation is "necessary." Mitigation should as a minimum offset all direct, indirect, and cumulative impacts, especially given the status and trend of the tortoise (please see *Affected Environment - Status of the Populations of the Mojave Desert Tortoise* below). BLM should ensure it is implementing its section 7(a)(1) mandate under the FESA. Mitigation should be applied only in areas where the lands are effectively managed for the benefit of the tortoise for both the short-term and long-term. As currently managed, a BLM ACEC in Nevada or the adjacent California Desert Conservation Area does not meet this criterion. Consequently, mitigation should be implements on lands where the landowner places a conservation easement or other legal designation and effectively enforces this management designation. Please see *Mitigation Plans* below for additional concerns and requested requirements.

Regarding the second bulleted action, a monitoring plan should (1) be scientifically and statistically credible, (2) be implementable, and (3) require BLM/project proponent to implement adaptive management to correct land management practices if the mitigation is not accomplishing its intended purposes. Please comply with chapter 11 of the BLM National Environmental Policy Act Handbook H-1790-1 BLM (2008a).

We note that a federal appellate court has previously ruled that in an EIS a federal agency must evaluate a reasonable range of alternatives to the project including other sites, and must give adequate consideration to the public's needs and objectives in balancing ecological protection with the purpose of the proposed project, along with adequately addressing the proposed project's impacts on the desert's sensitive ecological system [*National Parks & Conservation Association v. Bureau of Land Management*, Ninth Cir. Dkt Nos. 05-56814 et seq. (11/10/09)]. Therefore, the Council requests that the BLM describe the purpose and need for this project and develop and analyze other viable alternatives, such as rooftop solar, which we believe constitute "other reasonable courses of actions" (40 CFR 1508.25).

The Council supports alternatives to reduce the need for additional solar energy projects in relatively undisturbed habitats in the Mojave Desert. For example, the City of Los Angeles has implemented a rooftop solar Feed-in Tariff (FiT) program, the largest of its kind in America. The FiT program enables the owners of large buildings to install solar panels on their roofs, and sell the power they generate back to utilities for distribution into the power grid.

We request that BLM include an urban solar alternative. The owners of large buildings or parking areas would grant the project proponent permission to install solar panels on their roofs and cover parking areas, and sell the power they generate back to utilities for distribution into the power grid. This approach puts the generation of electricity where the demand is greatest, in populated areas. It may also reduce transmission costs, greenhouse gas emissions from constructing energy projects far from the sources of power demand and materials for construction, the number of affected resources in the desert that must be analyzed under the NEPA, and mitigation costs for direct, indirect, and cumulative impacts; monitoring and adaptive management costs; and habitat restoration costs following decommissioning. The DEIS should include an analysis of where the energy generated by this project would be sent and the needs for energy in those targeted areas that may be satisfied by urban solar. We request that at least one viable alternative be analyzed in the DEIS where electricity generation via solar energy is located much closer to the areas where the energy will be used, including generation in urban/suburban areas.

In addition, BLM should include another viable alternative of locating solar projects on bladed or highly degraded tracts of land (e.g., abandoned agricultural fields). Such an alternative would not result in the destruction of desert habitats and mitigation for the lost functions and values of these habitats. These losses and mitigation are costly from an economic, environmental, and social perspective.

The DEIS should consider the monitoring results of recently developed solar projects where soils have been bladed versus those facilities where the vegetation has been mowed or crushed and allowed to revegetate the area. In the latter case, it may be appropriate to allow tortoises to enter the facilities and re-establish residency (i.e., repatriate) under the solar panels as vegetation recolonizes the area. This could be an *option* for the currently described project alternative. It should be designed/implemented as a scientific experiment to add to the limited data on this approach to determine the extent of effects on Mojave desert tortoise populations and movements/connectivity between populations, which is an important issue for this species (Please see *Desert Tortoise Habitat Linkages/Connectivity among Populations and Recovery Units* below).

Connected Actions

Pursuant to Section 1508.25 of the Council on Environmental Quality's (CEQ) regulations (40 CFR 1508.25), any DEIS must cover the entire scope of a proposed action, considering all connected, cumulative, and similar actions in one document. Pursuant to Section 1506.1(a) of these regulations, an agency action cannot "[l]imit the choice of reasonable alternatives" before reaching a final decision in a published [Record of Decision] (ROD). These regulations ensure agencies will prepare a complete environmental analysis that provides a "hard look" at the environmental consequences of all proposed actions instead of segmenting environmental reviews (Novack 2015). Please explain whether any current proposed actions within the region are connected and if not, why.

Affected Environment

Status of the Population of the Mojave Desert Tortoise: The Council provides the following information for the proponent so that these or similar data may be included in the DEIS. There are 17 populations of Mojave desert tortoise described below that occur in Critical Habitat Units (CHUs) and Tortoise Conservation Areas (TCAs); 14 are on lands managed by the BLM; 8 of these are in the California Desert Conservation Area (CDCA). Note that the proposed project is located in the Eastern Mojave Recovery Unit for the tortoise.

Table 1. Summary of 10-year trend data for 5 Recovery Units and 17 CHUs/TCAs for Mojave desert tortoise. The table includes the area of each Recovery Unit and CHU/TCA, percent of total habitat for each Recovery Unit and CHU/TCA, density (number of breeding adults/km^2 and standard errors = SE), and the percent change in population density between 2004 and 2014. Populations below the viable level of 3.9 breeding individuals/km^2 (10 breeding individuals per mi^2) (assumes a 1:1 sex ratio) and showing a decline from 2004 to 2014 are in red.

Recovery Unit: Designated Critical Habitat Unit/Tortoise Conservation Area	**Surveyed area (km^2)**	**% of total habitat area in Recovery Unit & CHU/TCA**	**2014 density/km^2 (SE)**	**% 10-year change (2004–2014)**
Western Mojave, CA	**6,294**	**24.51**	**2.8 (1.0)**	**–50.7 decline**
Fremont-Kramer	2,347	9.14	2.6 (1.0)	–50.6 decline
Ord-Rodman	852	3.32	3.6 (1.4)	–56.5 decline
Superior-Cronese	3,094	12.05	2.4 (0.9)	–61.5 decline
Colorado Desert, CA	**11,663**	**45.42**	**4.0 (1.4)**	**–36.25 decline**
Chocolate Mtn AGR, CA	713	2.78	7.2 (2.8)	–29.77 decline
Chuckwalla, CA	2,818	10.97	3.3 (1.3)	–37.43 decline
Chemehuevi, CA	3,763	14.65	2.8 (1.1)	–64.70 decline
Fenner, CA	1,782	6.94	4.8 (1.9)	–52.86 decline
Joshua Tree, CA	1,152	4.49	3.7 (1.5)	+178.62 increase
Pinto Mtn, CA	508	1.98	2.4 (1.0)	–60.30 decline
Piute Valley, NV	927	3.61	5.3 (2.1)	+162.36 increase
Northeastern Mojave	**4,160**	**16.2**	**4.5 (1.9)**	**+325.62 increase**
Beaver Dam Slope, NV, UT, AZ	750	2.92	6.2 (2.4)	+370.33 increase
Coyote Spring, NV	960	3.74	4.0 (1.6)	+ 265.06 increase
Gold Butte, NV & AZ	1,607	6.26	2.7 (1.0)	+ 384.37 increase
Mormon Mesa, NV	844	3.29	6.4 (2.5)	+ 217.80 increase
Eastern Mojave, NV & CA	**3,446**	**13.42**	**1.9 (0.7)**	**–67.26 decline**

El Dorado Valley, NV	999	3.89	1.5 (0.6)	–61.14 decline
Ivanpah Valley, CA	2,447	9.53	2.3 (0.9)	–56.05 decline
Upper Virgin River	**115**	**0.45**	**15.3 (6.0)**	**–26.57 decline**
Red Cliffs Desert	115	0.45	15.3 (6.0)	–26.57 decline
Range-wide Area of CHUs - TCAs/Range-wide Change in Population Status	**25,678**	**100.00**		**–32.18 decline**

Table 2. Estimated change in abundance of adult Mojave desert tortoises in each recovery unit between 2004 and 2014 (Allison and McLuckie 2018). Decreases in abundance are in red.

Recovery Unit	Modeled Habitat (km^2)	2004 Abundance	2014 Abundance	Change in Abundance	Percent Change in Abundance
Western Mojave	23,139	131,540	64,871	-66,668	-51%
Colorado Desert	18,024	103,675	66,097	-37,578	-36%
Northeastern Mojave	10,664	12,610	46,701	34,091	270%
Eastern Mojave	16,061	75,342	24,664	-50,679	-67%
Upper Virgin River	613	13,226	10,010	-3,216	-24%
Total	**68,501**	**336,393**	**212,343**	**-124,050**	**-37%**

Important points from these tables include the following:

Change in Status for the Mojave Desert Tortoise Range-wide

● Ten of 17 populations of the Mojave desert tortoise declined from 2004 to 2014.

● Eleven of 17 populations of the Mojave desert tortoise are no longer viable. These 11 populations represent 89.7 percent of the range-wide habitat in CHUs/TCAs.

Change is Status for the Eastern Mojave Recovery Unit – Nevada and California

● This recovery unit had a 67 percent decline in tortoise density from 2004 to 2014, the largest decline of the five recovery units for the tortoise.

● Tortoises in this recovery unit have densities that are below viability.

Change in Status for the El Dorado Valley and Ivanpah Valley Tortoise Populations in the Eastern Mojave Recovery Unit.

● Both populations in this recovery unit experienced declines in densities of 61 percent and 56 percent, respectively from 2004 to 2014. In addition, there was a 67 percent decline in tortoise abundance.

● Both populations have densities less than needed for population viability.

Change in Status for the Mojave Desert Tortoise in California

● Eight of 10 populations of the Mojave desert tortoise in California declined from 29 to 64 percent from 2004 to 2014 with implementation of tortoise conservation measures in the Northern and Eastern Colorado Desert (NECO), Northern and Eastern Mojave Desert (NEMO), and Western Mojave Desert (WEMO) Plans.

● Eight of 10 populations of the Mojave desert tortoise in California are no longer viable. These eight populations represent 87.45 percent of the habitat in California that is in CHU/TCAs.

● The two viable populations of the Mojave desert tortoise in California are declining. If their rates of decline from 2004 to 2014 continue, these two populations will no longer be viable in about 2020 and 2031.

Change in Status for the Mojave Desert Tortoise on BLM Land in California
● Eight of eight populations of Mojave desert tortoise on lands managed by the BLM in California declined from 2004 to 2014.

● Seven of eight populations of Mojave desert tortoise on lands managed by the BLM in California are no longer viable.

Change in Status for Mojave Desert Tortoise Populations in California that Are Moving toward Meeting Recovery Criteria
● The only population of Mojave desert tortoise in California that is not declining is on land managed by the National Park Service, which has increased 178 percent in 10 years.

The Endangered Mojave Desert Tortoise: The Council believes that the Mojave desert tortoise meets the definition of an endangered species. In the FESA, Congress defined an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range…" Because most of the populations of the Mojave desert tortoise were non-viable in 2014, most are declining, and the threats to the Mojave desert tortoise are numerous and have not been substantially reduced throughout the species' range, the Council believes the Mojave desert tortoise should be designated as an endangered species by the USFWS.

Mojave desert tortoise is now on the list of the world's most endangered tortoises and freshwater turtles. It is in the top 50 species. The International Union for Conservation of Nature's (IUCN) Species Survival Commission, Tortoise and Freshwater Turtle Specialist Group, now considers Mojave desert tortoise to be Critically Endangered (Berry *et al. 2021*). "species that possess an extremely high risk of extinction as a result of rapid population declines of 80 to more than 90 percent over the previous 10 years (or three generations), a current population size of fewer than 50 individuals, or other factors." It is one of three turtle and tortoise species in the United States to be critically endangered.

The summary of data above indicates that BLM's current management actions for the Mojave desert tortoise are inadequate to help recover the desert tortoise. BLM has been ineffective in halting population declines, which has resulted in non-viable populations. The Council believes that these management actions are inadequate in preventing the extirpation of the Mojave desert tortoise in California and Nevada.

Standardized Surveys – Desert Tortoise and Other Species

For the DEIS to fully analyze the effects and identify potentially significant impacts, the following surveys must be performed to determine the extent of rare plant and animal populations occurring within areas to be directly and indirectly impacted.

Prior to conducting surveys, a knowledgeable biologist should perform a records search of the Nevada Natural Heritage Program (NNHP) (http://heritage.nv.gov/get_data) for rare plant and animal species reported from the region. The results of the NNHP review would be reported in the DEIS with an indication of suitable and occupied habitats for all rare species reported from the region based on performing the species-specific surveys described below.

The project proponent should fund focused surveys for all rare plant and animal species reported from the vicinity of the proposed project. Results of the surveys will determine appropriate permits from BLM, NDOW, and USFWS and associated avoidance, minimization, and mitigation measures. Focused plant an animal surveys should be conducted by knowledgeable biologists for respective taxa (e.g., rare plant surveys should be performed by botanists), and to assess the likelihood of occurrence for each rare species or resource (e.g., plant community) that has been reported from the immediate region. Focused plant surveys should occur only if there has been sufficient winter rainfall to promote germination of annual plants in the spring. Alternatively, the environmental documents may assess the likelihood of occurrence with a commitment by the proponents to perform subsequent focused plant surveys prior to ground disturbance, assuming conditions are favorable for germination.

Special Status Plants: There are likely to be special status plant species found in/near the project area. This information should be assessed by accessing the NNHP literature review prior to conducting field surveys. Species or their habitats known to occur in/near the project area should be sought during field surveys and their presence/absence discussed in the DEIS. Surveys should be completed at the appropriate time of year by qualified botanists using the latest acceptable methodologies. In addition, Nevada Administrative Code (NAC) 527 provides a list of species and subspecies of native plants to be critically endangered and threatened with extinction. These fully protected species may not be removed or destroyed except pursuant to a permit issued by the State Forester (NAC 527.090). The methods used to survey for special status plant species, the results, and the mitigation/monitoring/adaptive management that will be implemented to avoid or otherwise mitigate adverse effects to these species and their habitats should be included in the DEIS.

Migratory Birds/Eagles: BLM should ensure that all actions it authorizes are implemented in compliance with the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, and associated regulations, executive orders, and policies (e.g., Driscoll 2010, Pagel et al. 2010) to avoid mortality or injury to migratory birds and harassment of eagles.

Burrowing owl: Because of their use of burrows for shelter and breeding, surveys for western burrowing owl (*Athene cunicularia*) should be performed (CDFG 2012). In addition to the project footprint., the protocol requires that peripheral transects be surveyed at 30-, 60-, 90-, 120-, and 150-meter intervals in all suitable habitats adjacent to the subject property to determine the potential indirect impacts of the project on this species. If burrowing owl sign is found, appropriate minimization and mitigation measures need to be implemented. Also note that BLM should demonstrate in the DEIS how it will comply with "E.O. 13186 – Responsibilities of Federal Agencies To Protect Migratory Birds," since the burrowing owl is on the USFWS list of migratory birds. If burrowing owl sign is found, BLM and the project proponent should develop a science-based mitigation/monitoring/adaptive management plan with the USFWS and NDOW and ensure that this plan is implemented.

Mojave Desert Tortoise Surveys: Formal protocol surveys for Mojave desert tortoise (USFWS 2019) must be conducted at the proper times of year. Because USFWS (2009) requires only experienced biologists to perform protocol surveys, USFWS biologists should review surveyors' credentials prior to initiating the surveys. Per this protocol, if the impact area is larger than 500 acres, the surveys must be performed in the time periods of April-May or September-October so that a statistical estimate of tortoise densities can be determined for the "action area" (please see below). If any tortoise sign is found, the project proponent should coordinate with USFWS to determine whether "take" under FESA is likely to occur from implementation of the proposed project. If tortoises are present, the project proponent must obtain a biological opinion from the USFWS prior to conducting any ground disturbance.

We request that protocol-level surveys be performed at the area of the proposed project *and the alternatives that are being considered* in the DEIS. The results of these surveys should be published in the DEIS and should include density estimates for each alternative assessed.

To determine the full extent of impacts to tortoises and to facilitate compliance with the FESA, authorized biologist(s) must consult with the USFWS to determine the action area for this project. The USFWS defines "action area" the Code of Federal Regulations and their Desert Tortoise Field Manual (USFWS 2009) as "all areas to be affected directly or indirectly by proposed development and not merely the immediate area involved in the action (50 CFR §402.02)."

The Council's persisting concern is that proponents of solar projects continue to identify a single site for development without any attempt to identify alternative sites. As such, when focused studies reveal significant accumulations of tortoises on the proponent's selected site, because there is only one site identified for the project, there is no opportunity to select an alternative site where impacts would be minimized.

Too often, a single impact footprint is identified, all surveys are restricted to that site, and no alternative sites are assessed, as required by NEPA. We are concerned that this project may have already pre-determined the project footprint. As such, there may be other areas of lower tortoise densities where impacts could be minimized. However, those areas would not be considered if the project footprint is predetermined before survey data are available. As such, we request that more than one site, preferably three, be identified and analyzed in the DEIS and that the alternative with the fewest impacts to tortoises be adopted for development.

If that is not feasible, we ask that the "action area" of the proposed project be several times larger than the project footprint so that those portions of the site with fewer tortoises could be selected. Proponents of the Gemini Solar Site in southern Nevada, for example, ignored these recommendations, and displaced more than 100 tortoises, when based on their presence-absence tortoise surveys, a shift of the site to the east would have avoided many of those animals.

It is current management to require desert tortoise protocol surveys (USFWS 2019) on a given site, but all too often translocation sites are ignored. We feel strongly that protocol surveys should occur on multiple or enlarged sites as given above *and* in all proposed translocation sites, assuming tortoises will be displaced.

Mojave Desert Tortoise Impacts Analysis:

Analysis of Direct and Indirect Impacts: The alternatives analysis should include an economic analysis that provides the total cost of constructing the proposed project versus other alternatives, so the public can see how much the total cost of each alternative is. This would include an analysis of the costs of replacing all public resources that would be lost from granting the proposed project including direct, indirect, and cumulative impacts. Please note, this analysis would include replacement or creation costs including the time needed to achieve full replacement, not just acquisition, management, monitoring, and adaptive management costs.

The DEIS should include a thorough analysis of the status and trend of the tortoise in the action area, tortoise conservation area(s), recovery unit(s), and range wide. Tied to this analysis should be a discussion of all likely sources of mortality for the tortoise and degradation and loss of habitat from implementation of solar development including construction, operation and maintenance, decommissioning, and restoration of the public lands. The DEIS should use the data from focused plant and wildlife surveys in their analysis of the direct, indirect, and cumulative impacts of the proposed project on the Mojave desert tortoise and its habitat, other listed species, and species of concern/special status species.

We expect that the DEIS will document how many acres would be impacted directly by solar arrays, access roads to the site, administration/maintenance buildings, parking areas, transmission towers, switchyards, laydown areas, internal access roads, access roads along gen-tie lines, a perimeter road, perimeter fencing, substations (e.g., the project footprint). We also request that separate calculations document how many acres of desert tortoise habitats would be temporarily and permanently impacted both directly and indirectly (e.g., "road effect zone," etc.) by the proposed project. As given below, these acreages should be based on field surveys for tortoises not just available models.

Road Effect Zone: We request that the DEIS include information on the locations, sizes, and arrangements of roads to the proposed project and within it, who will have access to them, whether the access roads will be secured to prevent human access or vandalism, and if so, what methods would be used. The presence/use of roads even with low vehicle use has numerous adverse effects on the desert tortoise and its habitats that have been reported in the scientific literature. These include the deterioration/loss of wildlife habitat, hydrology, geomorphology, and air quality; increased competition and predation (including by humans); and the loss of naturalness or pristine qualities.

Vehicle use on new roads and increased vehicle use on existing roads equates to increased direct mortality and an increased road effect zone for desert tortoises. Road construction, use, and maintenance adversely affect wildlife through numerous mechanisms that can include mortality from vehicle collisions, and loss, fragmentation, and alteration of habitat (Nafus et al. 2013; von Seckendorff Hoff and Marlow 2002).

In von Seckendorff Hoff and Marlow (2002), they reported reductions in Mojave desert tortoise numbers and sign from infrequent use of roadways to major highways with heavy use. There was a linear relationship between traffic level and reduction. For two graded, unpaved roads, the reduction in tortoises and sign was evident 1.1 to 1.4 km (3,620 to 4,608 feet) from the road. Nafus et al. (2013) reported that roads may decrease tortoise populations via several possible mechanisms, including cumulative mortality from vehicle collisions and reduced population growth rates from the loss of larger reproductive animals. Other documented impacts from road construction, use, and maintenance include increases in roadkill of wildlife species as well as tortoises, creating or increasing food subsidies for common ravens, and contributing to increases in raven numbers and predation pressure on the desert tortoise.

Please include in the DEIS analyses, the five major categories of primary road effects to the tortoise and special status species: (1) wildlife mortality from collisions with vehicles; (2) hindrance/barrier to animal movements thereby reducing access to resources and mates; (3) degradation of habitat quality; (4) habitat loss caused by disturbance effects in the wider environment and from the physical occupation of land by the road; and (5) subdividing animal populations into smaller and more vulnerable fractions (Jaeger et al. 2005a, 2005b, Roedenbeck et al. 2007). These analyses should be at the population, recovery unit, and rangewide levels.

In summary, road establishment/increased use is often followed by various indirect impacts such as increased human access causing disturbance of species' behavior, increased predation, spread of invasive species that alters/degrades habitat, and vandalism and/or collection. The analysis of the impacts from road establishment and use should include cumulative effects to the tortoise with respect to nearby critical habitat and other Tortoise Conservation Areas (TCAs) , areas identified as important linkage habitat for connectivity between nearby critical habitat units/TCAs as these linkage areas serve as corridors for maintaining genetic and demographic connectivity between populations, recovery units, and rangewide (Please see *Desert Tortoise Habitat Linkages/Connectivity among Populations and Recovery Units* below). These and other indirect impacts to the Mojave desert tortoise should be analyzed in the DEIS from project construction, operations and maintenance, decommissioning, and habitat restoration.

Desert Tortoise Habitat Linkages/Connectivity among Populations and Recovery Units: The DEIS should analyze how this proposed project will impact the movement of tortoises relative to linkage habitats/corridors. The DEIS should include an analysis of the minimum linkage design necessary for conservation and recovery of the desert tortoise (e.g., USFWS 2011, Averill-Murray et al. 2013, Hromada et al. 2020), and how the project, along with other existing projects, would impact the linkages between tortoise populations and all recovery units that are needed for survival and recovery. We strongly request that the environmental consequences section of the DEIS include a thorough analysis of this indirect effect (40 Code of Federal Regulations 1502.16) and appropriate mitigation to maintain the function of population connectivity for the Mojave desert tortoise and other wildlife species be identified. Similarly, please document how this project may impact proximate conservation areas, such as BLM-designated ACECs.

Mitigation Plans

The DEIS should include effective mitigation for all direct, indirect, and cumulative effects to the tortoise and its habitats. The mitigation should use the best available science with a commitment to implement the mitigation commensurate to impacts to the tortoise and its habitats. Mitigation should include a fully-developed desert tortoise translocation plan (including protection of tortoise translocation area(s) from future development and human disturbance in perpetuity; raven management plan; nonnative plant species management plan; fire prevention plan; compensation plan for the degradation and loss of tortoise habitat that includes protection of the acquired, improved, and restored habitat in perpetuity for the tortoise from future development and human use; and habitat restoration plan when the lease is terminated and the proposed project is decommissioned.

All plans should be provided in the DEIS so the public and the decisionmaker can determine their adequacy (i.e., whether they are scientifically rigorous and would be effective in mitigating for the displacement and loss of tortoises and degradation and loss of tortoise habitat from project implementation). Too often, such plans are alluded to in the draft environmental document and promised at a later date, which does not allow the reviewers to assess their adequacy, which is unacceptable. If not available as appendices in draft documents, all indicated plans must be published in the final environmental documents. Their inclusion is necessary to determine their adequacy for mitigating direct, indirect, and cumulative impacts, and monitoring for effectiveness and adaptive management regarding the desert tortoise. If these plans are not provided, it is not possible for BLM to determine the environmental consequences of the project to the tortoise.

These mitigation plans should include an implementation schedule that is tied to key actions of the construction, operation, maintenance, decommissioning, and restoration phases of the project so that mitigation occurs concurrently with or in advance of the impacts. The plans should specify success criteria, include an effectiveness monitoring plan to collect data to determine whether success criteria have been met, and identify/implement actions that would be required if the mitigation measures do not meet the success criteria.

<u>BLM Manual 6840</u>: Special Status Species Management includes the following BLM directives (BLM 2008b) that are applicable to the Mojave desert tortoise:

6840.01 Purpose. The purpose of this manual is to provide policy and guidance for the conservation of BLM special status species and the ecosystems upon which they depend on BLM-administered lands. BLM special status species are: (1) species listed or proposed for listing under the FESA, and (2) species requiring special management consideration to promote their conservation and reduce the likelihood and need for future listing under the FESA, which are designated as BLM sensitive by the State Director(s).

6840.02 Objectives. The objectives of the BLM special status species policy are: A. To conserve and/or recover FESA-listed species and the ecosystems on which they depend so that FESA protections are no longer needed for these species. B. To initiate proactive conservation measures that reduce or eliminate threats to Bureau sensitive species to minimize the likelihood of and need for listing of these species under the FESA.

With respect to the Mojave desert tortoise, we request that the proposed action or other alternative contribute to meeting objectives in BLM Manual 6840 – Special Status Species Management (BLM 2008b).

Translocation Plan - Translocated Tortoises & Translocation Sites: How many tortoises will be displaced by the proposed project? How long will translocated tortoises be monitored? Will the monitoring report show how many of those tortoises lived and died after translocation? Are there any degraded habitats or barren areas that may impair success of the translocation? Are there incompatible human uses in the new translocation area that need to be eliminated or managed to protect newly-translocated tortoises? Were those translocation areas sufficiently isolated that displaced tortoises were protected by existing or enhanced land management? How will the proponent minimize predation of translocated tortoises and avoid adverse climatic conditions, such as low winter rainfall conditions, that may exacerbate translocation success? Were tortoises translocated to a site where they would be protected from threats (e.g., off-highway vehicles, future development, etc.)? These questions should be answered in the Environmental Consequences section of the DEIS.

The project proponent should implement the USFWS' Translocation Guidance (USFWS 2020) and coordinate translocation with BLM and NDOW. In addition, the proponent's project-specific translocation plan should be based on current data and developed using lessons learned from earlier translocation efforts (e.g., increased predation, drought). (Please see *Desert Tortoise Translocation Bibliography Of Peer-Reviewed Publications*[1] in the footnote).

The Translocation Plan should include implementation of a science-based monitoring plan approved by the Desert Tortoise Recovery Office that will accurately access these and other issues to minimize losses of translocated tortoises and impacts to their habitat. For example, the health of tortoises may be jeopardized if they are displaced during drought conditions, which is known to undermine translocation successes (Esque et al. 2010). If drought conditions are present at the time of project development, we request that the proponent confer with the USFWS immediately prior to displacing tortoises and seek input on ways to avoid loss of tortoises due to stressors associated with drought. One viable alternative if such adverse conditions exist is to postpone site development until which time conditions are favorable to enhance translocation success.

Moving tortoises from harm's way, the focus of the Translocation Guidance, does not guarantee their survival and persistence at the translocation site, especially if it will be subject to increased human use or development. In addition to the Translocation Guidance and because translocation sites are mitigation for the displacement of tortoises and loss of habitat, these sites should be managed for the benefit of the tortoise in perpetuity. Consequently, a conservation easement or other legal designation should be placed on the translocation sites. The project proponent should fully fund management of the site to enhance it for the benefit of the tortoise.

Tortoise Predators and a Predator Management Plan: Common ravens are known predators of the Mojave desert tortoise and their numbers have increased substantially because of human subsidies of food, water, and sites for nesting, roosting, and perching to hunt (Boarman 2003). Coyotes and badgers are also predators of tortoises. Because ravens can fly at least 30 miles in search of food and water daily (Boarman et al. 2006) and coyotes can travel an average of 7.5 miles or more daily (Servin et al. 2003), this analysis should extend out at least 30 miles from the proposed project site.

[1] https://www.fws.gov/nevada/desert_tortoise/documents/reports/2017/peer-reviewed_translocation_bibliography.pdf

The DEIS should analyze if this new use would result in an increase in common ravens and other predators of the desert tortoise in the action area. During construction, operations and maintenance, decommissioning, and restoration phases of the proposed project, the BLM should require science-based management of common raven, coyote, and badger predation on tortoises in the action area. This would include the translocation sites.

For local impacts, the Predator Management Plan should include reducing/eliminating human subsidies of food and water, and for the common raven, sites for nesting, roosting, and perching to address local impacts (footprint of the proposed project). This includes buildings, fences, and other vertical structures associated with the project site. In addition, the Predator Management Plan should include provisions that eliminate the pooling of water on the ground or on roofs.

The Predator Management Plan should include science-based monitoring and adaptive management throughout all phases of the project to collect data on the effectiveness of the Plan's implementation and implement changes to reduce/eliminate predation on the tortoise if existing measures are not effective.

For regional and cumulative impacts, the BLM should require the project proponent to participate in efforts to address regional and cumulative impacts. For example, in California, the project proponent should contribute to the National Fish and Wildlife Foundation's Raven Management Fund to help mitigation for regional and cumulative impacts. Unfortunately, this Fund that was established in 2010 has not revised its per acre payment fees to reflect increased labor and supply costs during the past decade to provide for effective implementation. The National Fish and Wildlife Foundation should revise the per acre fee.

We request that for any of the transmission options, the project use towers that prevent raven nesting and perching for hunting. For example, the tubular design pole with a steep-pointed apex and insulators on down-sloping cross arms is preferable to lattice towers, which should not be used.

<u>Fire Prevention/Management Plans</u>: The proposed project would include storage of power in lithium-ion batteries at the project site. These batteries have the potential to explode and cause fires and are not compatible with using water for fighting fires. We request that the DEIS include a Fire Prevention Plan in addition to a Fire Management Plan specifically targeting methods to deal with explosions/fires produced by these batteries as well as other sources of fuel and explosives on the project site.

<u>Habitat Compensation Plan</u>: The DEIS should include a Habitat Compensation Plan for the loss/degradation of habitat. This plan should calculate how it will fully mitigate for the impacts of the Proposed project including direct, indirect, cumulative, and temporal impacts. The DEIS should include an analysis of all proposed mitigation and how its implementation (including monitoring for effectiveness and adaptive management) would result in no net loss in quantity and quality of desert tortoise habitat and using offsite mitigation (compensation) for unavoidable residual habitat loss. We request that BLM include this analysis in its NEPA document.

Climate Change and Nonnative Plants

Climate Change: We request that the DEIS address the effects of the proposed action on climate change warming and the effects that climate change may have on the proposed action. For the latter, we recommend including: an analysis of habitats within the project area that may provide refugia for tortoise populations; an analysis of how the proposed action would contribute to the spread and proliferation of nonnative invasive plant species; how this spread/proliferation would affect the desert tortoise and its habitats (including the frequency and size of human-caused fires); and how the proposed action may affect the likelihood of human-caused fires. We strongly urge the proponent to develop and implement a management and monitoring plan using this analysis and other relevant data that would reduce the transport to and spread of nonnative seeds and other plant propagules within the project area and eliminate/reduce the likelihood of human-caused fires. The plan should integrate vegetation management with fire prevention and fire response.

Impacts from Proliferation of Nonnative Plant Species and Management Plan: The DEIS should include an analysis of how the proposed project would contribute to the spread and proliferation of nonnative invasive plant species; how this spread/proliferation would affect the desert tortoise and its habitats (including the frequency and size of human-caused fires); and how the proposed project may affect the frequency, intensity , and size of human-caused and naturally occurring fires. We strongly urge the BLM require the project proponent to develop and implement a management and monitoring plan using this analysis and other relevant data that would reduce the transport to and spread of nonnative seeds and other plant propagules within the project area and eliminate/reduce the likelihood of human-caused fires. The plan should integrate management/enhancement of native vegetation with fire prevention and fire response to wildfires.

Hydrology and Water Quality

Regarding water quality of surface and ground water, the DEIS should include an analysis of the impacts of water use and discharge for panel washing, potable uses, and any other uses associate with this proposed project, and cumulative impacts from water use and discharge on native perennial shrubs and annual vegetation used for forage by the Mojave desert tortoise, including downstream impacts.

Regarding quantity of surface water, the DEIS should analyze how any grading, placement, and/or use of any project facilities will impact downstream/downslope flows that are reduced, altered, eliminated, or enhanced. This analysis should include impacts to native and nonnative vegetation and habitats for wildlife species including the Mojave desert tortoise. Washes are of particular importance to the Mojave desert tortoise for feeding, shelter, and movements.

Therefore, we request that the DEIS include an analysis of how water use during construction, operations and maintenance, decommissioning, and habitat restoration will impact the levels of ground water in the region. These levels may then impact surface and near-surface flows at springs, seeps, wetlands, and pools in the basin. The analyses of water quality and quantity of surface and ground water should include appropriate measures to ensure that these impacts are fully mitigated, preferably beginning with avoidance and continuing through CEQ's other forms of mitigation (40 CFR 1508.20).

Federal Land Policy and Management and Federal Endangered Species Act

Federal Land Policy and Management Act (FLPMA): In 1976, Congress passed the FLPMA "to provide for the immediate and future protection and administration of the public lands in the California desert within the framework of a program of multiple uses and sustained yield, and the maintenance of environmental quality." Congress further declared "the desert environment is a total ecosystem that is extremely fragile, easily scarred, and slowly healed; the use of all desert resources [including rare and endangered species of wildlife, plants, and fishes] can and should be provided for in a multiple use and sustained yield management plan to conserve these resources for future generations…"

Congress wrote a lengthy definition of "multiple use" for the management of public lands and their various resource values. The definition included "… the use of some land for less than all of the resources; a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and non-renewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific and historical values; and harmonious and coordinated management of the various resources without permanent impairment of the productivity of the land and the quality of the environment with consideration being given to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output."

Congress defined "sustained yield" as the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the public lands consistent with multiple use. The Mojave desert tortoise and its habitats are renewable resources.

The definition of "environmental quality" is a set of properties and characteristics of the environment, either generalized or local, as they impinge on human beings and other organisms. It is a measure of the condition of an environment relative to the requirements of one or more species and or to any human need or purpose. Thus, BLM must consider the quality or condition of the environment of the Mojave desert tortoise with respect to the species' requirements for persistence and must maintain this habitat quality.

The Council believes that BLM's management of the Mojave desert tortoise and its habitats in Nevada is not in compliance with FLPMA. The large number of non-viable populations and downward trend in population densities for the Mojave desert tortoise are the data that confirm non-compliance with the "immediate and future protection of public lands," "conserving resources for future generations," and definitions of multiple use, sustained yield, and environmental quality.

Section 7(a)(1) of the Endangered Species Act: Section 7(a)(1) of the Endangered Species Act states that all federal agencies "…shall… utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to Section 4 of this Act." In Section 3 of the FESA, "conserve," "conserving," and "conservation" mean "to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition…"

The Council believes that the data given herein demonstrate that BLM's management of the Mojave desert tortoise and its habitat has not been effective in meeting BLM's Section 7(a)(1) mandate of carrying out programs for its conservation. To meet its Section 7(a)(1) responsibilities, the BLM needs to adopt and implement the management actions of the one population of the Mojave desert tortoise in California that is increasing, which is managed by the National Park Service (NPS). The NPS' land management practices are closer to managing areas of land as reserves, which is what the 1994 Recovery Plan (USFWS 1994b) described as part of the recovery strategy for the Mojave desert tortoise. While BLM designated Desert Wildlife Management Areas (DWMAs) as one part of the recovery strategy, it did not implement the other parts of the recovery strategy. According to the Recovery Plan, DWMAs were to be managed as reserves; that is, they were areas of land to keep, save, preserve, or protect tortoises and their habitats. BLM did not identify and implement needed recovery actions within each DWMA to manage the DWMAs as protected areas for the Mojave desert tortoise.

When analyzing and implementing aspects of the project, we request that BLM demonstrate how it is contributing effectively to the conservation and recovery of the Mojave desert tortoise in southern Nevada. We request that BLM show how mitigation for the project will do more than offset all direct, indirect, and cumulative impacts so that the status of the Mojave desert tortoise as described herein will improve. By providing this information, BLM would demonstrate its compliance with section 7(a)(1) of the FESA for the Mojave desert tortoise.

Cumulative Effects

With regards to cumulative effects, the DEIS should list and analyze all project impacts within the region including future state, federal, and private actions affecting listed species on state, federal, and private lands. The Council asks that the relationship between this proposed project and all other regional projects be analyzed. We also expect that the environmental documents will provide a detailed analysis of the "heat sink" effects of solar development on adjacent desert areas and particularly Mojave desert tortoise in addition to climate change.

In the cumulative effects analysis of the DEIS, please ensure that the CEQs "Considering Cumulative Effects under the National Environmental Policy Act" (1997) is followed, including the eight principles, when analyzing cumulative effects of the proposed action to the tortoise and its habitats. CEQ states, "Determining the cumulative environmental consequences of an action requires delineating the cause-and-effect relationships between the multiple actions and the resources, ecosystems, and human communities of concern. The range of actions that must be considered includes not only the project proposal but all connected and similar actions that could contribute to cumulative effects." The analysis "must describe the response of the resource to this environmental change." Cumulative impact analysis should "address the sustainability of resources, ecosystems, and human communities." For example, the DEIS should include data on the estimated number of acres of tortoise habitats degraded/lost and the numbers of tortoises that may be lost to growth-inducing impacts in the region.

CEQs guidance on how to analyze cumulative environmental consequences, which contains eight principles listed below:

1. Cumulative effects are caused by the aggregate of past, present, and reasonable future actions.
The effects of a proposed action on a given resource, ecosystem, and human community, include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to the effects (past, present, and future) caused by all other actions that affect the same resource.

2. Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (federal, non-federal, or private) has taken the actions.
Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effect at one time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.

3. Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected.
Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resources, ecosystem, and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.

4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.
For cumulative effects analysis to help the decision maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to the affected parties.

5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries.
Resources are typically demarcated according to agency responsibilities, county lines, grazing allotments, or other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects analysis on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.

6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects.
Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.

7. Cumulative effects may last for many years beyond the life of the action that caused the effects.

Some actions cause damage lasting far longer than the life of the action itself (e.g., acid mine damage, radioactive waste contamination, species extinctions). Cumulative effects analysis need to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.

8. Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters. Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.

We request that the DEIS (1) include these eight principles in its analysis of cumulative impacts to the Mojave desert tortoise; (2) address the sustainability of the tortoise given the information on the *Status of the Mojave Desert* given herein; and (3) include mitigation along with monitoring and adaptive management plans that protect desert tortoises and their habitats during both construction and operation of approved facilities.

We appreciate this opportunity to provide scoping comments on this project and trust that our comments will help protect tortoises during any resulting authorized activities. Herein, we reiterate that the Desert Tortoise Council wants to be identified as an Affected Interest for this and all other projects funded, authorized, or carried out by the BLM that may affect species of desert tortoises, and that any subsequent environmental documentation for this project is provided to us at the contact information listed above. Additionally, we ask that you respond in an email that you have received this comment letter so we can be sure our concerns have been registered with the appropriate personnel and office for this project.

Respectfully,

Edward L. LaRue, Jr., M.S.
Desert Tortoise Council, Ecosystems Advisory Committee, Chairperson

Literature Cited

Allison L.J. and McLuckie, A.M. 2018. Population trends in Mojave desert tortoises (*Gopherus agassizii*). Herpetological Conservation and Biology. 2018 Aug 1;13(2):433-52.

Averill-Murray, R.C., C.R. Darst, N. Strout, and M. Wong. 2013. Conserving population linkages for the Mojave desert tortoise (*Gopherus agassizii*). Herpetological Conservation and Biology 8(1):1–15.

Berry, K.H., L.J. Allison, A.M. McLuckie, M. Vaughn, and R.W. Murphy. 2021. *Gopherus agassizii*. The IUCN Red List of Threatened Species 2021: e.T97246272A3150871. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T97246272A3150871.en

[BLM] U.S. Bureau of Land Management. 1998. Record of Decision for the Approved Las Vegas Resource Management Plan and Final Environmental Impact Statement. BLM/LV/PL-99/002+1610. Las Vegas Field Office, October 1998.

[BLM] U.S. Bureau of Land Management. 2008a. National Environmental Policy Act Handbook H-1790-1. Washington, D.C. January 2008.

[BLM] U.S. Bureau of Land Management. 2008b. Manual 6840 – Special Status Species Management. Washington, D.C. December 12, 2008.

[BLM and DOE] U.S. Bureau of Land Management and Department of Energy. 2012. Final programmatic environmental impact statement for solar energy development in six southwestern states (Arizona, California, Colorado, Nevada, New Mexico, and Utah) (FES 12-24; DOE/EIS-0403).

Boarman, W.I, M.A. Patten, R.J. Camp, and S.J. Collis. 2006. Ecology of a population of subsidized predators: Common ravens in the central Mojave Desert, California. Journal of Arid Environments 67 (2006) 248–261.

[CDFG] California Department of Fish and Game. 2012. Staff report on burrowing owl mitigation. [The 7 March 2012 memo replaces the 1995 staff report and includes the Burrowing owl survey protocol], State of California Natural Resources Agency, Department of Fish and Game. Sacramento, CA. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83843&inline

[CEQ] Council on Environmental Quality. 1997. Considering Cumulative Effects under the National Environmental Policy Act.

Driscoll, D.E. 2010. Protocol for golden eagle occupancy, reproduction, and prey population assessment. American Eagle Research Institute, Apache Jct., AZ. 55pp. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83955&inline

Esque, T.C., K.E. Nussear, K.K. Drake, A.D. Walde, K.H. Berry, R.C. Averill-Murray, A.P. Woodman, W.I. Boarman, P.A. Medica. J. Mack, and J.H. Heaton. 2010. Effects of subsidized predators, resource variability, and human population density on desert tortoise populations in the Mojave Desert, U.S.A. Endangered Species Research, Vol. 12-167-177, 2010, doi: 10.3354/esr00298.

Hromada, S. J., T.C. Esque, A.G. Vandergast, K.E. Dutcher, C.I. Mitchell, M.E. Gray, T. Chang, B.G. Dickson, and K.E. Nussear. 2020. Using movement to inform conservation corridor design for Mojave desert tortoise. Movement Ecology 8, 38 (2020). https://movementecologyjournal.biomedcentral.com/track/pdf/10.1186/s40462-020-00224-8.pdf

Jaeger, J., L. Fahrig, and K. Ewald. 2005a. Does the configuration of road networks influence the degree to which roads affect wildlife populations? International Conference on Ecology and Transportation 2005 Proceedings, Chapter 5 - Integrating Transportation and Resource Conservation Planning - Landscapes and Road Networks, pages 151-163. August 29, 2005.

Jaeger, J., J. Bowman, J. Brennan, L. Fahrig, D. Bert, J. Bouchard, N. Charbonneau, K. Frank, B. Gruber, and K. Tluk von Toschanowitz. 2005b. Predicting when animal populations are at risk from roads: an interactive model of road avoidance behavior. Ecological Modelling 185 (2005) 329–348.

Nafus, M.G., T.D. Tuberville, K. A. Buhlmann, and B.D. Todd. 2013. Relative abundance and demographic structure of Agassiz's desert tortoise (*Gopherus agassizii*) along roads of varying size and traffic volume. Biological Conservation 162 (2013) 100–106.

Novack, E. 2015. Segmentation of Environmental Review: Why Defenders of Wildlife v. U.S. Navy threatens the effectiveness of NEPA and the FESA, 42 B.C. Envtl. Aff. L. Rev. 243 (2015). http://lawdigitalcommons.bc.edu/ealr/vol42/iss1/9.]

Pagel, J.E., D.M. Whittington, and G.T. Allen. 2010. Interim Golden Eagle inventory and monitoring protocols; and other recommendations. Division of Migratory Bird Management, U.S. Fish and Wildlife Service. https://www.fws.gov/southwest/es/oklahoma/documents/te_species/wind%20power/usfws_interim_goea_monitoring_protocol_10march2010.pdf]

Roedenbeck, I., L. Fahrig, C. Findlay, J. Houlahan, J. Jaeger, N. Klar, S. Kramer-Schadt, and E. van der Grift. 2007. The Rauischholzhausen Agenda for Road Ecology. Ecology and Society 12(1): 11. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art11/]

Servin, J., V. Sanchez-Cordero, and S. Gallina. 2003. Distances traveled daily by coyotes, C*anis latrans*, in a pine–oak forest in Durango, Mexico. Journal of Mammalogy 84(2):547–552.

[USFWS] U.S. Fish and Wildlife Service. 1994a. Determination of critical habitat for the Mojave population of the desert tortoise. 59 *Federal Register* 5820-5866.]

[USFWS] U.S. Fish and Wildlife Service. 1994b. Desert Tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, OR. Pp. 73, plus appendices.

[USFWS] U.S. Fish and Wildlife Service. 2009. Desert Tortoise (Mojave Population) Field Manual: (*Gopherus agassizii*). Region 8, Sacramento, California.

[USFWS] U.S. Fish and Wildlife Service. 2014. Status of the desert tortoise and critical habitat. Unpublished report available on the Desert Tortoise Recovery Office's website: "02/10/2014 Status of the Desert Tortoise and Critical Habitat (.704MB PDF)." Reno, NV.

[USFWS] U.S. Fish and Wildlife Service. 2019. Preparing for any action that may occur within the range of the Mojave desert tortoise (*Gopherus agassizii*). USFWS Desert Tortoise Recovery Office. Dated 21 August 2017. Reno, NV.]

[USFWS] U.S. Fish and Wildlife Service. 2020. Translocation of Mojave Desert Tortoises from Project Sites: Plan Development Guidance. U.S. Fish and Wildlife Service, Las Vegas, Nevada. https://www.fws.gov/nevada/desert_tortoise/documents/reports/2020/RevisedUSFWSDTTranslocationGuidance20200603.pdf.]

[USFWS] U.S. Fish and Wildlife Service. 2010. Common raven predation on the desert tortoise. USFWS, Ventura Fish and Wildlife Office, Ventura, CA.

von Seckendorff Hoff, K., and Marlow, R.W. 2002. Impacts of vehicle road traffic on desert tortoise populations with consideration of conservation of tortoise habitat in southern Nevada. Chelonian Conservation and Biology 4:449–456.

[EXTERNAL] Comment for Rough Hat and Copper Rays solor projects

[redacted]

Mon 12/20/2021 9:22 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>; [redacted]

To whom it many concern,

I am adamantly opposed to the proposed projects in the Pahrump Valley.
They will specifically impact my livelihood as an off-road motorcycle school and tour company and I feel they will significantly impact the community as a whole in ways that are being overlooked.
This "green" or "renewable" energy push is a shortsighted approach to a bigger problem. These measures of large scale solar facilities are just result of political promises and trying to make everyone feel good with a quick fix that will cause long lasting and irreversible damage to the land and the people who currently use and enjoy it. If solar was the answer and not just a get rich quick scheme for the developer it would be on all of the roofs in the adjacent community and being placed on private property before we go and close off and destroy open spaces in the desert.
I was advised to remove routes in the areas of these projects during my permit applications 2012-2014. I was told that there were cultural and biological concerns that would make it impossible for me to obtain a commercial recreation permit. I'm not sure what has changed and why I was not informed that these areas were now open for use?

The Yellow Pine project sure slid in under the radar and I hope that these additional projects are considered before we put another Black Eye on the process for public concerns. I'm sure the current rush is to get these projects rolling before the public outrage for the Yellow Pine project happens when the panels start to go up. There are a number of trails that are blocked and we will never get those back nor were mitigation concerns made showing a lack of research or on the ground knowledge from the BLM specifically.

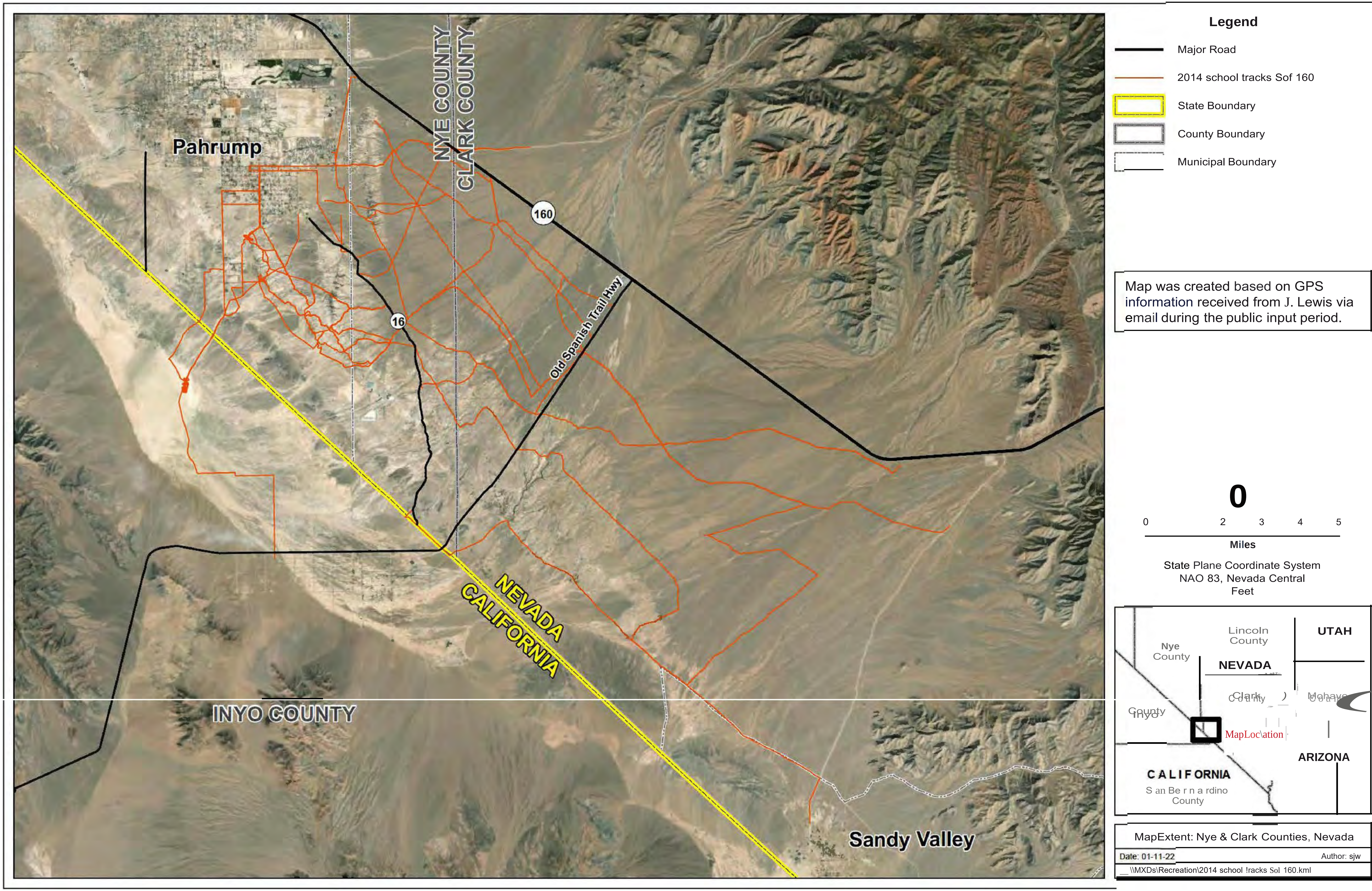
I have attached a set of track logs of trails in the area I'm familiar with. These were, when originally recorded, motorcycle single track but additional use may have changed some of them to wider UTV trails. I did most of this recording in the early 2000s and had to convert the logs into current programs to update the files. Most of these were submitted to the BLM in the past when previous recreation planners asked about trails in the area as well. Contact Mark Sanchez or Chris Leinehan for more information about this or to confirm this. There has never been a proper route inventory completed or a travel management plan in place for the area so I feel this information is being swept under the carpet and not being looked at.

OHV recreation and specifically looping and tour routes are being significantly reduced, segmented and cut off from the solar projects. This along with the impacts to the visual quality of the experience. Then we have the conflict of the dust and how quickly the solar companies like to blame OHV recreation for underperforming panels and increased costs to clean and maintain the panels. This in an area with horrible soils for this and an ever increasing concern about water supplies.
It is obvious that the companies coming in do not care about the communities they are near. They come in and lie to citizens and county commissioners, ramrod the project in and sell the project to get away from any liability for the mess they create.
Do not make the mistake of allowing destruction of open space in an area where people moved and live here in this valley specifically to avoid being near projects like this. If we "pave" the desert black with panels it will not solve any problems short or long term, but we will be stuck with a long term mess.

Please listen to us when we say "on our roof, not in our backyard."

Attached .gpx file and KML.

[redacted]
--


Pahrump
NYE COUNTY
CLARK COUNTY
160
16
Old Spanish Trail Hwy
NEVADA
CALIFORNIA
INYO COUNTY
Sandy Valley
Legend
Major Road
2014 school tracks Sof 160
State Boundary
County Boundary
Municipal Boundary
Map was created based on GPS information received from J. Lewis via email during the public input period.
0
0 2 3 4 5
Miles
State Plane Coordinate System
NAO 83, Nevada Central
Feet
Lincoln County
UTAH
Nye County
NEVADA
Clark County
Mohave
Inyo County
MapLoc\ation
ARIZONA
CALIFORNIA
San Bernardino County
MapExtent: Nye & Clark Counties, Nevada
Date: 01-11-22
Author: sjw
\\MXDs\Recreation\2014 school !racks Sol 160.kml

[EXTERNAL] Please use the Variance Process to reject the application for the Rough Hat Clark County Solar Project.

[redacted]
Mon 12/20/2021 4:35 AM
To BLM NV SND EnergyProject <BLM NV SND EnergyProject @blm gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Dear BLM Officials,

Please reject the application for the Rough Hat Clark County Solar Project. Yes we need more development of renewable energy. But this can be done in parking lots and roof tops in urban areas, not out in the pristine desert habitat, home to many sensitive plants, including the Mohave yucca, many cacti, Joshua trees and animals including the desert tortoise, kit fox, burrowing owl and more. The project site also contains soil crusts and desert pavement that is about 100,000 years old. Destruction of the desert surface will result in uncontrollable fugitive dust.

The project site contains old biological soil crusts and desert pavement that is about 100,000 years old. Removal of the desert surface will result in uncontrollable fugi ve dust. Located near the Old Spanish Historical Trail, the project also will impact historical resources.

In sum, this project has significant ecological impact, par cularly on the desert tortoise. This project's status as "low impact," should be reconsidered, and the review of this project cancelled based on new informa on on the ecological impacts.

Please preserve the Mojave Desert habitat.

Sincerely,
[redacted]

[EXTERNAL] Rough Hat Clark County Solar Project Variance

nv4wda@charter.net <nv4wda@charter.net>
Tue 12/21/2021 10:49 PM
To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Nevada Four Wheel Drive Associa on
65 Jasper Lane
Dayton, NV 89403
Phone 775-246-3212
Web www.N4WDA.org
Email nv4wda@charter.net

Dear Sirs,

A ached is comment le er from the Nevada Four Wheel Drive Associa on concerning the Rough Hat Clark County Project Variance.

Thank you,

Lawrence Calkins

Nevada Four Wheel Drive Association
65 Jasper Lane
Dayton, NV 89403
775-246-3212

www.n4wda.org

BLM Southern District Office
Attn: Rough Hat Clark County Solar Project Variance
4701 North Torrey Pines Drive
Las Vegas, NV 89130

December 22, 2021

Dear Sirs,

The Nevada Four Wheel Drive Association (N4WDA) is a statewide 501(c)7 non-profit organization consisting of volunteers dedicated to the sport of four wheel drive off highway vehicle recreation and the principle of multiple use management of US Forest Service, Bureau of Land Management and other public lands. We monitor the activities of these public agencies within Nevada and other areas where our membership recreates using Jeeps, trucks, ATVs and Side-by-Sides to determine whether proposed land use issues may result in a loss of access to Nevada's public lands.

Our members have become concerned about the proliferation of proposed solar and wind turbine electrical power generation projects. The twenty-six project applications currently under assessment by the BLM South District Office suggest that there is a "land rush" mentality for developers of green power. We are concerned that an overabundance of these projects will result in massive withdrawals of public lands therefore greatly affecting public access.

We have reviewed the available documents and we attended the December 8, 2021, virtual forum concerning the Rough Hat Clark County Solar Project Variance.

BLM and the US Department of Energy has studied, developed and issued the Final Programmatic Environment Impact Statement for Solar Energy Development (PEIS) which identifies public lands suitable for utility-scale solar energy development. This project is located on public lands that were NOT included in this PEIS consequently necessitating a "variance". We feel that the withdrawal of public lands at this location and prioritizing this project as "High Priority" is unwarranted and the variance should be denied by BLM.

The following are N4WDA's preliminary comments on this project:

- This project is located approximately 1-1/2 miles southeast of the City of Pahrump. It fronts Nevada highway 160, where expansion of the City of Pahrump would naturally occur. People buy property and move to Pahrump for many reasons including climate, scenery, access to public lands for hiking, equestrian and OHV opportunity. We think it ill-advised to locate this project at this location. We must assume that the developer's first consideration for this location is cost which would override any consideration for the residents of Pahrump.

- There is no quantification of the heat generated by this project and just how much heat , considering other nearby proposed solar projects, would be released into the atmosphere and theoretically affecting the climate in the Pahrump Valley.

- The Rough Hat Solar project and other pending solar and/or wind power projects will have a tremendous effect on the viewshed for nearby residents and travelers along Nevada highway 160. The parcel has been determined to be Visual Resource Management Class III, which is a low visual resource rating. After attending the aforementioned virtual forum it is apparent that the respondents disagree with this rating which raises the question of who is the person or persons that assign VRMs? Are local citizens and other area users included in this determination?

- Paragraph 5.1.8 of the Plan of Development addresses air quality concerns. It addresses only air quality issues during the construction phase of the project but does not address these issues during operation of this solar generation plant. The photovoltaic panels and mirrors, if needed, must be kept dust-free for efficient operation. We fear the probability that "buffer zones" may be necessitated around the perimeter of the solar plant to keep dust that may, among other sources, be caused by nearby OHV operation resulting in an additional loss of access to our public lands.

- Paragraph 5.1.9 of the above-mentioned document addresses recreation. Two sentences are inadequate to describe the impact of this project on hiking, equestrian, OHV and other recreation that occurs on this parcel that is located so near to Pahrump. As for OHV recreation there are numerous trails and dry washes within the parcel boundary. It is often forgotten by land management agencies that OHV recreation is a valid use under multiple use management and that it has an economic impact on nearby businesses.

- We also have concern that the power generated by this plant is intended by the applicant to be transmitted out-of-state, particularly to California. California has suitable areas for solar power generation that would be located closer to the end customers. NEVADA IS NOT A WASTELAND to be exploited by entities that are trying to save money because energy development in California is more costly. Additionally, the project applicant, Candella Renewables, LLC is securing foreign financing through a partnership with Naturdy Energy Group S.A. which is located in Spain. We beleive that any project that involves withdrawal of public lands, affecting public access, through approval by BLM or other public land managers <u>should benefit only American interests.</u>

In conclusion, we would like to BLM to add N4WDA to Southern Nevada District mailing lists for the following items:

- All solar and wind energy development projects within the district
- The Harris Springs Recreation Area
- Logandale Travel Management
- Tiehm Buckwheat Endangered Species
- Calico Basin Area

Thank you for the opportunity to voice our concerns and we intend to participate in the NEPA process,

Lawrence Calkins

Lawrence H. Calkins

President, Nevada Four Wheel Drive Association

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]

Tue 12/21/2021 1:41 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Huge solar energy projects negatively impact public land including extensive areas of private and public land around them. What's proposed east of Pahrump will concentrate multi-thousand acre projects into a ten thousand plus acres mega project taking public use of public land. That taking will degrade the quality of life of nearby communities and visitors who come to enjoy public land.

Urban centers can have solar power without degrading rural quality of life by limiting project size and dispersing projects by setting ratios of open space to development. Planners should look at cumulative effects. The proposed multiple projects footprint takes too much public land too close to Pahrump. Nearby Amargosa Junction is facing the same situation.

Keep public land public and open to the public.

At your service

Respectfully,

[redacted]

[EXTERNAL] Comments on the Rough Hat Clark County Solar Project Variance Process

K. Emmerich <atomicquailranch@gmail.com>

Wed 12/22/2021 10:19 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>; Pay, Nicholas B <npay@blm.gov>; Ransel, Beth E <bransel@blm.gov>

Hello,

Please accept these comments on the Rough Hat Clark County Variance Process from Basin and Range Watch and Western Watersheds Project.. Putting a few emails here just in case

Thanks and have a good holiday season,

Kevin Emmerich
Basin and Range Watch.
775-764-1080

Basin and Range Watch

Western Watersheds Project

December 22th, 2021

To: BLM_NV_SND_EnergyProjects@blm.gov, npay@blm.gov

To: Nicholas Pay
Pahrump Field Office
Bureau of Land Management

Re: Comments on the Rough Hat Clark County Solar Project Variance Application

Please accept these comments about our concerns over moving the problematic Rough Hat Clark Solar Project forward, by Basin and Range Watch and Western Watersheds Project.

Basin and Range Watch is a 501(c)(3) non-profit working to conserve the deserts of Nevada and California and to educate the public about the diversity of life, culture, and history of the ecosystems and wild lands of the desert. Federal and many state agencies are seeking to open up millions of acres of unspoiled habitat and public land in our region to energy development. Our goal is to identify the problems of energy sprawl and find solutions that will preserve our natural ecosystems, open spaces, and quality of life for local communities. We support energy efficiency, better rooftop solar policy, and distributed generation/storage alternatives, as well as local, state and national planning for wise energy and land use following the principles of conservation biology.

The mission of Western Watersheds Project (WWP) is to protect and restore western watersheds and wildlife through education, public policy initiatives, and legal advocacy.

We have visited the site of the Rough Hat Clark County Solar Project.

Variance Process

The BLM's Solar Energy Program allows utility-scale solar energy development in variance areas outside of Solar Designated Lease Areas. The BLM will consider ROW applications for utility-scale solar energy development in variance areas on a case-by-case basis based on environmental considerations; coordination with appropriate Federal, State, and local agencies and tribes; and public outreach.

The BLM is required to consider the following factors, as appropriate, when evaluating ROW applications in variance areas:[1] We have provided responses to each factor.

1. *The availability of lands in an SEZ that could meet the applicant's needs, including access to transmission.*

At this point, there are 4 unutilized solar energy zones in Nevada with about 57,000 acres to review as alternatives.

2. *Documentation that the proposed project will be in conformance with decisions in current land use plan(s) (e.g., Visual Resource Management class designations and seasonal restrictions) or, if necessary, represents an acceptable proposal for a land use plan amendment.*

The area is designated as a Visual Resource Management Class III, the same as the recently approved Gemini Solar Project. The objective of VRM Class III is to *"partially retain the existing character of the landscape. Allowed Level of Change: The level of change to the characteristic landscape should be moderate. Management activities may attract attention, but should not dominate the view of the casual observer."* The BLM had to amend their Las Vegas Resource Management Plan to approve the Gemini Solar Project because it was not in compliance with VRM Class III management objectives and the visual impacts could not be mitigated. Through the plan amendment, the entire view-scale in the Gemini Solar region was downgraded to VRM Class IV where activities are permitted to dominate the view.

3. *Documentation that the proposed project will be consistent with priority conservation, restoration, and/or adaptation objectives in the best available landscape-scale information (e.g., landscape conservation cooperatives, rapid ecological assessments, and State and regional-level crucial habitat assessment tools [CHATs]).*[2]

One of CHAT's goals is to focus on providing the most credible data source on crucial wildlife habitats and important migration/movement areas across the western North American landscape. The Rough Hat Clark County Solar Project is located in a region that the Fish and

---

[1] Factors To Be Considered [BLM Solar Energy Program Variance Process] (anl.gov)
[2] Crucial Habitat Assessment Tool – WAFWA

Wildlife Service identified as a Least Cost Corridor with a 90 percent contiguous high value habitat and good connectivity potential.

4. *Documentation that the proposed project is in an area with low or comparatively low resource conflicts and where conflicts can be resolved (as demonstrated through many of the factors that follow).*

The project will be 3.75 square miles or 2,400 acres. The site contains desert pavements that are 100,000 years old, hundreds of rare Parish club cholla, about 70,000 Mojave yuccas (most which will be destroyed), potential Gila monster, Joshua trees, and a significant view-shed near the Old Spanish National Historic Trial. Damage to these resources cannot be mitigated.

5. *Documentation that the proposed project will optimize the use of existing roads.*

The majority of the 2,400-acre site is roadless. Many new roads will need to be built for construction and maintenance.

6. *Documentation that the proposed project will optimize the capacity of existing and new transmission infrastructure, and avoid duplication in the use of or need for existing and new transmission and transmission interconnection facilities.*

New gen-tie lines would need to be built south to the Trout Canyon Substation.

7. *If applicable, documentation that the proposed project will be located in an area identified as suitable for solar energy development in an applicable BLM land use plan*

The BLM cancelled their revision of the Southern Nevada Resource Management Plan in 2018. The area has not been officially identified as a Designated Lease Area or "suitable for solar energy" in the existing Las Vegas Resource Management Plan.

8. *If applicable, documentation that the proposed project will be located in, or adjacent to, previously contaminated or disturbed lands such as brownfields identified by the U.S. Environmental Protection Agency's (EPA's) RE-Powering America's Land Initiative or State, local, and/or tribal authorities; mechanically altered lands such as mine-scarred lands and fallowed agricultural lands; idle or underutilized industrial areas; lands adjacent to urbanized areas and/or load centers; or areas repeatedly burned and invaded by fire-promoting non-native grasses where the probability of restoration is determined to be limited. Preference will be given to proposed projects that are located in, or adjacent to, previously contaminated or disturbed lands under the variance process, assuming all other factors are adequately considered.*

The project site is located on pristine, undisturbed Mojave Desert habitat with old growth Mojave yuccas and ancient desert pavement.

^Undeveloped project site in Pahrump Valley, NV.

9. *Documentation that the proposed project will minimize adverse impacts on access and recreational opportunities on public lands (including hunting, fishing, and other fish- and wildlife-related activities).*

Any roads though the site will be closed, and all public access will be cut off by barbed wire fencing on the 2,400 acres.

10. *Documentation that the proposed project will minimize adverse impacts on important fish and wildlife habitats and migration/movement corridors (e.g., utilizing the Western Wildlife CHAT, administered by the Western Association of Fish and Wildlife Agencies and coordinating with State fish and wildlife agencies).*

The Rough Hat Clark County Solar Project is located in a region that the Fish and Wildlife Service identified as a Least Cost Corridor for the desert tortoise with a 90 percent contiguous high value habitat and good connectivity potential.

11. *Documentation that any groundwater withdrawal associated with a proposed project will not cause or contribute to withdrawals over the perennial yield of the basin, or cause an adverse effect on Endangered Species Act (ESA)-listed or other special status species or their habitats over the long term. However, where groundwater extraction may affect groundwater-dependent ecosystems, and especially within groundwater basins that have been over appropriated by State water resource agencies, an application may be*

acceptable if commitments are made to provide mitigation measures that will provide a net benefit to that specific groundwater resource over the duration of the project.

Water use from construction may draw down the aquifer. The project would need about 800 acre-feet. Drawdown could impact adjacent mesquite areas and draw down local wells in Pahrump.

12. *Documentation that significant cumulative impacts on resources of concern should not occur as a result of the proposed project (i.e., exceedance of an established threshold such as air quality standards).*

Significant cumulative impacts are not avoidable if the BLM maintains plans to permit 18,000 acres of solar projects in the area. At this point BLM has approved the 3,000-acre Yellow Pine Solar Project and is considering Rough Hat Clark at 2,400 acres, Rough Hat Nye at 3,500 acres, Copper Rays at 5,100 acres and Sagittarius at 4,200 acres. BLM has also approved the Trout Canyon substation with the intention of developing the area and sacrificing the resources in the area.

13. *If applicable, documentation on evaluation of desert tortoise impacts based on the variance process protocol for desert tortoise.*

See below comments on desert tortoise

14. *If applicable, documentation on evaluation of impacts to National Park Service (NPS) units and other special status areas under NPS administration as defined in the variance process protocol for resources and values of units of the NPS.*

The Old Spanish National Historic Trail[3] is located about 4 miles from the project site. The undeveloped nature of the area will compromise and destroy the historic setting of the trail.

The "Prioritization" process

In late August 2020, the Bureau of Land Management (BLM) Southern Nevada District Office placed three large-scale solar energy applications on a High Priority Status. The projects are Copper Rays Solar NVN-099407, Rough Hat Clark NVN-099406 and Rough Hat Nye NVN-099407.

The applications have been prioritized under the screening criteria from CFR 2804.35. Under these criteria, the BLM may re-categorize these applications based on *new* information received through surveys, public meetings or other data collection or any changes to the application.

[3] Old Spanish National Historic Trail (U.S. National Park Service) (nps.gov)

The High Priority Status was based on what BLM determined were “Low Conflicts”, but the BLM missed several details that would place this application into a “Low Priority Status” including local considerations.

Significant New Information:

Desert Tortoise

In this case, as the BLM is aware, the desert tortoise numbers have a good chance of being much higher than predicted. The High Priority Status is based partly on low predicted desert tortoise numbers.

One of the justifications for designating the three projects as High Priority are desert tortoise surveys and projected numbers of tortoises. The BLM predicts that all three of these sites have a low density of desert tortoises at 3.04 per square mile. When the High Priority was selected by BLM, the three project sites had not been surveyed for desert tortoise since 1990 – 31 years ago. It is also based on the surveys that were conducted for the adjacent Yellow Pine Solar Project. As BLM is aware, the tortoise numbers were undercounted and nearly 3 times the predicted number of desert tortoises were located and moved on the Yellow Pine Solar site during the Spring 2021 desert tortoise clearance. It is also quite possible that the biologists did not locate all the adult tortoises because the clearance was conducted on a record-breaking drought year.

The numbers of desert tortoises found on the Yellow Pine site exceeded the predicted total by both the Bureau of Land Management and the U.S. Fish and Wildlife Service. The Final Environmental Impact Statement for the Yellow Pine Solar Project predicted that based on population estimates, approximately 53 adult desert tortoises, 276 subadults or juveniles, and 69 hatchlings are anticipated to be displaced by project-related construction activities via translocation. [4]

The Biological Opinion predicted that the Phase I Tortoise Clearance Area would enclose an area of 3,233.5 acres from which an estimated 39 adults (95% CI = 27 to 59) would need to be translocated from the Yellow Pine Solar Project, and 1 adult (95% CI = 0 to 2) would be translocated by GLW. In addition to adult tortoises, it was estimated that many more juvenile tortoises would also require translocation.

Starting in April of 2021, Boulevard Associates LLC hired tortoise biologists to clear the Yellow Pine site of every tortoise they could find. In spite of record-breaking dry conditions, biologists found and moved 139 desert tortoises from the site. In a personal communication with the BLM, the final numbers were reported as:

Adults = 85 (33 Females, 52 Males)

[4] Yellow Pine Solar Project Final Environmental Impact Statement, Volume I: Chapters 1-4 (blm.gov)

Juveniles 110-179mm = 30
Juveniles 110mm = 24

This is over double the predicted number of adults that were found. In fact, biologists for Candela Renewables recently stated in a public meeting that the desert tortoise density for the Yellow Pine Solar Project site in now believed to be 11 per square mile.

We also found out though personal communication with federal agencies that 26 to 30 of the relocated adults were killed by predators – mostly badgers. That is about a 30 percent mortality for the adults found. On Page 88, the Biological Opinion states *"we anticipate that survival rates of adult desert tortoises moved from the project sites will not significantly differ from that of animals that have not been moved. We expect that desert tortoises would be at greatest risk during the time they are spending more time aboveground than resident animals. We cannot precisely predict the level of risk that will occur after moving desert tortoises* ***because regional factors that we cannot control or predict (e.g., drought, predation related to a decreased prey base during drought, etc.) would likely exert the strongest influence on the mortality rates".***

This record-breaking drought year may have been the cause of the high mortality and there is no evidence that the resident tortoises experienced the same mortality as the relocated ones killed by predators.

The total incidental Take resulting from death or injury to sub-adult and adult tortoises is 5 outside the fenced perimeter, not to exceed 1 per calendar year or 5 during the life of the project inside and outside of fenced areas. and nearly 30 were killed after translocation. [5]

During a personal communication with the BLM we were told that they are asking the U.S. Fish and Wildlife Service to reinitiate consultation.

This is significant new information based on underestimated numbers and possible unique weather conditions during an extreme drought.

BLM's memorandum (IM-NV-SNDO-2020-001) notes that "a low priority application may not be feasible to process," and 43 CFR § 2804.35 ("How will the BLM prioritize my solar or wind energy application?") states "Low-priority applications may not be feasible to authorize" if the application meets certain criteria. In both the Information Memorandum and Code of Federal Regulations, the SB Solar project triggers "Low-Priority Criteria" #1 ("Lands near or adjacent to lands designated by Congress, the President, or the Secretary for the protection of sensitive viewsheds, resources, and values (e.g., units of the National Park System, Fish and Wildlife Service Refuge System, some National Forest System units, and the BLM National Landscape Conservation System), which may be adversely affected by development") and #4 ("Lands currently designated as Visual Resource Management Class I or Class II").

[5] Page 105 08ENVS00-2020-F-0071 Yellow Pine Solar Project (508 compliant).pdf (blm.gov)

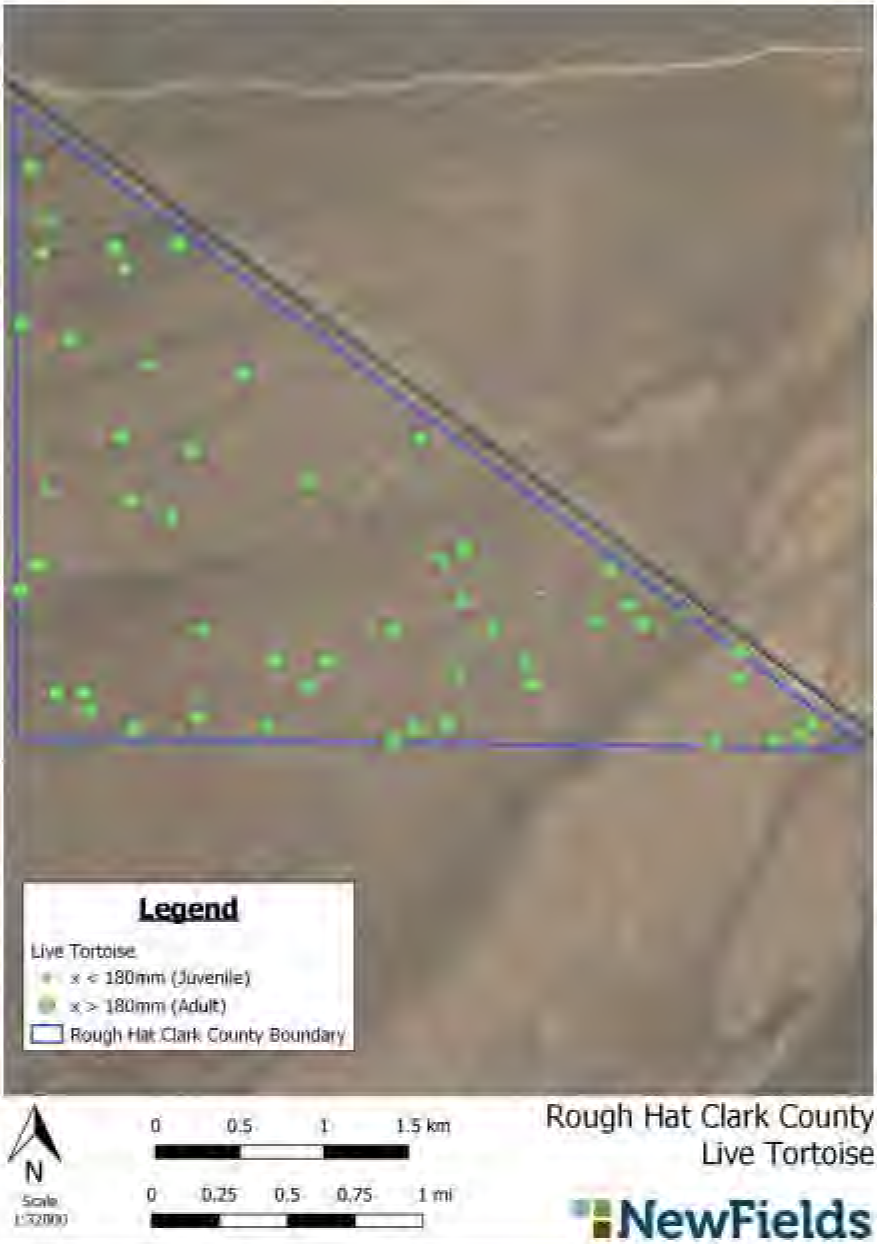
Tortoise Numbers on Copper Rays, Rough Hat Nye and Rough Hat Clark are Likely Underestimated

The three solar project proposals that BLM placed on a High Priority designation would impact an additional 11,000 acres of similar habitat. The northern parts of Rough Hat Nye and western part of Copper Rays occur on a saltbush, mesquite community near the town or Pahrump and have minimal disturbance for the first mile to the south from off highway vehicle recreation. But most of the 11,000 acres is not majorly disturbed and parts of these project sites are above 3,000 feet and may have a higher desert tortoise density than the Yellow Pine Solar Project. The sites even have some Joshua trees growing in the high elevations.

In May, 2021, Candela contracted the Newfields biological consulting company to conduct a presence/absence survey for desert tortoises on the proposed 2,400-acre Rough Hat Clark County Solar Project located directly north of Yellow Pine Solar. While the drought probably hampered survey results, they still did locate many live tortoises on the site. During the survey, 52 adult live tortoises were observed, and 5 juveniles. Total amount of desert tortoise burrows observed was 581. During the May 2 through May 14, 2021, combined with the Rough Hat Nye site surveys, a total of seventy-two (72) live adult tortoises were observed within the action area; therefore, the estimated number of tortoises throughout the action area was calculated to be 180, with a 95% confidence interval of 72 to 446 adult tortoises. Due to low winter precipitation, the estimated number of tortoises was calculated using a 64% chance of tortoises being detected above ground rather than 80% used on a year with normal precipitation.

In our experience, these numbers commonly are underestimated for large solar projects. Because the surveys were rushed through during a record-breaking drought, these survey results are questionable. The BLM should require Candela to resurvey the entire site.

^ Desert tortoise sign found on the project site during surveys in May, 2021.



^Live tortoises found on the project site. Surveys took place in record breaking drought conditions.

Undisturbed habitat

The 2,400 acres is not majorly disturbed Desert Tortoise Habitat.

Desert Tortoise Connectivity Areas

The U.S. Fish and Wildlife Service (USFWS) has identified certain other areas that may be important for desert tortoise connectivity (i.e., priority desert connectivity habitat). Recovering desert tortoises throughout their range requires that conservation areas be connected by habitat linkages in which tortoises reside and reproduce. Such areas will need to be free of large-scale impediments from human activities. The BLM has excluded from the Solar Energy Program approximately 515,000 acres (2,084 km^2) of land that coincides with priority desert tortoise connectivity habitat.[6]

The area has a very big population of tortoises, but the BLM has stated that it is not in a high connectivity zone due to a few factors including Highway 160, Tecopa Road, Saltbush habitat to the west, Pahrump, and the Yellow Pine Solar Project. In close examination, the two largest barriers would be Highway 160 and the Yellow Pine Solar Project. The projects would be located south of Pahrump in an area if the city that is sparsely populated. The Highway 160 barrier could be mitigated for connectivity with culverts, a proven working mitigation. Nextera should have been required to do this as mitigation for the Yellow Pine Solar Project. The Yellow Pine Solar Project has a requirement to mow vegetation but will not allow desert tortoises to pass though the project site. The numbers of tortoises found in this region are plentiful, probably in the thousands. It is a waste to write off the population as insignificant due to these connectivity barriers that can be mitigated. It should also be noted that saltbush communities can support healthy desert tortoise populations.

[6] Variance Process Protocol for Desert Tortoise [BLM Solar Energy Program] (anl.gov)

^Detail of U.S. Fish and Wildlife Service map showing high connectivity in the proposed solar areas. It is identified as a Least Cost Corridor with a 90 percent contiguous high value habitat.

^Above 3 photos: Three of the 30 tortoises that were killed by badgers on the Yellow Pine Solar site.

Disease in desert tortoises

Two of the Yellow Pine Solar project desert tortoises tested positive for Upper Respiratory Tract Disease. One on the project site and one on the recipient site. The unfavorable conditions during the translocation may have caused tortoises to develop symptoms. *"Although drought is a natural part of the desert tortoise's environment (Henen et al., 1998), it can contribute to morbidity and mortality if combined with disease or habitat loss (Peterson, 1996). Clinical signs of URTD and heteropenia were noted at the time of emergence of desert tortoises from hibernation in years that followed periods of intense drought (Christopher et al., 2003), suggesting that tortoises entering hibernation in a drought year may be physiologically compromised."*[7]

Human impacts on tortoises and their habitats, whether through disruption of normal behavior patterns, degradation of habitats through agriculture, silviculture, mining, land development or pollution, may cause sufficient physiological stress to trigger outbreaks of mycoplasmal disease. Wild tortoises in remote areas of the central Mojave Desert, distant from human beings and paved roads, were significantly less likely to be seropositive for M. agassizii *than those in close proximity to human developments (Berry et al., 2006).*[8]

The full development of all of these projects could contribute to disease outbreak for tortoises on the project site and recipient site.

Changing Priority Status

[7] Mycoplasmosis and upper respiratory tract disease of tortoises: A review and update - ScienceDirect

[8] Mycoplasmosis and upper respiratory tract disease of tortoises: A review and update - ScienceDirect

We are requesting that the Bureau of Land Management change the designation of these project applications as Low Priority based on the new information regarding under-predicted desert tortoise numbers.

The Code of Federal Regulations 2804.35 - How will the BLM prioritize my solar or wind energy application?

The BLM will prioritize a solar application by placing it into one of three categories – Low Priority, Medium Priority or High Priority and may re-categorize the application based on new information received through surveys, public meetings, or other data collection, or after any changes to the application. The BLM will generally prioritize the processing of leases awarded under subpart 2809 before applications submitted under subpart 2804. For applications submitted under subpart 2804, the BLM will categorize an application as High Priority based on the following screening criteria: (a) High-priority applications are given processing priority over medium- and low-priority applications and may include lands that meet the following criteria:

(1) Lands specifically identified as appropriate for solar or wind energy development, other than designated leasing areas;

(2) Previously disturbed sites or areas adjacent to previously disturbed or developed sites;

(3) Lands currently designated as Visual Resource Management Class IV; or

(4) Lands identified as suitable for disposal in BLM land use plans.

1. These lands were never specifically identified for solar and wind development

2. The disturbance on these sites is about 1 percent and closest to Pahrump.

3. The lands are VRM Class III, not IV.

4. These are not disposal lands

Other Impacts and Local Considerations:

Water

The project would need 800 acre-feet for construction and 16 acer feet per year for operation. Basin 162, the Pahrump Valley is over-drafted. Use of water for this project and others could eventually cause residents to have to sink their wells and more groundwater decline would kill local mesquite in the area.

An Analysis of Storm Water should be made

The applicant should develop a detailed erosion and sedimentation control plan, and a flood risk control plan now for public review. Proposed project sites are often located on an alluvial fan that acts as an "active stormwater conveyance" between mountains and valleys. Widespread bajada flooding events and sheetwash deposition occurs. The consequences of allowing flooding through the project would be too great. How does the project propose to maintain the solar fields if floodwaters jump the banks of the washes. In addition, alluvial fans often have shifting flow channels and pathways, so there is no guarantee that washes will not shift over 30 years.

Property Values

Nobody wants to live next to or near a visually unattractive solar project. At a meeting in Nye County, Candela said that adjacent solar projects would cause property values to decline by 5 to ten percent. This may be an underestimate.

Fugitive Dust:

Nevada large-scale solar projects have recently had a poor record in violating air quality controls, as we have recorded in photographs such as at the 800-acre Sunshine Valley Solar Project in Amargosa Valley. This mowed-vegetation project repeatedly had fine particulate whirlwinds, and dust clouds emerging from disturbed desert surfaces in construction zones. Despite water trucks attempting to water-down loose dirt, the solar project was too large to control all dust. Construction continued on windy days, yet even on mild breezy days we saw wind-blown dust and clouds of fine particulates from disturbed ground in the construction site. Construction, especially on windy days, would create huge dust black-outs and greatly impact visibility. Removal of stabilized soils and biological soil crust creates a destructive cycle of airborne particulates and erosion. As more stabilized soils are removed, blowing particulates from recently eroded areas act as abrasive catalysts that erode the remaining crusts, thus resulting in more airborne particulates. We are concerned that industrial construction in the region will compromise the air quality to the point where not only visual resources, but public health will be impacted. Epidemiologists investigated an outbreak of valley fever that had sickened 28 workers at two large solar power construction sites in San Luis Obispo County[9]

[9] https://www.latimes.com/archives/la-xpm-2013-may-01-lame-ln-valley-fever-solar-sites-20130501- story.html

^Photo of the fugitive dust caused by the Sunshine Valley Solar Project, Amargosa Valley, Nevada in summer of 2019.

Reasonable Alternatives to this Project: Distributed Energy

In 2020, the nation of Vietnam installed 9 GW of solar energy on rooftops[10] . They simply don't have volumes of land to sacrifice for large-scale solar projects, so they utilized their built environment, proving that significant amounts of solar energy can be generated from rooftops and other built structures.

Researchers from Vibrant Clean Energy found the cheapest way to reduce emissions actually involves building 247 gigawatts of rooftop and local solar power (equal to about one-fifth of the country's entire generating capacity today). In this scenario, consumers would save $473 billion, relative to what electricity would otherwise cost.

In September, 2016, Dr. Rebecca Hernandez of University of California, Davis published a study, Solar Energy Potential on the Largest Rooftops in the United States. This study was conducted on the rooftops of 5,418 elementary schools in Korea to determine the feasibility of achieving net-zero energy solar buildings through rooftop PV systems (Hernandez et al. 2013)

Mojave yuccas and Joshua trees

[10] Scaling up Rooftop Solar in Vietnam – More than 9GW installed in 2020 – pv magazine International (pv-magazine.com)

The project would destroy about 70,000 Mojave yuccas according to BLM. There are also Joshua trees on the site.

Mojave yuccas can live to be about 200 to 500 years old and provide food and habitat for multiple species.

Joshua trees are considered threatened by drought and climate change by many scientists. The species is being considered for Endangered listing by the Fish and Wildlife Service. [11]

The BLM clamed that no Joshua trees are on the site at the variance meeting. This is not true. They are not in high density, but are located in the area.

^Joshua tree on the Rough Hat Clark solar site.

Avian impacts

---

[11] Judge moves iconic Joshua tree closer to endangered species protections | Courthouse News Service

Placing up to 30 square miles of solar panels in this area from 5 projects will have avian impacts. The avian impacts are documented in several solar projects. It is thought that the projects mimic water and cause birds to hit the solar panels. Data from 7 solar projects in California has revealed 3,545 bird kills from 183 species from 2012 to 2016. This can be referenced from the 2016 Multi-Agency Avian Solar Working Group conference from 2016.[12]

The area is close to the Stump Spring wetland and only about 30 miles from the Tecopa/ Shoshone Amargosa River area. It is quite possible this project could cause avian mortality.

Other Wildlife and Plants

The project will impact:

Burrowing owls

American badgers

Kit foxes

Pahrump buckwheat

Pahrump Valley buckwheat *(Eriogonum bifurcatum*), a BLM Sensitive Species. Alkaline sand flats and slopes, within saltbush communities at elevations of 1,969–2,700 feet amsl. Associated with Corncreek-Badland-Pahrump soils due to its salinity and association with relict lakebeds and lake terraces. May occur. Evaluation of this soil type during reconnaissance surveys indicated the habitat for Pahrump Valley buckwheat is limited. The project area lacks the loose sandy soils where Pahrump Valley buckwheat is typically identified. During vegetation surveys, no individuals of Pahrump Valley buckwheat were observed, yet we request that the project be completely moved off this soil type to avoid potential for destroying populations of this species that did not flower during 2018 and 2019.. Pahrump Valley buckwheat is a BLM Sensitive species, meaning population or distribution of the wildlife is in a significant decline, the population is threatened as a result of disease or predation or ecological or human causes, and/or the primary habitat of the wildlife is deteriorating.

Other rare plants possibly impacted:

Aven Nelson Phacelia (*Phacelia anelsonii*)

Rosy Twotone Beardtongue (*Penstemon bicolor ssp. roseus*)

Yellow Twotone Beardtongue (*Penstemon bicolor ssp.bicolor*) (deserving of ESA protection)

White-Margined Beardtongue (*Penstemon albomarginatus*) (deserving of ESA protection)

[12] http://blmsolar.anl.gov/program/avian-solar/docs/Avian Solar_CWG_May_2016_Workshop_Slides.pdf

Death Valley Ephedra (*Ephedra funerea)*

New York Mountains *Catseye (Cryptantha tumulosa*)

Spring Mountains Milk-Vetch (*Astragalus remotus*)

Nye Milk-Vetch (*Astragalus nyensis*)

Mojave Milk-Vetch (*Astragalus mohavensis var. mohavensis)*

White Bear Poppy (*Arctomecon merriamii*)

Cacti and Yucca are considered Forest Products under 43 CFR 5420.0-6. Even with a site plan that avoids washes, the majority of these plants would be destroyed.

Possible mule deer and bighorn sheep

And a host of other species. Construction will kill millions of living organisms.

Sensitive Birds Will Be Impacted Bendire's thrasher (*Toxostoma bendirei)* may occur. Joshua trees are present in areas near the project, and Mojave yuccas are abundant. Therefore, the project may impact suitable breeding or foraging habitat for this species. Targeted surveys should be undertaken for this species. Le Conte's thrasher (*Toxostoma lecontei)* was observed during site visits.

The project may impact suitable breeding or foraging habitat for this species Phainopepla *(Phainopepla nitens)* was recorded by Nevada Division of Wildlife (NDOW) within 8 miles of the project area. There are no stands of mesquite and/or acacia located within the project area; however, mesquite stands are present in areas near the project; therefore, the project may impact suitable breeding or foraging habitat for this species. Scott's oriole *(Icterus parisorum)* was recorded by NDOW within 8 miles of the project area. The project may impact suitable breeding or foraging habitat for this species

Large Mammal Habitat Will Be Fragmented

A Mountain lion was recorded within the analysis area from NDOW records. We have seen mule deer in Mojave yucca and creosote scrub on alluvial fans within a few miles of the project site in Pahrump Valley.

Bats May Be Impacted A diversity of bats may feed in the project area, migrate through, and roost in yuccas: Allen's big-eared bat (*Idionycteris phyllotis),* Big brown bat (*Eptesicus fuscus),* Big free-tailed bat (*Nyctinomops macrotis*), Brazilian free-tailed bat (*Tadarida 30 brasiliensis*), Brazilian free-tailed bat (*Tadarida brasiliensis*), Canyon bat (formerly western pipistrelle) (*Parastrellus hesperus*), Fringed myotis (*Myotis thysanodes*), Hoary bat (Lasiurus cinereus), Long-eared myotis (Myotis evotis), Long-legged myotis (Myotis volans), Pallid bat (*Antrozous pallidus*), Silver-haired bat (*Lasionycteris noctivagans*), Spotted bat (*Euderma maculatum*), Townsend's big-eared bat (*Corynorhinus townsendii*), Western red bat (*Lasiurus blossevillii),* Western small-footed myotis (*Myotis ciliolabrum*), and Yuma myotis (*Myotis yumanensis*). Night-lighting installed for safety purposes may create light pollution in bat foraging areas, which may disorient foraging bats. Long terms impacts of operational night lighting is not addressed. Bats May Be Impacted A diversity of bats may feed in the project area, migrate through, and roost in yuccas: Allen's big-eared bat (*Idionycteris phyllotis*), Big brown bat (*Eptesicus fuscus*), Big free-tailed bat (*Nyctinomops macrotis),* Brazilian free-tailed bat (*Tadarida 30 brasiliensis*), Brazilian free-tailed bat (*Tadarida brasiliensis*), Canyon bat (formerly western pipistrelle) (*Parastrellus hesperus*), Fringed myotis (*Myotis thysanodes*), Hoary bat (*Lasiurus cinereus*), Long-eared myotis (*Myotis evotis*), Long-legged myotis (*Myotis volans*), Pallid bat (*Antrozous pallidus*), Silver-haired bat (*Lasionycteris noctivagans*), Spotted bat (*Euderma maculatum*), Townsend's big-eared bat (*Corynorhinus townsendii*), Western red bat (*Lasiurus blossevillii),* Western small-footed myotis (*Myotis ciliolabrum),* and Yuma myotis (Myotis *yumanensis*). Night-lighting installed for safety purposes may create light pollution in bat foraging areas, which may disorient foraging bats. Long terms impacts of operational night lighting is not addressed.

Soils and Biological Soil Crusts Will Be Significantly Impacted

Biotic soils and desert pavement commonly occur as a mosaic on the project site. Desert pavements are a matrix of rock fragments that form smooth, pavement-like surfaces. Biotic soils are living surface features comprised of soil particles enmeshed in a complex web of cyanobacteria, mosses, lichens, bacteria, algae, and fungi that send roots and filaments deep into the soil, helping to sequester Carbon. Both desert pavements and biotic soils provide a protective soil covering that reduces wind and water erosion potential and further impact soil moisture dynamics. Disruption of fragile biotic soils or removal of desert pavements generally increase wind and water erosion potential.

Visual Resources Will Be Significantly Impacted

The Project would be built in a high conflict Visual Resource area. Although the lands directly impacted would be in the VRM III Class Objective, the massive size of the project would impact other conservation and specially designated areas in the region. The objective of VRM Class III is to *"partially retain the existing character of the landscape. Allowed Level of Change: The level of change to the characteristic landscape should be moderate. Management activities may attract attention, but should not dominate the view of the casual observer."* The Rough Hat Clark Solar Project would be visible in Nevada from the Old Spanish National Historic Trail, Potosi Mountain, Lovel Summit, Mt. Charleston, the Griffith Peak Trail and the Bonanza Peak Trial in Nevada. In California, the project would be visible from the Nopah Range Wilderness Area, Pahrump Valley Wilderness Area, Clark Mountain in the Mojave National Preserve and the Kingston Wilderness. Because of this, these resources should be reviewed for Visual Impacts under VRM II standards also.

VRM Class II Objective: *To retain the existing character of the landscape. Allowed Level of Change: The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.* The project would also be visible from major roads including Highway 160 going north from Las Vegas. The project would dominate that view. The project would impact the view and experience for people driving on the Tecopa Road and Old Spanish Trail Highway.

The Clark County Multi-Species Habitat Conservation Plan

Several of the species that will be impacted by the Rough Hat Clark County Project are protected under the Clark County Multi-Species Habitat Conservation Plan (MSHCP). The County has also nominated a major portion of the area to be protected as an Area of Critical Environmental Concern. Several species protected under the plan occur on the site. This is not addressed in this application.

A high conflict situation is present and overlooked with respect to this MSHCP: this area should be managed for conservation, as groups bought out the privileges for grazing leases on these BLM allotments decades ago, in order to mitigate Clark County urbanization and growth. Retiring livestock grazing on these desert allotments was decided as a benefit to desert tortoise and many other covered species in this part of Clark County, yet many years later, BLM allows large utility-0scale solar applications to move forward on these same administratively closed allotments. Again, this is a high conflict area.

Variance Process for BLM lands close to National Park Service Lands

The BLM has adopted the following protocol for variance applications that have the potential to impact resources and values of units of the National Park System and other special status areas under the National Park Service (NPS) Administration.[13]

Proximity to Units of the NPS

The construction and operation of utility-scale solar energy projects and related transmission infrastructure near units of the National Park System and other special areas administered by the NPS, including National Historic Trails, may significantly affect park programs, resources, and values. For example, ecological resources (such as habitat and migration of species) and physical resources (such as wind, water, air, and scenic views) cross park boundaries, and park boundaries often do not contain all of the natural resources, cultural sites, and scenic vistas that affect the quality of the park visitor’s experience within these special places.

High-Potential Conflict Exclusions

[13] Variance Process Protocol for Resources and Values of Units of the National Park Service [BLM Solar Energy Program] (anl.gov)

The NPS has identified areas within the proposed variance areas where utility-scale solar energy development poses a high potential for conflict with the natural, cultural, and/or visual resources administered by the NPS. The BLM has excluded from the Solar Energy Program approximately 821,000 acres (3,322 km^2) of land that coincides with NPS-identified areas of high-potential conflict.

The Rough Hat Clark County Solar Project will be built within 4 miles of the Old Spanish National Historic Trial managed by the National Park Service. The industrial desert scraping, the solar panels, battery storage banks and transmission lines will all degrade the experience for anybody seeking the historic character of the region.

Variance Process

In 2014, the Bureau of Land Management California State Director used the Variance Process to reject the application for the Silurian Valley Solar Project. It would have been a 200 megawatt photovoltaic solar project on 1,616 acres about 10 miles north of Baker along highway 127. The BLM determined that the solar project would not be in the public interest after undergoing a rigorous review process in accordance with the BLM's Western Solar Plan.

The initial review and analysis indicated that the impacts to the Silurian Valley, a largely undisturbed valley that supports wildlife, an important piece of the Old Spanish National Historic Trail, and recreational and scenic values, had too great of an impact on the resources. The BLM concluded that these impacts likely could not be mitigated and that the project would not be in the public interest.

Conclusion

Please use the Variance Process to reject the Rough Hat Clark County Solar Project. The project has too many impacts and would provide little benefits to the adjacent community of Pahrump. The BLM can easily reject this project as it is not in the public interest.

Thank you,

Kevin Emmerich
Co-Founder
Basin and Range Watch
P.O. Box 70
Beatty, NV 89003

Laura Cunningham
Western Watersheds Project
Cima, CA 92323

References:

Hernandez, R., M. Hoffacker, and C. Field. 2013. Land-Use Efficiency of Big Solar. Environmental Science & Technology, December 2013.

Elliott R.Jacobson, Mary B.Brown, Lori D.Wendland, Daniel R.Brown, Paul A.Klein, Mary M.Christopher, Kristin H.Berry, Mycoplasmosis and upper respiratory tract disease of tortoises: A review and update, The Veterinary Journal, Volume 201, Issue 3, September 2014, Pages 257-264

[EXTERNAL] Rough Hat Clark County Solar Project Variance

[redacted]

Wed 12/22/2021 6:33 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

I am writing to oppose the Clark County Rough Hat 1 (Trout Canyon) and Nye County Rough Hat 2 (Pahrump) Solar Project Variance applications for permitting.

Trout Canyon was the place Las Vegas developers paid for, to get LV-displaced desert tortoises to be fitted for telemetry and "translocated" into a USFWS- assessed, but untested, unknown (to the tortoises) environment, far from LV realty boom development. This was regarded as unfair, dumping on Pahrump realtors, who now could not sell their acreages without maybe having to add costs of the temporarily disoriented, wandering, "translocated" endangered species to the price of an acre, ~$550-$1250/tortoise/acre. The probable number of tortoises/acre in Pahrump, is determined by a 1992 USGS survey algorithm. Despite caring researchers and biologists at the (holding facility) conservation center, it is clear, welfare of the removed keystone tortoise species was of lower importance than avoiding paying to have it "clearanced" out of the picture. There are still tortoises out there in the S end desert.

In Pahrump, dust from construction is the main problem for the people protesting against the panel installation. Property owners believed their close proximity to attractive back country (with a view of BLM desert), was an asset to their realty investment. Now, if there are only solar panel fields out there, the value of their investment has fallen. For 30-40? years. And the broken soil crust from construction and maintenance at the solar facility, will be upwind, coming as thick dust rolling across their home and vehicles in waves.

I feel there were already in place, sufficient declarations, notifications, documentations - that the Mojave Desert, its ancient water systems, vegetation, wildlife - above and below ground - are not to be "taken" for purposes of any extractive industry, which degrades or undoes the health of the rest of the ecosystem. I think the FLPMA writers' "fair multiple use" demand is outdated and was always recognized as wrong for good land management. The health of the ecosystem depends on the healthy survival of the desert tortoise. Human busyness on the desert seems to stress or harm the tortoise and its community, directly and indirectly. The "highest, best use" of the Mojave Desert is not about being a "free" parking lot for millions of solar panels.

Thank you for the use of this space for public input.

[EXTERNAL] Rough hat Clark county variance process

Shannon Salter <shannon@mojavegreen.org>

Wed 12/22/2021 4:03 PM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

Dear BLM staff,

My name is Shannon Salter and I represent the group Mojave Green. We combine art and activism to draw attention to issues of environmental injustice, and we highlight viable solutions.

I am writing today to endorse the letter of comments submitted by Kevin Emmerich and Laura Cunningham of Basin and Range Watch and the Western Watersheds Project.

The desert tortoise relocation at the Yellow Pine Solar site was shameful and egregious. This scenario is likely to repeat itself on the Rough Hat Clark proposed project site. I have been hiking daily on both the Yellow Pine and Rough Hat Clark sites and they both exhibit prime desert tortoise habitat. It is likely there will be far more desert tortoises than biologists anticipate.

Furthermore, scientists are only recently coming to understand the carbon sequestration capacity of desert soils. It is believed that deserts are storing a third of land based carbon. It is senseless to build solar on wild desert land. It might make the developer a lot of money, but at what cost? We need so ar infrastructure over parking lots and on rooftops.

The Pahrump Valley is not a wasteland to be needlessly destroyed. I would also submit that the mental health effects on the residents of Pahrump, as well as everyone that uses this public land, should be considered. Imagine the beautiful open desert being bulldozed before your eyes. It is unthinkable, and the effects on mental health must be astronomical. It is well documented that access to nature plays a significant role in mental health. As a Las Vegas resident, I frequently use the public lands around Pahrump for hiking and solitude, as nearby Red Rock Canyon is bursting at the seams with visitors. To see the ecosystem that I love and spend time in destroyed for an industrial facility will undoubtedly have a detrimental effect on my own mental well being. I can only imagine the effects on the 50,000 people that live within a few miles of the area.

Sincerely,

Shannon Salter
Executive Director
Mojave Green

[EXTERNAL] Rough Hat Clark County Solar Variance

Simone Griffin <brsimone@sharetrails.org>

Thu 12/23/2021 6:23 AM

To: BLM_NV_SND_EnergyProjects <BLM_NV_SND_EnergyProjects@blm.gov>

1 attachment (193 KB)

Rough Hat Clark County Solar Project.docx.pdf;

Please see attached comment. Please confirm receipt.

--

Simone Griffin
Policy Director
BlueRibbon Coalition/ShareTrails
435-459-1030

BlueRibbon Coalition / Sharetrails
P.O. Box 5449
Pocatello, ID 83202-0003
1-208-237-1008 • brc@sharetrails.org

Ben Burr, Executive Director **December 20, 2021**
BlueRibbon Coalition
P.O. Box 5449
Pocatello, ID 83202

BLM Southern Nevada District Office
Attn: Rough Hat Clark County Solar Project Variance
4701 N. Torrey Pines Drive
Las Vegas, NV 89130

BlueRibbon Coalition/ShareTrails (BRC) is writing to provide feedback for Rough Hat Clark County Solar Project.BRC is a national non-profit organization that champions responsible recreation and encourages a strong conservation ethic and individual stewardship. We champion responsible use of public lands and waters for the benefit of all recreationists by educating and empowering our members to secure, protect, and expand shared outdoor recreation access and use by working collaboratively with natural resource managers and other recreationists. Our members use motorized and non-motorized means of recreation, including OHVs, horses, mountain bikes, and hiking to enjoy federally managed lands throughout the United States, including those of the Bureau of Land Management. Many of our members and supporters live in Nevada or travel across the country to visit Nevada and use motorized vehicles to access BLM managed lands throughout Nevada. BRC members visit the Rough Hat area for motorized recreation, sightseeing, photography, hunting, wildlife and nature study, camping, water sports, and other similar pursuits.

We would like to add our support to any comment submitted by any other individuals or organizations that advocate for motorized use and increased recreation access overall. BRC members and supporters have concrete, definite, and immediate plans to continue such activities in the future. Many of our members are individuals and organizations with extensive on-the-ground experience in Clark County. BRC supports local groups and recreation enthusiasts comments regarding this solar project. They have substantive comments that are accurate and thorough.

Roads and Trails

BRC is concerned with the variance of the solar energy zones being proposed. Solar projects should not be built in non solar energy zones until all current allocated zones are being utilized. Nevada should prioritize building out projects where there is already approval.

The Rough Hat area is commonly used to access trails for recreation purposes. Off-roading is popular and any project proposal needs to account for the effects to the recreation and motorized use community. A thorough inventory of all current trails needs to be completed so that the BLM is working with an accurate baseline. This area has a high recreation value for locals in the surrounding community and any project proposed should be developed in a way that does not restrict access to users.

Dispersed Camping

The proposed solar project should analyze how it would affect all types of recreation including dispersed camping. Recreation has grown in popularity, dispersed camping has become much more common across public lands. The solar project should not impede dispersed camping and more documentation needs to be collected on how the project will be implemented to address the concerns of dispersed camping and recreation users.

Organized Events

Many of our members hold organized events that include organized rides and races in this area. We would like to see these continue even if the project and variance is approved. A significant portion of the education mission of organizations like ours and the fundraising that supports organizations like ours comes from these organized events, and we see the continuation of these events as an integral expression of protected rights including freedom of speech and freedom of assembly. We believe these events are protected by the First Amendment and believe they are crucial to clubs and organizations.

Economic Benefits

Local communities rely on motorized recreation for economic opportunities. There has been a surge of use throughout the nation on public lands as well as in Clark County and surrounding areas. Local groups have worked hard to put the area on the map so that they could reap the economic benefits. Closing roads or restricting access in response to this project would greatly hinder economic opportunity.

Conclusion

We would like to close by saying we support “shared use”. As long as overall visitation numbers are appropriate for the affected resources, motorized and non-motorized users can be compatible with one another so long as individual users understand designations and plan their activities accordingly. Indeed, motorized and nonmotorized recreation use often overlap as OHV’s often increase accessibility to non-motorized recreational activities such as hiking, camping, equestrian use, etc. We also hold that responsible recreational use of public lands can exist in harmony with ecosystem needs.

BRC would like to be considered an interested public for this project. Information can be sent to the following address and email address:

Ben Burr
BlueRibbon Coalition
P.O. Box 5449
Pocatello, ID 83202
brmedia@sharetrails.org

Sincerely,

Ben Burr
Executive Director
BlueRibbon Coalition

Simone Griffin
Policy Director
BlueRibbon Coalition