

TITLE: Ecology of riparian communities adjacent to tinajas:
impacts of livestock in Capitol Reef National Park.

OBJECTIVES:

1. To characterize the physical ecosystem components of four representative tinaja systems:
 - A. To describe all tinaja basins to be compared:
tinaja basin volume and surface area.
pool maximum volume and maximum surface area.
riparian zone surface area and soil volume.
 - B. Soil profiles--particle size categories, soil horizon development.
 - C. Soil chemistry--pH, conductivity, total and available N, P, K, total and organic C.
 - D. Soil water content--followed through year, correlate with tinaja drying cycles, and transpiration of riparian vegetation.
 - E. Insolation--available photosynthetic radiation.
 - F. Temperature, humidity--"in riparian zone," "out of riparian zone."
 - G. Precipitation--describe each drainage fairly completely: area, substrate. measure precipitation at top of one or two systems, and near tinajas studied in all systems.

2. To characterize the biotic ecosystem and community components of the riparian zones of four representative tinaja systems:
 - A. Identify the species (where possible), guilds, and functional groups of organisms using tinaja riparian zones: plants, animals, and micro-organisms.
 - B. Identify how each group depends on tinajas (food, moisture, shelter, etc.).
 - C. Identify interactions centered around tinajas between organisms in riparian communities (e.g., plant-herbivore, predator-prey, etc.).
3. To assess the effects of cattle on tinaja riparian ecosystem.
4. To estimate the role of tinaja riparian zones in the overall ecology of the Waterpocket Fold.

HYPOTHESES:

Because the ecology of tinajas and tinaja riparian zones is essentially unknown, this project will concentrate on gaining an understanding of tinaja riparian zone ecology, primarily through observation, not manipulation. The impact of cattle on tinaja riparian zones can be assessed by manipulating cattle use. The following hypotheses are formulated based on preventing cattle from using selected tinajas and their associated riparian zones.

Ho: Removal of cattle will not affect:

1. primary production of riparian vegetation.
2. plant species diversity.
3. architectural characteristics of riparian vegetation.
4. invertebrate species diversity and/or use patterns.
5. vertebrate species diversity and/or use patterns.
6. soil chemistry and/or physical structure of riparian soils.
7. soil biota.
8. community interactions and/or structure.
9. physical environment around tinaja (temp., insolation, rel. humidity, etc.).

Impact of livestock on tinaja riparian zones will be considered significant and adverse for each hypothesis if the null hypothesis is rejected at $p \leq 0.05$.

The National Park Service was established primarily to protect and preserve ecosystems in their natural, climax condition, or to allow them to develop toward climax without unnatural intervention. Man-caused perturbations of ecosystems in National Parks are inconsistent with National Park management goals, and should be avoided whenever possible. Any man-caused action that tends to move these natural ecosystems away from climax, or alters the environment in such a way that a different climax community becomes established is considered a negative action. An adverse impact, then, is any impact that changes any ecosystem in a park, or some component of an ecosystem in an unnatural manner, thus interrupting successional processes, whether on a temporary or a permanent basis.

JUSTIFICATION:

The Waterpocket Fold of Capitol Reef National Park (CARE) is currently being grazed by cattle during winter months (October to April) in accordance with PL 97-341. This law states that grazing will continue in CARE at least until 1992, during which time studies of the impacts of cattle and cattle grazing on the ecology and visitor enjoyment of CARE will be conducted. The National Academy of Sciences (NAS) recommended ten studies (NAS 1984), including one titled "Livestock grazing impacts on riparian areas." The objectives of this recommended study were to:

1. Characterize the historical composition and structure of riparian areas.
2. Locate riparian areas and determine current water quality, riparian vegetation, aquatic life, erosion, and aesthetics.
3. Assess the impact livestock have had on riparian areas.
4. Evaluate management strategies to minimize livestock impact on riparian areas.

Tinajas are eroded depressions in bedrock, carved by water, and/or wind action, that act as water catchments in arid and semiarid lands (Elston 1917). Tinajas are also known as waterpockets, potholes, tanks, plunge pools, as well as a number of other names (Brown and Johnson 1983). Waterpocket Fold, the east flank of the Circle Cliffs anticline in south central Utah, was named after the abundant tinajas in the Navajo and Wingate sandstones along the Fold. Most of this steep, uplifted region is included in CARE.

The relative permanence of a tinaja depends on tinaja size (volume and area/volume ratio), size of bedrock catchment area, protection (e.g., shading), and proportion of basin volume displaced by sediments (Brown and Johnson 1983). Plant abundance near the tinaja (size of tinaja riparian zone) also affects tinaja longevity (pers. observation): increasing water loss through transpiration, and/or decreasing water loss by shading when trees are present.

Tinajas represent the primary source of water for wildlife, backcountry users, and cattle along the Waterpocket Fold at the south end of CARE. Subjective comparisons of tinajas cattle have

access to, with tinajas inaccessible to cattle indicate that cattle have a strong impact on riparian zones around tinajas. Subjective impressions carry little weight in trying to convince Congress that cattle have adverse effects on the natural ecosystems in CARE. To accurately document the impacts of cattle, changes in riparian zones must be quantified.

Ecological studies of tinajas and tinaja riparian systems can be used to examine various theories in ecology such as island biogeography and the structuring of communities by competition and/or predation. The role of tinajas and tinaja riparian zones in the overall ecology of the Waterpocket Fold region is unknown, but these small systems probably export biomass to the surrounding terrestrial systems (Bunch and Fisher 1984). Thus, there are sound ecological reasons for studying the tinaja riparian zones, and tinajas of the Waterpocket Fold. In addition, the impact of livestock on ecosystems and communities in CARE must be assessed and documented (PL 97-341).

Quantitative studies of the ecology of tinajas and their associated riparian zones with and without cattle, along with recovery experiments by excluding cattle from selected tinajas can provide conclusive data concerning the impacts of livestock on these important components of Capitol Reef National Park.

Information on the ecology of tinajas is almost nonexistent. A few "preliminary surveys" have been done on the Colorado Plateau (e.g., ^{aquatic - Grand Canyon} Kingsley 1984, ^{aquatic - mosquitos} Lindahl 1977 ^{aquatic - 607} Romney 1971), but little ecological work has been done (c.f., Dodson, in prep.). Inferences from studies of the same or related species in other

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bodies of water (e.g., Svensson 1985, Johnson et al. 1985, Thorp and Cothran 1984, Wilbur and Alford 1985) are limited because conditions in these studies are quite different from the environment of tinajas on the Colorado Plateau. Predictions of tinaja ecosystem responses to perturbations (e.g., cattle) cannot be based on studies from other areas.

There have been no specific studies of riparian zones around tinajas on the Colorado Plateau or elsewhere. Ecological interactions may be similar to riparian zones around other small, lentic systems, but significant differences in climate and other environmental variables limit the applicability of studies of such systems to the ecology of tinaja riparian zones. In particular, the responses of tinaja riparian ecosystems to disturbance (e.g., cattle grazing) cannot be accurately predicted based on studies of riparian zones in other environments (e.g., Whyte and Cain 1981, Hoffman and Stanley 1978, Szaro and Pase 1983).

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Tinaja ecology is currently being studied in CARE (Waterpocket Ecology Study, Terry Boyle, NPS and Colorado State University). It is important to learn what role tinaja riparian systems play in linking tinajas to the terrestrial ecology of the Waterpocket Fold region. Aquatic and terrestrial ecosystems should be studied together to gain a complete understanding of both systems, and their relationships (Likens and Bormann 1974). The proposed project will provide important information on the link between the ecology of tinajas and the terrestrial ecology of the Waterpocket Fold. These studies will also provide quantitative data on the effect of cattle on tinajas and tinaja

riparian zones, and recovery from cattle impacts once the cattle are removed. These data will result in a better understanding of the effects of livestock on Waterpocket Fold ecology in CARE.

LITERATURE REVIEW

Very little is known about the riparian ecosystems surrounding tinajas of the Waterpocket Fold. A preliminary survey of the plants of the Waterpocket Fold was done in 1977 (Camp 1978), but the tinaja riparian zones were not directly addressed. For the purposes of this study, "tinaja riparian zone" will be defined as: The sedimented portion of a bedrock catchment basin that is not covered by standing water for more than a few days at a time, that is kept relatively moist, but not necessarily saturated, much of the year (or at least growing season), either by direct contact with the water table of the basin, or via capillary action from the water table and/or pool.

A number of studies have documented the impact of livestock on riparian zones (e.g., Kauffman et al. 1983a, 1983b, Roath and Krueger 1982, Szaro and Pase 1983). Primary effects are changes in native plant communities: changes in dominance relations, and in species abundance and/or presence (e.g., Hoffman and Stanley 1978); and changes in soil characteristics: compaction and/or increased erosion (e.g., Kauffman et al. 1983a). Because of the small areal extent of most tinaja riparian zones, and the concentration of livestock around only a few, accessible tinajas, livestock impacts on tinaja riparian zones may be more intense than along streams, or large reservoirs and lakes. These effects should be studied and documented to provide a

quantitative assessment of the impacts of livestock on the ecosystems of the Waterpocket Fold.

Riparian zones often constitute critical wildlife habitat (Thomas et al. 1979)⁸⁹⁶⁻⁷. These systems tend to have greater species diversity and density than surrounding terrestrial systems, especially in semi-arid and arid regions (Odum 1978), and the magnitude of biotic diversity in many areas depends largely on concentration of species in riparian ecosystems (Hubbard 1977, Johnson et al. 1977). Riparian ecosystems provide food, cover, and water for animals, as well as reproductive habitat, and protection from predators, wind, and sun (Carothers et al. 1974,^{183-COlo. R. Dams} Stevens et al. 1977, Thomas et al. 1979).

Several studies have shown that cattle grazing can affect both vertebrate and invertebrate populations. Changes in bird populations have been related to grazing-caused alterations in plant communities (Overmire 1963, Owens and Meyers 1973, Townsend and Smith 1977). Small mammal populations have also been affected (Frank 1957, Kauffman et al. 1982, Reid 1982, Reynolds and Trost 1980). Jones (1981)^{354 * 775 907} demonstrated that lizard species abundances and diversity were adversely affected by livestock grazing. Arthropod community composition and structure may change in response to changes in plant community species composition and/or architectural diversity (Morris 1971a, 1971b). Grazing of riparian zones can change many parameters influencing arthropod abundance and distribution.

Other studies of riparian zones have been of streamsides, or pond/lake/reservoir shorelines (e.g., Chabreck 1968, Kauffman et al. 1982, Whyte and Cain 1981). This study will examine small mammal, bird, lizard and arthropod populations in tinaja riparian zones, as well as patterns of use of tinaja riparian zones by these faunal groups. Data from tinajas cattle frequent will be compared to data from inaccessible waterpockets to determine whether cattle affect the community dynamics of any of these organisms. Changes in animal communities in riparian zones of tinajas that have been fenced to exclude cattle will also be documented as another measure of cattle impact on faunal components of tinaja riparian ecosystems.

Differences in micrometeorological parameters (e.g., temperature, relative humidity, insolation, wind velocity) can be very important in determining distribution patterns of small animals (e.g., insects, and small rodents) (Hadley 1975, Schmidt-Nielsen 1979). The appearance of tinaja riparian zones cattle use is quite different from undisturbed tinaja riparian habitat. There are probably large differences in these micrometeorological parameters between the respective riparian zones. Differences in arthropod and small mammal species presence and population sizes may be related to the presence/absence of ameliorating riparian vegetation. Accurate measurements of these physical factors should be made to document correlations between microhabitat differences and observed differences in animal communities of grazed and ungrazed tinaja riparian zones. Changes in riparian

zone microclimate after cattle are excluded should be documented to correlate changes in fauna with changes in microclimate as well as changes in plant community and ecosystem parameters.

Differences in animal communities may be due to differences in physical characteristics of the plant communities, or differences in biological characteristics of the plants (Crawley 1983, Parmenter and MacMahon 1984, Price et al. 1980, robinson 1981, Vanderwall and MacMahon 1984). Physical characteristics that may influence animal community composition include alteration and amelioration of the physical environment (e.g., increased relative humidity, decreased temperature, insolation, wind velocity, and erosion), and architectural characters used for hunting and/or shelter. Biological attributes of plants that could play a role in animal community composition include food quality of the plants, herbivore fauna present for predators as a result of differences in plant food quality, and presence of appropriate nesting materials.

Reproducing as accurately as possible, the structure of the plant community without the biological attributes would help determine the relationships of riparian animals to riparian vegetation. A physical model could be developed by constructing shading screens, shrub models (c.f., Robinson 1981), and arrays of vertical rods to simulate graminoid architecture.

PROCEDURES

There are three ways to examine the impacts of cattle on tinaja riparian zones:

1. Find and characterize a number of tinaja riparian zones that have not been exposed to cattle, then introduce cattle into these areas. This approach could provide the most conclusive evidence of impact, because the addition of cattle would be to a known, described ecosystem, with other variables controlled or accounted for as much as possible, but it is not without some problems. The tinajas would have to be accessible to cattle, yet unimpacted by cattle at this time. Such a situation is very rare, if it exists at all in the park. Cattle could be driven up slickrock to gain access to a pristine tinaja system, but the impacts would be artificial because the cattle would be confined and would not be able to move into and out of the tinaja zone freely. Introducing cattle into pristine areas is not consistent with the NPS goals of maintaining natural ecosystems in the parks, or of eliminating cattle from CARE.

2. Compare similar tinaja riparian ecosystems, one set that has cattle impacts, the other set inaccessible to cattle. This approach provides for simultaneous comparisons between systems which will reduce variability between systems due to differences in weather from one year to the next. But the systems need to be close enough to each other that weather patterns are similar among all the systems.

3. Characterize similar tinaja riparian ecosystems, both sets accessible to cattle, then exclude cattle from one set and document changes in the protected riparian zones. The assumption is that successional changes in protected systems will be the result of excluding cattle, and these changes will be toward the natural climax of tinaja riparian ecosystems. Using this method provides data on the recovery patterns of tinajas once cattle are removed from the park. It also has the advantage of simultaneous comparisons as mentioned in 2. above.

A combination of options 2 and 3 will be used in the proposed study to examine impacts of cattle on tinaja riparian ecosystems. Four tinaja systems are currently being studied for the Waterpocket Ecology Study of aquatic ecology of tinajas. There are 5 tinajas in each system. Of these 20 tinajas, 8 appear suitable for a tinaja riparian ecology study--4 accessible to cattle, 4 that are inaccessible. Two of the accessible tinajas can be fenced off using a single fence to exclude cattle to study riparian recovery.

Similarities between the tinajas are at present subjective. Quantitative comparisons will be done during fall and winter 1986-1987. The major criteria to be used to compare tinajas and their riparian zones are as follows:

1. Volume of basin: Volume of the bedrock depression the tinaja is in, as estimated as accurately as possible by probing to the bottom along transects. Shape of basin may be a factor if the shape could affect other important qualities. A long narrow basin would probably not be comparable, overall, with a rounder basin, even if they had similar estimated volumes. Surface area

of basin at ground level should also be estimated.

2. Volume of pool: Pool volume is important because it represents water available to aquatic and riparian organisms, and is a major factor in determining degree of tinaja permanence (along with abundance of riparian vegetation, and substrate). It will probably be easier to estimate the volume of the riparian zone as the difference between basin and pool volume than to measure riparian volume itself.

3. Surface area of pool: This is a good measure of potential evaporation, so rates of water loss can be calculated. In conjunction with transpiration rates through the plants, total water flux can be estimated. Similar areas should have similar loss rates if patterns of insolation exposure are comparable.

4. Protection of pool: Proportion of pool that is shaded at some time during the day, proportion of day that pool is shaded, when during the day the pool is shaded, and what provides the shade are all important parameters that affect the longevity of a tinaja. Riparian vegetation around a tinaja may shade part of the pool, keeping the water temperature lower, reducing evaporation, but at the same time, transpiration water loss would be greater than for tinajas surrounded by more rock.

No data are available on the reduction of water loss by shading from plants vs. the increased water loss from transpiration by plants. Transpiration rates of the major vegetation types in the riparian zones should be measured. These rates can be compared to evaporation rates in the shade, and in the sun, from the tinajas to determine how plants influence the

seasonal longevity of a tinaja pool. The dynamics of tinaja water loss, and the roles of evaporation and transpiration should be carefully examined to fully understand the impact of vegetation loss from around tinajas due to cattle grazing and trampling.

5. Volume of riparian zone: As mentioned above, this will probably be easiest to estimate from basin and pool volumes. Sediments in the bottom of the pool may be included in riparian volume with this method.

6. Surface area of riparian zone: This would be the available colonization area at any given tinaja for riparian vegetation. It could be measured directly, or estimated from basin and pool areas.

7. Ratio of surface area:volume for each category (basin, pool, riparian zone): This may allow a standardization of comparisons such that a small pool could still be compared to a larger pool.

8. Percent of riparian zone soils that are "permanently" saturated (i.e., for weeks or months), and percent of soils that are "intermittently" saturated (i.e., for a few days or weeks after a runoff event fills the tinaja). A quantitative definition for "permanent," and "intermittent" should be developed, perhaps patterned after that used for tinajas in Organ Pipe National Monument (Brown and Johnson 1983). They included an "ephemeral" category as well.

Tinajas should be within 15% of each other for all 8 characters, or at least for 5 of the 8, and within 30% for the other 3. Some criteria are probably more important than others

from an ecological perspective. Each character should be weighted according to its perceived importance.

OUTLINE OF METHODS

1. Physical parameters

A. Physical characters of basins:

Characterize each bedrock basin--

measure basin surface area, probe along transects for basin shape and depth, calculate basin volume and surface area/volume ratios.

Characterize each tinaja--

measure pool surface area, measure depth along transects, calculate maximum, and interval volumes (20cm intervals), and surface area/volume ratios.

Characterize each tinaja riparian area--

measure surface area, calculate riparian volume (difference between basin and pool volumes), and surface area/volume ratios.

B. Soil parameters:

Soil profiles--

take soil cores from each tinaja riparian zone, determine sediment particle size distribution, horizon development, and saturation levels and degree of saturation.

Soil chemistry--

have soils analyzed for: total N, P, NO₃, NH₃, total and organic C, others?? (e.g., K, Ca, SO₄, CO₃, HCO₃), water content, pH, conductivity.

C. Climatic parameters:

Measure temperature and relative humidity at each tinaja--in riparian zone, and outside of riparian zone. Measure incoming solar radiation at canopy level and ground level. Measure precipitation--two existing rain gauges at each tinaja system near tinajas being studied that will indicate precipitation falling in vicinity of tinajas. A tipping bucket recording rain gauge should be installed in the upper reaches of each of 2 drainages to record the precipitation that will drain into the tinaja systems.

Pan evaporation rates will be determined in the riparian zones, out on the rock, and from the pools themselves.

2. Biological and ecological parameters

A. Plants:

Identify all bryophytes, ferns, and flowering plants found in the tinaja riparian zones to species. This is being done by the plant survey team headed by Ken Heil (vascular plants), and a reference collection of nonvascular plants will be collected by Neil West during his cryptogam study beginning in fall 1986. Determine frequency, density, and cover for each species.

Measure above-ground biomass at end of the growing season for each species.

Determine architectural complexity of the riparian plant communities (e.g., Robinson 1981).

Transpiration rates of major plant types will be measured in the riparian zones. These rates will be compared to evaporation rates in shade and sun to learn how riparian vegetation influences tinaja water loss.

B. Animals:

Vertebrates--

Identify to species all vertebrates using riparian zones.

Attempt to obtain population estimates for each species, or at least for guilds and functional groups:

Mammals--live traps, observations, tracks.

Birds--observations, censuses

reptiles--observations, perhaps lizard arrays

amphibians--observations, possibly tadpole counts

Classify vertebrates into guilds and functional groups. Determine how riparian habitat is used by each species, guild, and functional group.

Invertebrates--

Identify all invertebrates using riparian zones (will probably have to send some to experts).

Classify insects and other invertebrates into guilds and functional groups.

Determine how riparian habitat is used by each species; by each guild; by each functional group.

Sampling: pitfall traps, sweep nets, vacuum sampling?, light traps?

Try to estimate "population" sizes for guilds and functional groups at least.

For both vertebrates and invertebrates:

Estimate trophic relations.

Estimate "importance value" to riparian ecology of each category.

Identify links between aquatic and terrestrial ecosystems through riparian ecosystems.

C. Soil biota:

We lack the expertise at this time to do much with soil biota, but we feel that given the impacts livestock have on soils, it is important to document differences between grazed and ungrazed riparian soils. We will be seeking guidance for direction on this part of the study, but perhaps contracting out this portion would be the best approach.

BUDGET

GS-5 Biological technician 48 days		\$2770.00
GS-3 Biological technician 36 days		1660.00
Sherman live traps 120 @ \$9.85 each		1182.00
Soil analyses:		
characterization of anions and cations		
twice (once before grazing, once right		
after cattle are removed).		
8 tinajas, 2 samples/tinaja/sample period=		
32 samples @ \$12.50 each		400.00
Insect nets		39.90
Invertebrate identifications		200.00
Microclimatic recording sensors:		
hygrothermographs- need 2 sensors/tinaja		
(est. \$50 each)	\$ 800	
need 1 recorder/system		
(est. \$500 each)	4000	
total:		4800.00
insolation meter- 2 @ \$79.95 each		159.90
tipping bucket rain gauges 2 @ \$1600 each		3200.00
miscellaneous supplies		300.00
utilities		50.00
TOTAL		\$14761.80
(Total without meteorological instruments:		\$ 6601.90)