

**ORGAN PIPE CACTUS NATIONAL MONUMENT
RESEARCH**

Project Title: Climatic Variation and Photosynthetic Adaptation in Warm Desert Plants

Principal Investigator: Jonathan Comstock

Project Start Date: 1992

Project End Date: 19

CORRESPONDENCE

01/27/94	From:	Harold J. Smith, Supt., ORPI
	To:	Dr. Jonathan Comstock
	Subject:	Request for Investigator's Annual Report for 1993
01/07/94	From:	Harold J. Smith, Supt., ORPI
	To:	Dr. Jonathan Comstock
	Subject:	Request for Investigator's Annual Report for 1993
11/07/93	From:	Harold J. Smith, Supt., ORPI
	To:	Dr. Jonathan Comstock
	Subject:	Request for Investigator's Annual Report for 1993
02/03/92	From:	Harold J. Smith, Supt., ORPI
	To:	Dr. Jonathan Comstock
	Subject:	Application for Collection Permit for 1992
02/03/92	From:	Harold J. Smith, Supt., ORPI
	To:	Mr. Theodore N. Boratynski
	Subject:	Collection Permit for 1992
12/05/91	From:	Dr. Jonathan Comstock
	To:	Harold Smith, Supt., ORPI
	Subject:	Request for Collecting Permit

PROPOSAL

Climatic Variation and Photosynthetic Adaptation in Warm Desert Plants

Principal Investigator: Jonathan Comstock, Biology Department, University of Utah

CERTIFICATION/CONTRACT

unsigned

Tracking Sheet for Research Projects

FINANCIAL DOCUMENTATION

PERMITS

Application for Permission to Conduct Scientific research/Collect Specimens of Plants, Rocks, Minerals, and Animals, DOI, NPS, WRO, ORPI

Valid: 01/31/92 - 12/31/92

INVESTIGATOR'S ANNUAL REPORT

FINAL REPORT

OTHER REPORTS

DATABASE

OTHER

[135] From: Jonathan Comstock <jpc8@cornell.edu> at NP--INTERNET 3/20/98 4:13PM
(1891 bytes: 2 ln)

To: Tim Tibbitts at NP-ORPI

Subject: final report

----- Message Contents -----

Text item 1: Text Item

Dear Tim,

Sorry that I have been slow to respond to your letters. My project "Climate variation and photosynthetic adaptation in warm desert plants" is indeed over and I will not need collecting permits this year. In the end, we did much less field work than intended, and with less success than hoped. These data may or may not see the light of day. I am, however, writing up and have in part submitted several papers on greenhouse studies comparing plants grown from different geographically distinct seed sources, with your park being one source. I will make sure that you get reprints of all such papers as they come out over the next year. Thanks for your help and support in our research efforts,

Jonathan Comstock

Jonathan Comstock
Boyce Thompson Institute
Tower Road
Ithaca, NY 14853
USA

phone: 607-254-1214
fax: 607-254-1242

N22

January 11, 1995

Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

*Boyer Thompson last letter
Teresa Reed
Misses 214 14857*

Dear Dr. Comstock:

607 254-1214

On November 14, 1994, a request was sent to you to complete an Investigator's Annual Report (IAR) covering research at Organ Pipe Cactus National Monument over the past calendar year. The due date for submittal was December 26, 1994. As of this date we have not received your report.

I have enclosed another copy of the IAR for calendar year 1994. Please take the time to fill out the report and return it to the monument no later than **January 23, 1995**. This report must be filled out for all projects worked on in 1994, even for those that were completed during the year and final reports submitted. If you are working on more than one project, fill out one form for each. This report must be received by the monument before authorization will be granted to continue research into 1995 or to conduct any future research in the monument. If you have recently send your IAR, thank you, and please disregard this letter.

We appreciate your cooperation with this request and thank you for your efforts in bringing a greater base of knowledge about the resources of Organ Pipe Cactus National Monument. If you have any questions please contact Research Coordinator Tim Tibbitts or Chief of Resources Management Jim Barnett on (602) 387-7661, extension 7113 or 7110, respectively. Thank you.

Sincerely,

/s/ Harold J. Smith

Harold J. Smith
Superintendent

Enclosure

bcc: Files
Reading
Superintendent
Chief, Resources Management
Research Coordinator

C:\WP51\FILES\TIBBITTS\LETTERS\94MEMO2.IAR

94MEMO2.IAR (shell document)
94MAILLIS2.IAR (merge list)
94MASME2.IAR (merged document)

N22

November 14, 1994

Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

Dear Dr. Comstock:

Enclosed is a copy of the Investigators Annual Report for calendar year 1994. We are asking that each principal investigator conducting research within Organ Pipe Cactus National Monument complete and return this form to us no later than December 26, 1994. This report should be filled out for all projects worked on or approved in 1994. This includes projects that were completed during the year and had final reports submitted, as well as projects approved but for which field work has yet to begin. A 1994 Research Program Principal Investigator (P.I.)/Project List is enclosed identifying all projects in progress during the calendar year. If you are working on more than one project identified on the P.I./Project List, fill out one form for each.

For projects that were active in 1993, enclosed is a copy of last year's data to assist you with the 1994 report. For fields that are identical to this year's (i.e., project objectives) simply place "SAME AS 93" under the appropriate category. Once we receive your report, the information that you provide will be entered into the monument's research database. This information serves as a valuable reference for us in managing, coordinating, and developing the research program, and is also required by our Regional and Washington Offices. In 1994, there were 43 approved research projects in progress.

This report must be received before authorization can be granted to continue your research into 1995 or before authorization can be given to conduct any future research in the monument. We request that a strong effort be made to meet the submission deadline. Annually, ten percent of the reports are not in the monument by the due date. As a result, an inordinate amount of effort is required to bring in these last few reports. If for some reason the December 26, 1994, deadline cannot be met, I request that you contact the monument's research coordinator identified below.

We appreciate your cooperation with this request and thank you for your efforts in bringing about a greater base of knowledge on the resources of Organ Pipe Cactus National Monument. As part of the development of our research program, Wildlife Biologist Tim Tibbitts recently joined our staff and will now be coordinating the monument's research program. If you have any questions, please contact Tim at (602) 387-7661, extension 7113. From the staff at Organ Pipe Cactus, we wish you all the best during the coming holiday season.

Sincerely,

Harold J. Smith
Superintendent

Enclosure

cc: Tim Tibbitts (research files)



IN REPLY REFER TO:

United States Department of the Interior



NATIONAL PARK SERVICE
Organ Pipe Cactus National Monument
Route 1, Box 100
Ajo, Arizona 85321-9626

N22

January 27, 1994

Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

Dear Dr. Comstock:

On November 7, 1993, a request was sent to you to complete an Investigator's Annual Report (IAR) covering research at Organ Pipe Cactus National Monument over the past calendar year. The due date for submittal was December 27, 1993. Since a report was not received by the submittal date, a follow-up letter repeating this request was sent on January 7, 1994. As of this date we have not received your report.

I have enclosed another copy of the IAR for calendar year 1993. Please take the time to fill out the report and return it to the monument. This report must be filled out for all projects worked on in 1993, even for those that were completed during the year and final reports submitted. At this time we have assumed your research within the monument is concluded and we will not be issuing you a 1994 research permit (which will be required for all projects in 1994).

If you have recently sent your report please disregard this request. We appreciate your cooperation and the courtesy of a response. If you have any questions please contact Jim Barnett, Chief of Resource Management and Research, at (602) 387-7661 ext. 7110. Thank you.

Sincerely yours,

Harold J. Smith
Superintendent

encl.



IN REPLY REFER TO:

United States Department of the Interior

NATIONAL PARK SERVICE
Organ Pipe Cactus National Monument
Route 1, Box 100
Ajo, Arizona 85321-9626

TAKE
PRIDE IN
AMERICA

N22

January 7, 1994

Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

Dear Dr. Comstock:

On November 7, 1993, a request was sent to you to complete an Investigator's Annual Report (IAR) covering research at Organ Pipe Cactus National Monument over the past calendar year. The due date for submittal was December 27, 1993. As of this date we have not received your report.

I have enclosed another copy of the IAR for calendar year 1993. Please take the time to fill out the report and return it to the monument no later than **January 21, 1994**. This report must be filled out for all projects worked on in 1993, even for those that were completed during the year and final reports submitted. If you are working on more than one project, fill out one form for each. This report must be received by the park before authorization will be granted to continue research into 1994 or to conduct any future research in the monument. If you have recently sent your IAR, thank you, and please disregard this letter.

We appreciate your cooperation with this request and thank you for your efforts in bringing a greater base of knowledge about the resources of Organ Pipe Cactus National Monument. If you have any questions please contact Jim Barnett, Chief of Resource Management and Research, at (602) 387-7661 ext. 7110. Thank you.

Sincerely yours,

Harold J. Smith
Superintendent

encl.



IN REPLY REFER TO:

United States Department of the Interior

NATIONAL PARK SERVICE
Organ Pipe Cactus National Monument
Route 1, Box 100
Ajo, Arizona 85321-9626



N22

November 7, 1993

Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

Dear Dr. Comstock:

Enclosed is a copy of the Investigators Annual Report for calendar year 1993. We are asking that each principal investigator conducting research within the monument complete and return this form to us no later than December 27, 1993. This report should be filled out for all projects worked on or approved in 1993. This includes projects that were completed during the year and final reports submitted as well as projects approved but for which field work has yet to begin. If you are working on more than one project, fill out one form for each.

For projects that were active in 1992, enclosed is a copy of last years data to assist you with the 1993 report. For fields that are identical to this years (i.e. project objectives) simply place "SAME AS 92" under the appropriate category.

Once we receive your report, the information that you provide will be entered into the monument's research database. This information serves as a valuable reference for us in managing and coordinating the research program, and is also required by our Regional and Washington Offices. In 1993 there were 40 approved research projects in progress. This report must be received before authorization can be granted to continue your research into 1994 or before authorization can be given to conduct any future research in the monument.

We appreciate your cooperation with this request and thank you for your efforts in bringing about a greater base of knowledge on the resources of Organ Pipe Cactus National Monument. If you have any questions please contact Jim Barnett, Chief of Resources Management, at (602) 387-7661 ext. 7110. From the staff at Organ Pipe Cactus we wish you all the best during the coming holiday season.

Sincerely yours,

Harold J. Smith
Superintendent

encl.



United States Department of the Interior

NATIONAL PARK SERVICE ORGAN PIPE CACTUS NATIONAL MONUMENT

IN REPLY REFER TO:

ROUTE 1, BOX 100
AJON, ARIZONA 85321

N22

February 3, 1992

Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

Dear Dr. Jonathan Comstock:

Enclosed is your collection permit for 1992. Please sign page one of the permit and return it to the park in the enclosed envelope. Retain page two, and if you have any assistants identified on the permit, please make them a copy. When at the park doing field work, be sure you have the permit in your possession. Research findings must be reported to the Monument. If you have any questions, please contact Jim Barnett at (602) 387-6849.

Sincerely yours,

Harold J. Smith
Harold J. Smith
Superintendent

*From:
J. Comstock
6/11/92*

Enclosures

- * *Franseria*
- * *Bebbia juncea*
- * *Hemerocallis*
- * *Viguiera*
- * *...*

- * *Enochia*
- * *Salsola*
- * *Physalis*
- * *...*

THE UNIVERSITY OF UTAH

Dr Jonathan Comstock
Department of Biology
Salt Lake City, Utah 84112

Telephone 801-581-5927
FAX 801-581-4685
E-mail Comstock@biology.utah.edu

RECEIVED	
Organ Pipe Cactus N. M.	
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12/5/91

Harold Smith
Superintendent
Organ Pipe Cactus National Monument
Route 1, Box 100
Ajo, Az 85321

Dear Sir,

I am writing as a follow-up to a phone conversation I had with Jim Barnett. I wish to obtain a plant collection permit which will enable me to make seed collections of common shrub species within the Monument. I am a Research Assistant Professor at the University of Utah currently supported by an NSF grant entitled "Hydraulic Limitations in Aridland Shrubs". I also have a Faculty Grant with provisions to make an extensive seed collecting trip throughout the Mojave and Sonoran Deserts during May and June of 1992 in order to test a hypothesis concerning ecotypic differentiation of water-use characteristics along climatic gradients. A copy of the Faculty Grant, which has already received funding, is enclosed with this letter.

The seed collected on this trip will be used in common-garden experiments at the University of Utah in a study of ecotypic differentiation. I will have a large number (two-or three dozen) of target species, all chosen for their broad geographic distributions in our North American warm deserts. Only a few of these species are likely to occur within the Monument boundaries. My goal is to collect seed for each species from a large number (10-20) of sites with substantial variation among sites in relevant climatic parameters. It is not important that all species be found at the same sites. The amount of seed needed per species at each site will be approximately one 3X5 seed envelope from each of 35 non-contiguous individuals. This will permit me to fulfil my current grant obligations, and also have some seed for follow-up studies. I will also need to take one non-lethal voucher specimen each of the target species from each population sampled.

If weather records of temperature and precipitation are collected within the park, I would be interested in obtaining access to this information. Also, if there are precipitation gauges at different elevations this could be very helpful to me. If there are no weather records in the park, what are the closest weather bureau stations?

Please inform me if I can provide any further information. I look forward to your response.

Sincerely,



Dr Jonathan Comstock

THE UNIVERSITY OF UTAH

Dr Jonathan Comstock
Department of Biology
Salt Lake City, Utah 84112

Telephone
FAX
E-mail

RECEIVED	
Organ Pipe Cactus N. M.	
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801-581-5321 RANGER	
801-581-4684 RES MGMT	
CH MAINT	
Comstock@utah.edu	

12/5/91

Harold Smith
Superintendent
Organ Pipe Cactus N
Route 1, Box 100
Ajo, Az 85321

Dear Sir,

I am writing as a full collection permit which Monument. I am a Re grant entitled "Hydrau make an extensive se of 1992 in order to tes climatic gradients. A letter.

The seed collected on this trip will be used in common-garden e study of ecotypic differentiation. I will have a large number (two- chosen for their broad geographic distributions in our North Ame species are likely to occur within the Monument boundaries. My from a large number (10-20) of sites with substantial variation among sites in relevant climatic parameters. It is not important that all species be found at the same sites. The amount of seed needed per species at each site will be approximately one 3X5 seed envelope from each of 35 non-contiguous individuals. This will permit me to fulfil my current grant obligations, and also have some seed for follow-up studies. I will also need to take one non-lethal voucher specimen each of the target species from each population sampled.

If weather records of temperature and precipitation are collected within the park, I would be interested in obtaining access to this information. Also, if there are precipitation gauges at different elevations this could be very helpful to me. If there are no weather records in the park, what are the closest weather bureau stations?

Please inform me if I can provide any further information. I look forward to your response.

Sincerely,

Jonathan Comstock

Dr Jonathan Comstock

*Sent letter
asking for
more info.
on 1/7/92*

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N22

February 3, 1992

Mr. Theodore N. Boratynski
SW Boll Weevil Eradication Project
P.O. Box 820
El Centro, CA 92244

Dear Mr. Boratynski:

Enclosed is your collection permit for 1992. Please sign page one of the permit and return it to the park in the enclosed envelope. Retain page two, and if you have any assistants identified on the permit, please make them a copy. When at the park doing field work, be sure you have the permit in your possession. Research findings must be reported to the Monument. If you have any questions, please contact Jim Barnett at (602) 387-6849.

Sincerely yours,

Harold J. Smith
Superintendent

Enclosures

Identical copies sent to:

Hodgson
Rosen
Comstock
F. Phillips
Goodman
Nabhan
Rankin
Larnen
Felger
Cornett
Schmidt

RECEIVED
Organ Proc Cactus N. M.

DEC 10 '91

APPENDIX A

Faculty Grant Proposal

CTION	INFO
Investigator	SUPERINTENDENT
	ADMIN TECHN
	CHANGER
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	CH MAINT
	INTERP. SPEC

Date: October 15, 1991

Name (typed): Jonathan Comstock

Soc. Sec. No: 458-02-0990

Signature: Jonathan Comstock

Phone No: 581-5927

Campus Address: rm201 S. Biology

Mail Code: 08402

Department: Biology

Home Dept. No: 41420

Faculty Rank: Research Assistant Professor

Department Chairperson:

Name (typed): Dr John Roth

Signature: John Roth

Project Title:

Climatic Variation and Photosynthetic Adaptation in Warm Desert

Plants

Project Short Title (30 characters or less): Climate and Photosynthesis

Duration of Activity: One year

Amt. Funds Requested: \$4,982.00

Abstract: This summary should be understandable by informed scholars outside the investigator's field. Use provided space only!

This proposal deals with the relationships between climatic variation among arid-land sites, and ecotypic variation in the water-use characteristics of plants. A rigorous test is proposed of a new climatic index intended to facilitate such studies. The index evaluates climatic parameters as they influence specific *processes* of water utilization by plants, and it is quite distinct from analyses of total water resources available. It is asserted that this approach can substantially improve our understanding of the relationship between climate and photosynthetic processes. In addition, the experiment proposed will address the long-standing controversy over the relative importance of high water-use efficiency verses the conflicting need for rapid utilization of limited and ephemeral water resources in arid environments. The experiments and population libraries (seed-stock) established here will also serve as a foundation for more extensive future work.

***Does project include: No Animals No Human Subjects No Radioisotopes?
Does budget include any computer equipment or software? No

Climatic Variation and Photosynthetic Adaptation in Warm-Desert Plants

**Dr Jonathan Comstock
Biology Department
University of Utah
581-5927**

Table of Contents

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Objectives. The objective of this study is to gain baseline information on the inter-relationships between climatic variation and genetic differentiation in water-use-characteristics of arid-land plants. A little preliminary data has already been collected, but two strongly divergent interpretations can be made. An additional experiment is proposed which, while of substantial interest in itself, is primarily intended to enhance my ability to gain major financial support from outside agencies in two key respects. First of all, I have recently proposed a simple model relating complex climatic variation in temperature and precipitation patterns to specific processes of plant water-use in ecophysiological studies. The validity of this climatic index is strongly supported by available preliminary data, but these data include only a single experiment with a single plant species. Acquiring external funding to test the biological implications of this model will require a more general demonstration of its utility. Secondly, as stated above, two strongly divergent mechanistic interpretations are possible for the patterns of genetic differentiation in water-use characteristics along the described climatic gradient. An experiment is proposed to broaden the preliminary observations to include several species, and to distinguish between the two general interpretations outlined below so that a focused mechanistic study can subsequently be proposed to study the observed patterns. The research topics developed below are of interest from several diverse perspectives including 1) the ecological adaptation of desert plants to key environmental parameters, 2) physiological and morphological integration of plant water-use characteristics, 3) the manipulation of plant water-relations in cultivated arid-land systems, and 4) the mechanistic interrelationship of climatic variation and plant function needed to predict the impact of climate change in arid lands. Given sufficient background data, this project should have a high probability of attaining funding from outside sources in the future.

Theoretical Background.

The linkage of water-loss and productivity. Plant productivity is limited by water-availability in arid regions due to the unavoidable linkage of photosynthetic processes with processes of water loss (Nobel 1983, Stanhill 1986). Transpiration (E ; the rate of water loss from a leaf or plant canopy) is determined as the product of stomatal conductance to water vapor (symbolized as g ; a measure of the degree of opening of stomatal pores in the leaf epidermis), and the diffusion gradient for water vapor (Δw) between the leaf and the surrounding atmosphere.

$$E = g \Delta w$$

Eq. 1

The direction of the diffusion gradient, Δw , is always such as to promote water loss from the leaf (Nobel 1983). This is because air-spaces inside the leaf are always at 100% relative humidity at the leaf

temperature due to the high surface area of wet cell walls and membranes inside the leaf. Transpiration imparts relatively minor direct benefits to a plant, but it is an unavoidable accompaniment to photosynthesis (A), which depends on the capture of atmospheric CO₂ by diffusion through the same stomatal pores.

$$A = \frac{g \Delta c}{1.6} \quad \text{Eq. 2}$$

Δc is the diffusion gradient in CO₂ between the atmosphere (where the concentration is highest) and the leaf mesophyll (where it is consumed in photosynthesis), and 1.6 is a constant reflecting the different diffusivities of H₂O and CO₂ in air. The degree to which arid-land plants should attempt to maximize A in the short term and accept whatever value of E results, versus the degree to which water-use efficiency (W), defined as the ratio A/E, is an important parameter determining successful performance is controversial (Maximov 1931, Cohen 1978, Cowan 1982), and is directly addressed in the proposed research.

$$W = \frac{A}{E} = \frac{g \Delta c}{1.6 g \Delta w} = \frac{\Delta c}{1.6 \Delta w} \quad \text{Eq. 3}$$

Measuring Water-Use Efficiency with Naturally-Occurring Carbon Isotopes. The combined processes of water loss (transpiration, E) and carbon dioxide uptake (photosynthesis, A) are commonly referred to as plant 'gas-exchange'. Earlier studies on variation in leaf-level water-use efficiency were hampered by the difficulty of gas-exchange measurements, and the intractability of large sample sizes and temporal integration. Both of these problems have been overcome by the recent introduction of stable isotopic techniques utilizing natural isotopic abundances. Naturally occurring carbon dioxide in the atmosphere exists as approximately 99% ¹²CO₂, and 1% ¹³CO₂. During photosynthesis, discrimination occurs against CO₂ molecules containing the heavier carbon isotope; this results in a lower ratio of ¹³C/¹²C in plant tissues compared to the atmospheric carbon source (Farquhar, Ehleringer and Hubick 1989). Most importantly, the degree of discrimination which occurs is variable, and it is a direct function of Δc :

$$\text{Carbon Isotope Discrimination} = a + (b-a) \frac{c_i}{c_a} = a + (b-a) \left(1 - \frac{\Delta c}{c_a} \right) \quad \text{Eq. 4}$$

Where a and b are fractionation constants related to diffusional and biochemical events, respectively, and c_a and c_i are the CO₂ concentrations in the atmosphere and internal leaf airspaces respectively ($c_a - c_i =$

Δc ; c_a is relatively constant, so variation in Δc depends primarily on variation in c_i). This means that the levels of carbon isotope discrimination in a plant sample are linearly related to variations in Δc during the period that the carbon sampled was captured from the atmosphere in photosynthesis. When Δw is the same for all plants sampled (Eq 3), levels of discrimination are also linearly related to variation in water-use efficiency. Numerous leaves are typically dried and ground together prior to isotopic analyses, thus yielding discrimination values which give useful spacial and temporal averages for the water-use efficiency of the entire plant canopy.

ω , a new climatic index for studies of plant water-use. I have recently proposed a model for relating climatic variation to specific processes in plant productivity and water-use (Comstock and Ehleringer, in review). This model combines standard calculations from climatology (calculation of potential evapo-transpiration and precipitation sufficiency; Thornethwaite 1948) with standard equations from plant physiology (Eq 1-3; Stanhill 1986), and an understanding of how water availability controls vegetative phenology in arid-land systems (Beatley 1974, Ackerman et al. 1980, Ehleringer 1985, Smith and Nowak 1990, Comstock and Ehleringer in press). This model emphasizes that plants have very limited control over Δw , which, for arid-land plants, is determined primarily by air temperature. The proposed model estimates the growing season of a given site from the monthly ratios of actual mean precipitation (ppt) to potential monthly evapo-transpiration (PET), and uses these monthly ratios of precipitation sufficiency to do a weighted average of the expected Δw gradient in each month of the year.

$$\omega = \frac{\frac{1}{p_{\text{tot}}} \sum_{\text{jan}}^{\text{dec}} \left(p_{w, \text{sat}} \frac{\text{ppt}}{\text{PET}} \right)}{\sum_{\text{jan}}^{\text{dec}} \frac{\text{ppt}}{\text{PET}}} \quad \text{Eq. 5}$$

Where p_{tot} is ambient barometric pressure, and $p_{w, \text{sat}}$ is the saturation vapor pressure at air temperature. If leaf temperature is near air temperature and relative humidity is constantly low, $p_{w, \text{sat}}/p_{\text{tot}}$ is a close estimate of Δw . These assumptions are closely met for typical microphyllous species in North American warm deserts (Gibbs and Patten 1970, Smith 1978, Hidy and Klieforth 1990). ω yields a single mean value for Δw at each site, weighted for those months most likely to support plant growth. This index differs from many climatic indices in that it directly estimates climatic effects on specific physiological processes (Eq. 1&3). Furthermore, ω estimates environmental conditions during the expected growing season as they affect those specific processes, rather than classifying sites along a single resource availability axis

such as absolute levels of aridity, with unspecified relationships to particular plant characters. Assuming constant values for leaf conductance and photosynthesis, variation in ω would cause transpiration rates during the growing season to vary two to three fold along climatic gradients within the warm desert biome of North America (Table 1). This variation is due to variation in both annual and seasonal temperatures, and also variation in total annual precipitation and its seasonal distribution. Based on ω rankings of different sites, genetic variation in water-use characteristics can be predicted, and specific mechanistic hypotheses generated of the expected relationships of plant characters and climatic variation; the robustness of this index, however, has not yet been rigorously determined.

Differentiation of plant water-use characters along gradients in ω .

Current evidence. Preliminary data suggest that ω does indeed accurately predict genetic differentiation in water-use characteristics at the ecotype level for at least one wide-ranging desert species, *Hymenoclea salsola*. *H. salsola* differs in both water-use efficiency (Fig. 1A) and photosynthetic surface area development (Fig. 1B) in a manner predicted by variation in ω , but not predicted by isolated climatic variables such as total annual precipitation, or seasonal patterns of precipitation or temperature alone (Comstock and Ehleringer, in review). The data indicate that, when grown in a common garden, plants originating from high ω populations were more water-use efficient than plants originating from a low ω population. The high ω ecotypes also had less leaf area production and less total photosynthetic area per unit of canopy biomass (Fig. 1B).

Competing interpretations. Two contrasting, mechanistic hypotheses explaining the observed dependence of water-use characteristics on ω can be formulated. These hypotheses are strongly divergent not only in proposed underlying mechanisms, but also in the experimental procedures required to embark upon more detailed studies. It is thus highly desirable to distinguish between them in a preliminary experiment.

Theoretical Hypothesis 1) Genetic differentiation resulting from natural selection acts directly to reduce variation in water-use-efficiency (A/E) otherwise expected with geographic variation in evaporative demand (ω). This hypothesis recognizes water availability as the single factor imposing the most stringent limitations on plant productivity, and asserts that water within the soil volume occupied by a specific plant root system can be effectively hoarded. Critical to the implications of this hypothesis is the fact that stomatal closure increases water-use efficiency, but decreases the absolute rates of both A and E (Fig 2). Higher A/E in high ω ecotypes would be achieved at the cost of lower Δc and lower absolute rates of photosynthesis. The ability of arid-land plants to translate a higher water-use-efficiency into higher

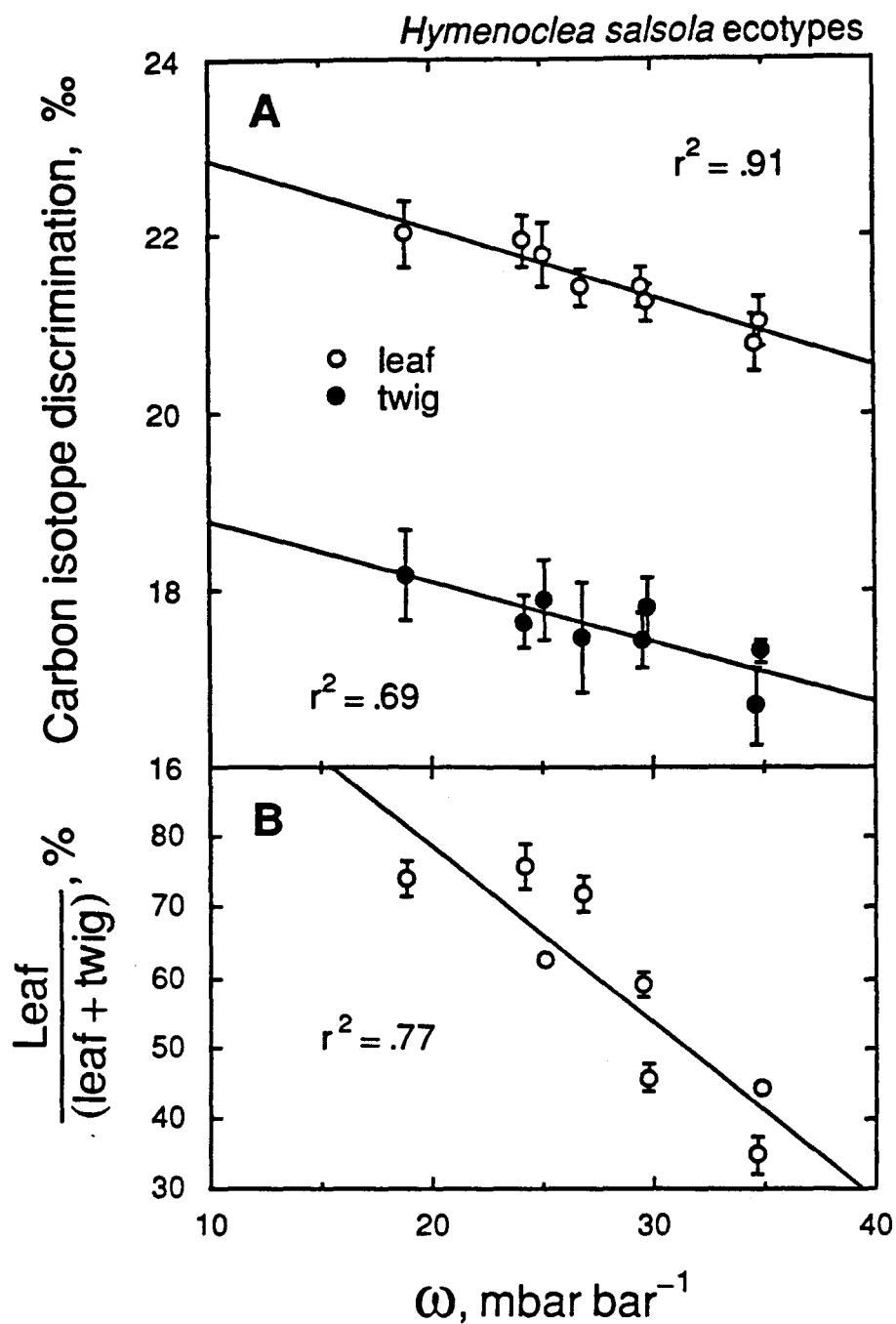


Fig. 1. The relationships between climatic variation in ω across the sites of population origin and the expression of traits affecting water relations under common garden conditions. Regression lines are based on the mean value for plants from each population in the common garden, and error bars represent ± 1 se. A) Tissue-level variation for carbon isotope discrimination in leaves and twigs. The lines indicated are the least-squares best-fits: Discrimination (leaf) = $23.6 - .078 \omega$ ($p < 0.001$), and Discrimination (twig) = $19.4 - .068 \omega$ ($p < 0.01$). B) Variation in leaf contribution to total canopy surface area. Leaf area development is expressed as the percentage of the total photosynthetic surface area (combined leaves and twigs) in the canopy contributed by leaves alone. Relative leaf area, % = $128.5 - 2.5 \omega$ ($p < 0.005$).

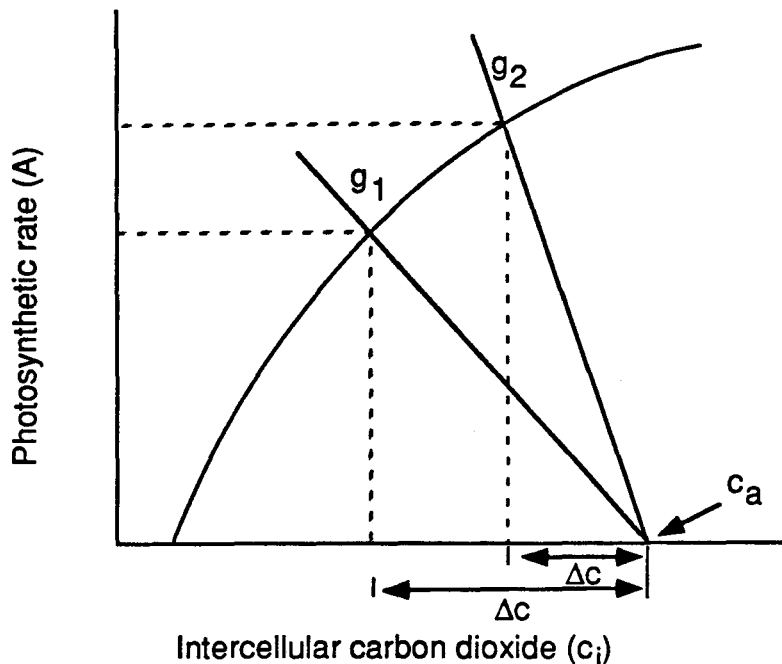


Figure 2. The relationship between stomatal conductance (g), photosynthesis (A), and water-use-efficiency (WUE). When photosynthesis is plotted against the internal carbon dioxide concentration, the curve is referred to as a "demand function" (Farquhar and Sharkey, 1982). The "supply function" is a straight line representing the diffusional limitation of carbon dioxide supply from the atmosphere. The slope is equal in magnitude to g (but opposite in sign). The intersection of supply and demand curves gives a graphical solution for both A and intercellular carbon dioxide concentration predicted for that combination of biochemical capacity and stomatal conductance. If biochemical capacity is held constant, but g increases from g_1 to g_2 , A increases because intercellular carbon dioxide increases and becomes less limiting to the biochemistry. Water-use-efficiency, however, decreases. This occurs because both carbon dioxide and water vapor diffuse through the same stomatal pathway, and the increase in transpiration (E) with increasing g is greater than that of A . The photosynthetic gain with stomatal opening depends on reduction of the carbon-dioxide gradient (Δc) between leaf and atmosphere. In contrast, the gradient for water loss (Δw) is, to a first approximation, independent of g . Thus WUE depends on the relative magnitudes of Δc and Δw , and it is therefore negatively correlated with A when variation is due to stomatal aperture.

$$WUE = \frac{A}{E} = \frac{g \Delta c}{1.6 g \Delta w} = \frac{\Delta c}{1.6 \Delta w}$$

seasonal biomass production would depend on whether they are actually able to use conserved water at future dates, and the environmental conditions at the end of the season when saved water extends the growing season (Fischer and Turner 1978, Cohen 1978, Cowan 1982). Evaluating such patterns would involve extensive field work measuring seasonal courses of water inputs by precipitation and the storage capacity of the soil within the rooting zone, and measuring seasonal water losses by a) soil evaporation, b) transpiration by competing plants, and c) water consumption and water-use efficiency by the target subject. Plants are hypothesized to be genetically adapted in gas exchange characters affecting Δc (leaf conductance relative to photosynthetic capacity; Eq. 1-3, Fig 2) . In the source populations, which differed in Δw , this genetic differentiation would have acted to reduce variation in water-use efficiency. In a common garden experiment where Δw is constant for all population collections, the genetic differentiation would be phenotypically expressed as a difference in water-use efficiency due to variation in Δc (Eq 3). Thus the pattern observed in Fig 1A is consistent with this hypothesis.

Theoretical Hypothesis 2) Genetic differentiation resulting from natural selection has produced plants which are adapted to maximize short-term rates of productivity under the most likely growing conditions of their respective sites. Optimal water-use efficiencies may be too unpredictable and too difficult for a plant to control in the face of widely fluctuating temperatures for natural selection to act on this character directly in response to climatic variation (Ehleringer Philips and Comstock in review). If, in addition, water cannot be effectively hoarded because of interplant competition and soil-surface evaporation, then the highest productivity will be achieved by maximizing photosynthesis during the brief periods of resource availability, even though such maximization involves low instantaneous water-use efficiency at the leaf level (Maximov 1931, Cohen 1978, Smith and Nowak 1991) . Each plant should maximize absolute rates of water use rather than water-use efficiency in order to capture and use as much of the limited water resource as possible before soil drying ends the growing season. Variation in expected evaporative demand among different sites will select for diverging suites of plant characters which permit immediate rates of photosynthesis and productivity to be as high as possible during the contrasting growing season conditions of the respective sites (Fig 3 & 4). Low ω ecotypes are then predicted to have higher photosynthetic surface-area development (leaf area) per unit of root uptake and stem transport capacity for water (low leaf-specific hydraulic conductivity), and higher maximal stomatal conductances per unit of canopy surface area. These plant features take advantage of the expected, low evaporative demand to maximize capture of light and CO_2 , but transpiration rates exceeding uptake and transport capacities will result in rapid stomatal closure limiting photosynthesis under high Δw conditions. In contrast, high ω ecotypes are predicted to have reduced photosynthetic surface area development and lower maximal stomatal conductances, but will have a greater capacity for water uptake and transport per unit of canopy (high hydraulic conductivity). These characters result in a high leaf-specific hydraulic conductivity, and will permit higher rates of photosynthetic activity under high Δw conditions. This hypothesis would best be

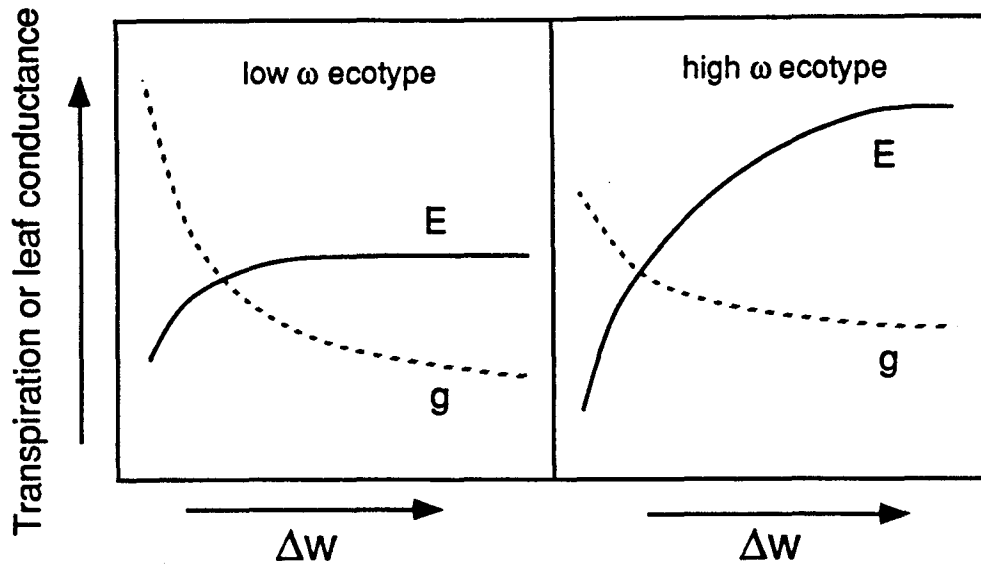


Fig. 3. The hypothesized responses of stomatal conductance (g) and transpiration rate (E) to variation in the tissue-to-air humidity gradient (Δw). The x-axis indicates immediate response to changes in ambient Δw , and the two panels indicate the effects of ecotypic differentiation to climates differing in expected mean Δw during the growing season (high and low ω). The low ω ecotype, genetically adapted to functioning at low Δw , operates with very high leaf conductance at low Δw , but hydraulic limitations force rapid stomatal closure as Δw increases, and the maximal transpiration rate is low. The high ω ecotype, adapted to function at high Δw , has a low maximal stomatal conductance, but has a higher hydraulic conductivity per unit of canopy, allowing stomata to remain open in the face of decreasing Δw . It is capable of sustaining higher maximal transpiration rates per unit of canopy.

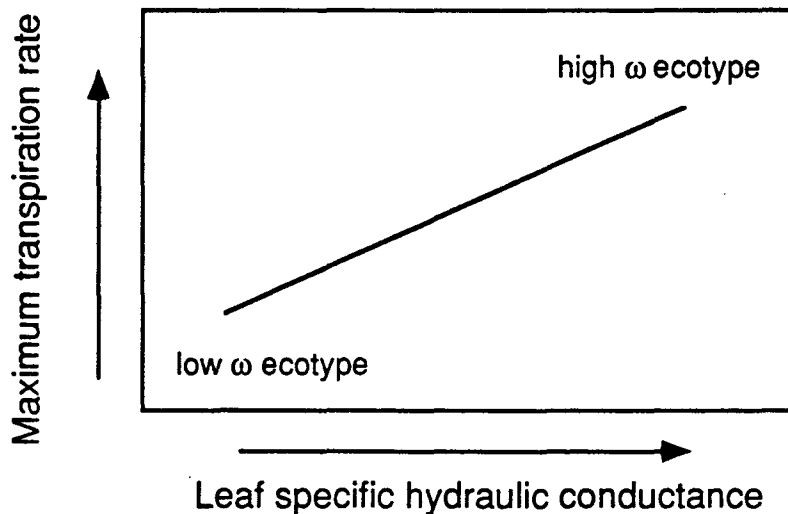


Fig. 4. Maximum transpiration rate is conjectured to depend on the magnitude of leaf-specific hydraulic conductance (the ratio of (leaf area) : (root and stem water transport capacities)). Hydraulic limitations therefore play a fundamental role in ecotypic differentiation. The proposed gas exchange patterns of the upper two panels are based on known reductions in photosynthetic surface area production (Fig 1B) and possible increases in hydraulic capacity resulting in substantially higher leaf-specific hydraulic conductance in high ω ecotypes.

tested under greenhouse and laboratory conditions measuring ecotypic differences in allocation patterns between root and shoot systems, and how these different allocation patterns affect hydraulic conductance of root and stem systems and whole-plant photosynthetic performance under contrasting environmental conditions. Since the common garden study (Fig 1) was conducted at a low ω site (low Δw growth conditions), both hypotheses 1 and 2 predicted that water-use efficiency should have been lowest in the low- ω ecotypes. Both hypotheses are thus consistent with existing data.

Proposed Experiment.

Experimental Hypothesis. If selection has acted primarily on instantaneous, leaf-level water-use efficiency, water-use-efficiency rankings of different ecotypes will be stable and independent of the experimental growth conditions (each ecotype may respond to environmental conditions, but the relative ranking will not change), but, if selection has acted primarily to maximize immediate rates of photosynthesis under contrasting conditions, water-use efficiency rankings will be labile in response to experimental growth conditions, with low ω ecotypes being least water-use efficient in a low Δw growth environment, and high ω ecotypes least water-use efficient in a high Δw growth environment. These contrasting predictions make it possible to provide support for either theoretical hypothesis 1 or 2 in a single modest experiment prior to a more major investment of experimental resources. The 1st general hypothesis states that selection has acted directly on water-use-efficiency (A/E, eq 1&2). The ranking of water-use-efficiencies among genetically distinct populations grown in a common environment should then be constant, and largely independent of growth conditions within boundaries set by avoiding lethal or damaging extremes. In contrast, the second general hypothesis suggests that each ecotype is adapted to maximize photosynthetic rates under conditions similar to its climate of origin, and that water-use efficiency differences are an indirect effect of selection on related characters. Maximal immediate productivity in each case involves low water-use efficiency (Fig 2), and the ranking of water-use efficiency for plants from contrasting sites should then be labile, and dependent on growth conditions. Grown in a low Δw environment, low ω ecotypes will have the highest photosynthetic rates and the lowest water-use efficiencies, but, when grown in a high Δw environment, low ω ecotypes will be forced to close their stomata due to insufficient water uptake and transport capacity (hydraulic conductance) and high ω ecotypes will then have higher photosynthetic rates and lower water-use efficiencies.

Experimental Design. To establish the validity of ω as a climatic index in physiological studies, and to distinguish between the two theoretical hypotheses described above before embarking on a more exhaustive mechanistic study, funds are requested for a seed collecting trip to include at least 17 sites scattered across the Mojave and Sonoran Deserts, and chosen to maximize the range in ω (Table 1), and

Table 1. Sites from diverse geographic locations in the Sonoran and Mohave Deserts and some descriptive climatic parameters. ω is a derived variable (Eq 5) which estimates the expected leaf to air humidity gradient for microphyllous desert shrubs. The most important single climatic variable affecting the magnitude of this gradient is mean air temperature, but total annual precipitation and its seasonal distribution are also both important in determining the temperature of the actual growing season. The values of ω shown here are somewhat lower than the range indicated in Fig 1 because they are based on mean daily temperatures rather than maximum daily temperatures. This difference in calculation merely reflects readily accessible climate data for different regions. While the choice of mean verses maximum temperature makes a large difference in the absolute range of computed ω values, it makes almost no difference in the ranking of different sites.

Site	annual precip. mm	summer precip. %	annual temp. °C	ω mbar bar ⁻¹
Mina (Nv)	92.5	26.6	12.1	10.7
Silver Peak (Nv)	83.8	26.7	11.9	10.8
Bishop (Ca)	148.3	8.9	13.4	11.4
Haiwee (Ca)	128.8	6.1	15.1	12.1
Trona (Ca)	102.1	10.9	19.0	13.3
Lathrop Wells (Nv)	74.7	13.6	17.9	13.6
Joshua Tree Nat. Area (Ut)	42.8	28.1	15.2	14.1
Rhodes Hill (Death Valley, Ca)	113.3	32.5	17.8	14.5
Oatman (Az)	199.7	32.7	18.9	16.7
Parker Dam (Az)	97.0	29.6	22.5	17.6
Palm Spring (Ca)	159.5	13.5	22.0	17.7
San Luis Gonzaga (Mexico)	48.8	13.7	23.5	18.1
Vizcaino (Mexico)	79.8	27.1	18.8	18.5
Silver Bell (Az)	253.8	48.7	20.8	20.8
Organ Pipe Nat. Mon. (Az)	232.9	49	20.6	20.8
San Filipe (Mexico)	56.7	37.4	24	22.9
Santa Rosalia (Mexico)	104.5	56.1	23.6	25.8

to carry out one greenhouse experiment. The number of collection sites may at first appear to be redundant, but, to adequately test the robustness of ω , it is necessary to have several sites with the same ω which yet differ in other climatic parameters. For example, by definition high ω sites have high growing season temperatures, but these are found in response to variation in three separate climatic variables: 1) high annual mean temperature 2) high % of summer precipitation emphasizing the warmer months as the growing season or 3) high total annual precipitation which extends the growing season into the late spring and early summer. By having sites which are redundant in the value of ω but divergent in these contributory climatic parameters the relationship between biological variation and ω can be clearly distinguished from other climatic parameters. The primary target species for seed collection will be *Encelia Farinosa*, *Ambrosia dumosa*, *Porophyllum gracile*, *Bebbia juncea*, and *Salizaria mexicana*, although efforts will be made to obtain seed collections for as many species as possible. In addition to pursuing the mechanisms of hypotheses 1 & 2 above, future projects that could build from the current study might include such questions as how these climatic effects on ecotypic differentiation differ among different plant lifeforms (ie annual & perennial, tree & shrub, drought-deciduous & evergreen) and how within-population genetic variation for these traits may vary between extreme and intermediate environments. Seed collections will be made in such a way that they lay groundwork for such future projects as well as the current study. The primary target species listed above are typical drought-deciduous desert species which frequently occur on the same sites, and were also chosen for their common spring flowering phenology which should make it possible to collect seed for all species on a single collection trip beginning with the southernmost sites and working northward. Not all species will be found at each site, but all species have sufficiently broad geographic ranges (from the border of the Mojave and Great Basin Deserts in Utah and Nevada across the Mojave Desert in California and down into the Sonoran Desert of Arizona and Northern Mexico) to occur on sites differing substantially in ω . The collection trip is anticipated to require four to six weeks beginning in May and ending in June. This allows for long-distance travel, extensive site exploration (it is highly desirable to find sites where several of the key species co-occur, and which are close enough to meteorological stations to accurately calculate ω), careful seed-collection of as many species as possible, and the possible need to visit some sites more than once if seed maturation of different key species is not synchronous.

Plants will be grown from these seed collections in the greenhouse at the Biology Department of the University of Utah. Five populations spanning the greatest possible range in ω will be chosen for each of the target species listed above and grown under two contrasting environmental temperatures. The maximum daily temperatures will be 25 and 34 °C in the two treatments respectively. These maximum temperatures both allow photosynthetic rates for warm desert plants within 90% of those at the temperature optimum for photosynthesis (Comstock and Ehleringer 1988; Ehleringer 1985), or even lie within the range of acclimation of the temperature optimum to growth conditions (Berry and Björkman

1980). Nonetheless, *these growth environments will differ 2.5-fold in Δw* . The five target species will all be grown under both temperature regimes. *After three months of growth, six plants representing each source population will be harvested from each environment (the plants will actually be analyzed as two bulked samples of three individuals each)*. The plants will be measured for carbon isotope ratio and leaf area development/unit plant biomass. The number of carbon isotope samples needed will be five species * five populations * two bulked samples of three individuals each * two growth treatments = 100 samples. The data will be analyzed to answer 2 major questions: 1) Do unrelated species with similar geographic ranges show parallel adaptation in water-use characteristics in response to climatic gradients as expressed by ω ? and 2) Are the rankings of different populations within a species for genetic variation in Δc and hence water-use efficiency fixed (as predicted by hypothesis 1 above), or do they change as a function of growth temperature and Δw (as predicted by hypothesis 2). These will be important results in their own right, but will also provide a strong foundation for applying for extensive outside funding to examine the detailed mechanistic relationships underlying the observed patterns of geographic differentiation.

Conclusions

The conceptual approach employed in this study incorporates some major innovations with substantial contributions to be made to the study of plant adaptation and plant performance in arid regions. While many studies have focused on the size and quality of key resource bases such as annual precipitation, ω evaluates the environmental conditions which influence the *processes* of resource utilization. These two approaches can lead to fundamentally different expectations! Very low annual precipitation, for example, if seen as a limiting resource base, might lead to predictions of conservative water use and plant characteristics such as low maximal stomatal conductance. In strong contrast, calculation of ω for a site with very low annual rainfall yields a low value for expected growing season Δw because only the cool winter months (winter months in the warm desert are all warm enough to support growth) have enough moisture to support substantial growth (high ratio of precipitation:potential evapo-transpiration). Based on ω we predict that extremely arid sites will have plants with photosynthetic physiology specialized to take advantage of the brief winter and early-spring growing season under cool mild conditions, and to have characteristics such as very high maximal stomatal conductance. Thus ω is an index which lends itself to process-oriented studies, and it can potentially contribute substantially to understanding both native and cultivated plant systems in arid regions. This is not to suggest that the size of the resource base is unimportant to overall plant performance; total water availability is expected to have profound effects ranging from differing life-history patterns and plant habits to community structure (Shantz 1927, Mac MacMahon and Schimpf 1981, Fowler 1986). Resource abundance may not be the most insightful parameter, however, in understanding variation in those plant characters most directly involved in the

actual processes of photosynthesis. The work outlined above constitutes a critical test of the new index, ω , and will also provide a key test on the importance of water-use-efficiency per se as a factor in the ecotypic differentiation of arid-land plants.

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IV. Additional Information

Applicant's qualifications.

I am currently an Assistant Research Professor in Biology at the University of Utah. As a researcher scientist, my career has been focused on the morphological and eco-physiological specializations of desert plants. I have extensive field and laboratory experience evaluating the water relations and photosynthetic performance of both warm and cold desert plants. All techniques to be employed in these studies are familiar to me from past work and present no technical difficulties. This proposal represents an attempt to identify more general principles controlling plant performance in these systems, and its contribution will be conceptual rather than technical.

Most Relevant Publications:

- Comstock, J. and J. Ehleringer. 1984. Photosynthetic responses to slowly decreasing leaf water potentials in *Encelia frutescens*. *Oecologia* (Berl.) 61: 241-248.
- Comstock, J. 1985. Photosynthesis and canopy responses to water status. Masters Thesis. University of Utah.
- Comstock, J. and J. Ehleringer. 1986. Canopy dynamics and carbon gain in response to soil water availability in *Encelia frutescens* Gray., a drought-deciduous shrub. *Oecologia* (Berl.) 68: 271-278.
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- Ehleringer, J., J. Comstock, and T. Cooper. In review. Seasonal variation in carbon isotopic composition and water-use efficiency of desert shrubs. *Functional Ecology*.
- Comstock, J. and J. Ehleringer. in prep. Genetic variation in stomatal sensitivity to atmospheric water deficits and water-use efficiency in common bean.

Past and Present Funding for the proposed work.

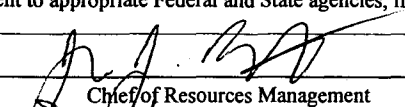
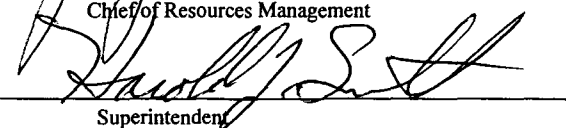
The proposed work neither has previously been nor is it currently funded. The very limited data shown in Fig 1 were derived from my PhD. A proposal submitted by me through the University of Utah and currently under review by NSF (The role of Hydraulic Limitations in Aridland Shrubs) deals with some of the putative mechanistic relationships between photosynthetic performance and hydraulic conductance discussed under "competing interpretations:hypothesis 2" pg 5 in this proposal. However, the NSF grant, even if funded, contains no allotment for travel and seed collection, deals only with the single species *Hymenoclea salsola*, and will not provide a robust test of my proposed climatic index, ω . Thus, the two proposals have only minor overlap in concept and experimental design, no overlap in cost outlays, and will not substitute one for the other even in the event that both are funded. The demonstration of a general utility to the ω index is a distinct research goal unaddressed in the larger NSF grant, and would make possible future research directions that a successful completion of the NSF proposal alone would not. I am not currently funded for any other projects.

APPLICATION FOR PERMISSION TO CONDUCT SCIENTIFIC RESEARCH / COLLECT SPECIMENS

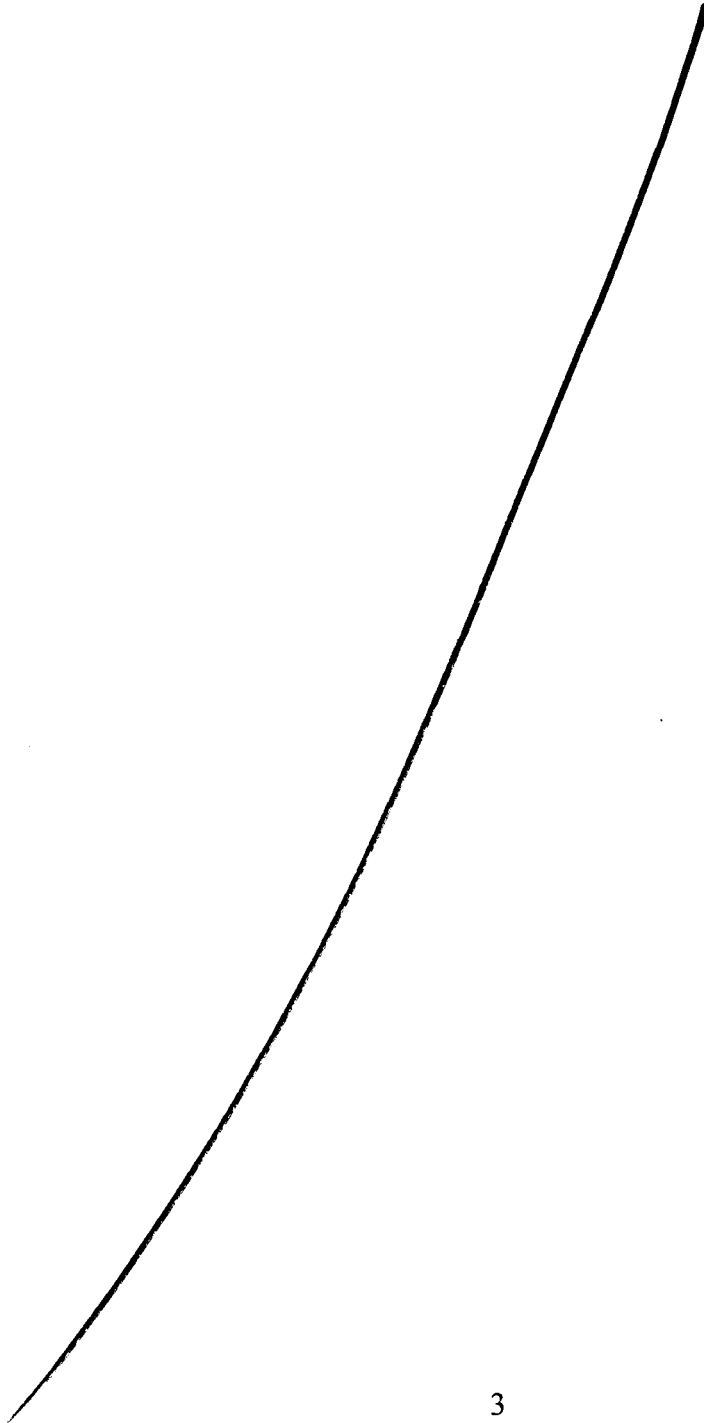
Name of Area:	Organ Pipe Cactus National Monument	Date:	2/22/95
Name of Applicant:	Dr. Jonathan Comstock	Assistants:	None
Address:	Boyce-Thompson Institute Tower Road		
City, State Zip Country	Ithaca, NY 14857		
Phone Number:	(607) 254-1214		
Representing (Name of Institution):	Boyce-Thompson Institute		
Period of Collecting	from: 01/01/95 to: 12/31/95		
Specimens to be Collected (Type and Quantity):	Seeds from up to 25 individuals each of the following plants: Encelia farinosa, Ambrosia deltoidea, Porophyllum gracile, Bebbia juncea, Hymenoclea salsola, and Salizaria mexicana <i>Collecting plant parts of above species, and placing metal tags on study sites / plants.</i>		
Other Applicable Collection Permits:			
Federal:	As Appropriate	State:	As Appropriate
Research Topic / Reason for Collecting in this Area:	Climatic variation and photosynthetic adaption in warm desert plants (PROPOSAL AND DOCUMENTATION ON FILE)		
Place Where Specimens are to be deposited (See 36 CFR, Chap.1, Sect. 2.5(g)(1):	Specimens will be deposited in the ORPI museum. Collected specimens (not destroyed by analysis), copies of all field notes, and other pertinent information regarding the project are to be provided to the Monument Curator. Approval must be obtained from the Superintendent to deposit specimens in collections outside the Monument.		
I, the applicant, having read the conditions attached to the permit relating to research and collections within area administered by the Western Region of the National Park Service, agree that, if the permit is granted, I will comply with all the conditions stated therein.			

Signed: _____ Date: _____

DO NOT WRITE BELOW THIS LINE -- TO BE FILLED IN BY ISSUING OFFICE ONLY

Approved For Collecting the Following Specimens (Type and Quantity):	Seeds from up to 25 individuals each of the following plants: Encelia farinosa, Ambrosia deltoidea, Porophyllum gracile, Bebbia juncea, Hymenoclea salsola, and Salizaria mexicana		
Locality of Collecting Limited To:	Organ Pipe Cactus National Monument		
Permit Number:	ORPI-95-04		
Special Conditions or Restrictions:	Abide by permit stipulations	Expiration Date:	12/31/95
Copies of this permit sent to appropriate Federal and State agencies, if applicable:	☒ YES ☐ NO		
Recommended By:	 Chief of Resources Management	<u>3/5/95</u> Date	
Approved By:	 Superintendent	<u>3/6/95</u> Date	

should be made to reduce fire hazards and reduce or eliminate fire risks?



Organ Pipe Cactus National Monument
United States Department of the Interior
National Park Service, Western Region

RECEIVED
Organ Pipe Cactus N. M.

1514'92

APPLICATION FOR PERMISSION TO CONDUCT SCIENTIFIC RESEARCH/
COLLECT SPECIMENS OF PLANTS, ROCKS, MINERALS AND ANIMALS

Name of Area: Organ Pipe Cactus National Monument

Date: 01/31/92

✓	SUPERINTENDENT
✓	ADMIN. TECHN.
✓	CH. RANGER
✓	CH. RES. MGMT.
✓	MAINT.
✓	INTERP. SPEC.
✓	FILE

Name of Applicant: Dr. Jonathan Comstock
Department of Biology
University of Utah
Salt Lake City, UT 84112

Representing (Name of Institution): University of Utah

Period of Collecting: 01/31/92 - 12/31/92

Specimens to be Collected: Seed collection of various type desert plant species. Any collecting of seeds must first be cleared with the Superintendent at the time of field work. Specific species and location of collection must be given.

Other Applicable Collection Permits:

Federal: N/A

State: N/A

Research Topic/Reason for Collecting Within this Area: Seed collection to study climatic variation and photosynthetic adaptation in warm desert plants.

Place Where Specimens are to be Deposited (See 36 CFR, Chap. 1, Sect. 2.5(g)(1): Copies of all field notes and other pertinent information for seed collection and research results are to be provided to the Monument Curator. Approval must be obtained from the Superintendent to deposit specimens in collections outside of the Monument.

I, the applicant, having read the conditions attached to the permit relating to research and collections within areas administered by the Western Region of the National Park Service, agree that, if the permit is granted, I will comply with all the conditions stated therein.

Signed: _____

Date: 2/11/92

TO BE FILLED BY THE ISSUING OFFICE
DO NOT WRITE BELOW THIS POINT

Approved for collecting following Specimens (Type and Quantity): Seed collection of various type desert plant species. Any collecting of seeds must first be cleared with the Superintendent at the time of field work. Specific species and location of collection must be given.

Locality of Collecting Limited To: Organ Pipe Cactus National Monument

Permit No.: ORPI-92-12

Expiration Date: 12/31/92

Special Conditions or Restrictions: Abide by permit stip. Specimens collected in the Monument and placed in a permanent collection outside of the monument, upon approval of the Superintendent, will include the Monument name as part of the locality of collection on labels and will be cataloged into the National Park Service National Catalog by the National Park Service using data provided by the collector.

Copies of this permit sent to appropriate State and other Federal agencies, if applicable: Yes _____ No _____

Recommended By:

James J. Bell
Chief of Resources Management

2/5/92
Date

Approved By:

Donald J. Smith
Superintendent

2/5/92
Date

APPLICATION FOR PERMISSION TO CONDUCT SCIENTIFIC RESEARCH / COLLECT SPECIMENS

Name of Area:	Organ Pipe Cactus National Monument	Date:	2/22/95
Name of Applicant:	Dr. Jonathan Comstock	Assistants:	None
Address:	Boyce-Thompson Institute Tower Road		
City, State Zip Country	Ithaca, NY 14857		
Phone Number:	(607) 254-1214		
Representing (Name of Institution):	Boyce-Thompson Institute		
Period of Collecting	from: 01/01/95 to: 12/31/95		
Specimens to be Collected (Type and Quantity):	Seeds from up to 25 individuals each of the following plants: Encelia farinosa, Ambrosia deltoidea, Porophyllum gracile, Bebbia juncea, Hymenoclea salsola, and Salizaria mexicana <i>Collecting plant parts of above species, and placing metal tags on study sites / plants.</i>		
Other Applicable Collection Permits:			
Federal:	As Appropriate	State:	As Appropriate
Research Topic / Reason for Collecting in this Area:	Climatic variation and photosynthetic adaption in warm desert plants (PROPOSAL AND DOCUMENTATION ON FILE)		
Place Where Specimens are to be deposited (See 36 CFR, Chap.1, Sect. 2.5(g)(1):	Specimens will deposited in the ORPI museum. Collected specimens (not destroyed by analysis), copies of all field notes, and other pertinent information regarding the project are to be provided to the Monument Curator. Approval must be obtained from the Superintendent to deposit specimens in collections outside the Monument.		
I, the applicant, having read the conditions attached to the permit relating to research and collections within area administered by the Western Region of the National Park Service, agree that, if the permit is granted, I will comply with all the conditions stated therein.			

Signed: _____ Date: _____

DO NOT WRITE BELOW THIS LINE - TO BE FILLED IN BY ISSUING OFFICE ONLY

Approved For Collecting the Following Specimens (Type and Quantity):	Seeds from up to 25 individuals each of the following plants: Encelia farinosa, Ambrosia deltoidea, Porophyllum gracile, Bebbia juncea, Hymenoclea salsola, and Salizaria mexicana		
Locality of Collecting Limited To:	Organ Pipe Cactus National Monument		
Permit Number:	ORPI-95-04		
Special Conditions or Restrictions:	Abide by permit stipulations	Expiration Date:	12/31/95
Copies of this permit sent to appropriate Federal and State agencies, if applicable:	☒ YES ☐ NO		
Recommended By:	<i>[Signature]</i> Chief of Resources Management	<i>3/5/95</i> Date	
Approved By:	<i>[Signature]</i> Superintendent	<i>3/6/95</i> Date	

8. Funding

FUNDING

ORPI-I-104 Monitor and Control Trespass Grazing	YEAR IN PROGRAM SEQUENCE			
	1st	2nd	3rd	4th
Contract	30,000	0,000	0,000	0,000
Personnel Services	1,800	1,800	1,800	1,800
Other	1,000	1,000	1,000	1,000
TOTAL	32,800	2,800	2,800	2,800
Funds Available in Park Base	0,000	0,000	0,000	0,000
Additional Funds Needed	32,800	2,800	2,800	2,800