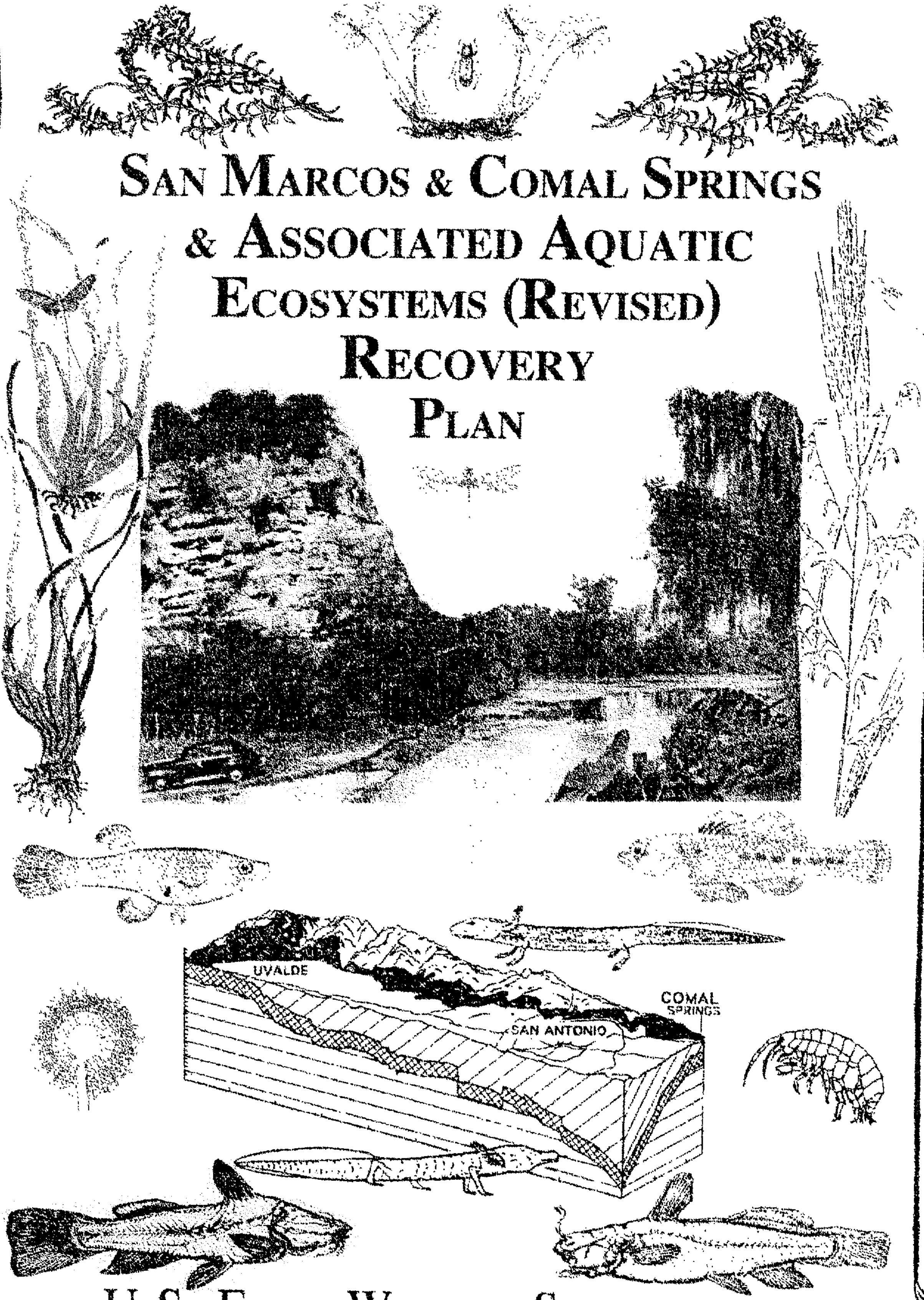
SAN MARCOS & COMAL SPRINGS & ASSOCIATED AQUATIC ECOSYSTEMS (REVISED) RECOVERY PLAN



U.S. FISH & WILDLIFE SERVICE — 1996

San Marcos and Comal Springs
and
Associated Aquatic Ecosystems
(Revised)
Recovery Plan

(Short title: San Marcos/Comal
(Revised) Recovery Plan)

for

San Marcos Gambusia (*Gambusia georgei*)
Fountain Darter (*Etheostoma fonticola*)
San Marcos Salamander (*Eurycea nana*)
Texas Wild-rice (*Zizania texana*)
Texas Blind Salamander (*Typhlomolge rathbuni*)

(Original approved: April 8, 1985)

Prepared by
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and

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for

Region 2
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

Approved: Nancy M. Kaufman
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Date: February 14, 1996

United States Department of the Interior

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March 22, 1996

CORRECTION SHEET FOR SAN MARCOS/COMAL (REVISED) RECOVERY PLAN

The following corrections should be noted to the San Marcos & Comal Springs and Associated Aquatic Ecosystems (Revised) Recovery Plan (U.S. Fish and Wildlife Service 1996):

P.iv, the literature citation should read "U.S. Fish and Wildlife Service. 1996. . . . . ", not 1995.

P.7, column 2, second paragraph, line 13: "atchment" should be "catchment"

P. 33, column 1, under "**Habitat**", first paragraph: the list given there should be numbered 1-6.

P. 34, column 1, lines 4-5: For clarification, the "-" on the end of line 4 is a negative number sign.

P. 59, task 2.3: for clarification, the reference to task 2.11, actually refers to subtask 2.11 listed above task 2.3.

P. 64, column 2, line 7: the sentence beginning "Some mechanism . . . " should read "Some mechanism for assuring adequate aquifer levels and springflows is essential to assure success of this plan, otherwise all the efforts of the involved parties could be offset by parties who choose not to participate in the implementation of the Aquifer Management Plan."

P. 114, column 2, line 14: replace "without" with "which does not impose"

P. 116, column 1, 7 lines from the bottom: "task 2.11" should read "subtask 2.12".

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DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Because of furloughs of Federal employees and ongoing litigation regarding the Edwards Aquifer and species covered by this plan, there was considerable urgency to finalize this plan. Therefore, the normal critique and input to the final version of the plan was minimal. The Service does, however, appreciate the Recovery Team's substantial efforts in completing the earlier drafts of this plan. As is customary, objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service *only* after they have been signed by the Regional Director or Director as *approved.* Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

LITERATURE CITATIONS

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1995. San Marcos/Comal (Revised) Recovery Plan. Albuquerque, New Mexico. pp. x + 93 with 28 pages of appendices.

Additional copies of this plan, when finalized, may be purchased from:

Fish and Wildlife Reference Service:
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814
(800) 582-3421 or (301) 492-6403

The fee for the plan varies depending on the number of pages of the plan.

ACKNOWLEDGEMENTS

The Service would like to express its appreciation for the many individuals, groups and agencies who have been actively working to resolve problems and gather information needed to achieve the goals of stabilizing the habitats and populations of these species, and making progress toward recovery. The Service looks forward to continued collaboration to achieve the conservation of these unique resources.

Many individuals and groups have conducted or assisted in field research on the Comal and San Marcos rivers, including people from city departments, universities, state and Federal agencies, non-profit groups, local businesses, landowners, and interested individuals. Thanks to one and all.

The Service gratefully acknowledges the Alabama Museum of Natural History and the Illinois Natural History Survey for use of the line drawing of the fountain darter found in Figure 4. In addition, thanks is due the Texas Parks and Wildlife Department for permission to use the illustration of Texas wild-rice used in Figure 6.

EXECUTIVE SUMMARY

CURRENT SPECIES' STATUS

The fountain darter, San Marcos gambusia, Texas blind salamander, and Texas wild-rice are endangered. The San Marcos salamander is threatened. Critical habitat is designated for all except the Texas blind salamander. The fountain darter occurs in the San Marcos and Comal systems in central Texas. The Texas blind salamander is restricted to the Edwards Aquifer. The other three species occur in the San Marcos system. Other species of concern also occur in these ecosystems including three that have been proposed for listing: Peck's Cave amphipod, Comal Springs riffle beetle, and the Comal Springs dryopid beetle.

HABITAT REQUIREMENTS AND LIMITING FACTORS

All species are aquatic and inhabit ecosystems dependent on the Edwards Aquifer. All but the subterranean Texas blind salamander occur in spring-fed systems. Loss of springflows due to drawdown of the aquifer is one of the primary threats. Other threats include nonnative species, recreational activities, predation, and direct or indirect habitat destruction or modification by humans (e.g., dam building, bank stabilization, and control of aquatic vegetation) and factors that decrease water quality.

RECOVERY GOALS

The goals of recovery are: 1) to secure the survival of these species in their native ecosystems; 2) to develop an ecosystem approach using strategies to address both local, site-specific, and broad regional issues related to recovery; and 3) to conserve the integrity and function of the aquifer and spring-fed ecosystems that these species inhabit.

RECOVERY CRITERIA

Delisting is considered unattainable in the near future for all five species due to the potential for extinction from catastrophic events. Consequently, this plan calls for the establishment and continued maintenance of refugia capability for all five species in case of a catastrophic event. Downlisting is considered feasible for the fountain darter, Texas wild-rice, and Texas blind salamander and detailed criteria are given in the plan. The potential for downlisting the San Marcos gambusia is problematic. Interim objectives are given for that species to measure progress toward preventing extinction.

ACTIONS NEEDED

1. Assure sufficient water levels in the Edwards aquifer and flows in Comal and San Marcos Springs to maintain habitat for all life stages of the five listed species and integrity of the ecosystem upon which they depend.
2. Protect water quality.
3. Establish and maintain populations for all five listed species in their historic habitats.
4. Conduct biological studies necessary for successful monitoring, management, and restoration.
5. Encourage partnerships with landowners and agencies to develop and implement conservation strategies.
6. Develop and implement a regional Aquifer Management Plan.
7. Develop and implement local management and restoration plans to address multiple threats.
8. Promote public information and education.

Costs (Dollars × 1000):

Year	Priority 1 Tasks	Priority 1• Tasks	Priority 2 Tasks	Priority 3 Tasks	Total
1996	256.0	506.5	234.5	5.0	1,002.0
1997	238.0	530.5	233.5	5.0	1,007.0
1998	205.0	439.5	182.0	5.0	831.5
1999-2025	1,140.0	1,329.5	592.0	—	3,061.5
Total	1,839.0	2,806.0	1,242.0	15.0	5,902.0

Date of Recovery: If continuous progress is made, downlisting the fountain darter and Texas wild-rice should be possible by 2025.

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OVERVIEW OF THE RECOVERY PLAN

This plan addresses recovery actions for the fountain darter, San Marcos salamander, San Marcos gambusia, Texas blind salamander, and Texas wild-rice. The recovery goal is to secure the survival of all five species and the ecosystem upon which they depend. This plan provides criteria for downlisting the fountain darter, Texas wild-rice, and Texas blind salamander from endangered to threatened. This overview summarizes 1) the water resource issues associated with the recovery of these species and the Edwards aquifer and spring ecosystems; 2) efforts by individuals, state and local governments, and private organizations to resolve these issues; 3) tasks and recommended actions to achieve recovery; 4) technical evaluation and technical assistance needed for planning; and 5) the process for developing a regional Habitat Conservation Plan or one or more smaller regional or local HCPs that could contribute to overall aquifer management.

To conserve these species and meet the objectives of this recovery plan, the ecosystems upon which these species depend must be conserved. These ecosystems include the Edwards aquifer and the systems associated with Comal and San Marcos Springs (including spring runs, lakes, rivers, and caves).

The recovery of these species depends on actions taken at three levels: broad regional issues of water use and landscape level management that influence these systems; localized actions taken by municipalities and landowners that affect these systems; and species-specific or site-specific actions that directly affect the species. Current information about these endangered and threatened species and their habitats is not complete, and some tasks will only be conducted after additional research or evaluations are completed. This Recovery Plan includes tasks to deal with recovery needs at all of these levels and addresses all identified issues.

Regional resource issues critical to the survival of the species of concern and their habitat require maintaining sufficient water in the habitat, and ensuring that water quality is not degraded to levels that compromise the integrity of the systems and the survival and recovery of the species.

Decreased aquifer levels and loss of adequate springflows are imminent. The recovery plan identifies the U.S. Fish and Wildlife Service's preliminary evaluation of the springflow levels needed at Comal and San Marcos Springs to prevent "take" of the listed species. The Service continues to conduct and fund studies to refine understanding of what springflow levels are needed, under varying conditions, to maintain the species and their habitat. Such studies, evaluations, and monitoring will be an ongoing need to evaluate management efforts (see tasks 1.22, 1.23, 1.3, 2.12 and 3.2).

To assure adequate springflows for the long-term, a mechanism to provide and maintain aquatic habitat must be in place; e.g., conservation measures and management of groundwater withdrawal. Efforts have been made to achieve this goal. In 1993, the Texas legislature passed S.B. 1477 creating an Edwards Aquifer Authority to regulate groundwater withdrawal. The legislation was challenged over Voting Rights Act concerns, which were resolved by the legislature in 1995 with amendments (H.B. 3189). The legislation was again challenged by the Medina and Uvalde County Underground Water Districts and the court ruled that the legislation was unconstitutional. The Authority's ability to regulate water withdrawal from the aquifer depends on resolution of these concerns.

A sound overall plan for sharing and managing groundwater use from the aquifer is needed (task 2.1). This is a complicated task, considering the diversity of water users and need for water. The Recovery Plan cannot determine or dictate the specific provisions of an Aquifer Management Plan. State and local involvement in developing specific strategies is important to ensure consideration of local and regional socio-economic concerns, provide flexibility in the evolution and fine-tuning that will be needed to address changing local and regional needs, and to achieve compliance with the plan.

Many water management agencies and aquifer users have begun to address the issues of maintaining ecosystems and species dependent upon the Edwards Aquifer. These efforts will be useful in forging an overall plan. In June 1994, a court appointed monitor, Joe Moore, Jr., prepared an emergency withdrawal reduction plan, revised in March of 1995. In May of 1995, Judge Bunton formed a committee to develop an alternative emergency withdrawal reduction plan for 1995. The committee developed an ordinance to limit municipal and industrial water use for 1995, which has been largely adopted by the city of San Antonio.

Progress has also been made on developing and implementing several other beneficial practices. For example, New Braunfels, San Antonio, and San Marcos have water conservation ordinances. The city of San Antonio has developed a wastewater re-use plan that promises conservation of a significant amount of water. Many municipalities and water conservation districts are exploring alternative sources of water.

In August of 1994, the Court Monitor initiated discussions among the city of San Antonio, the Uvalde Underground Water District, the Medina County Underground Water District, the Edwards Underground Water District, the San Antonio River Authority, and the Guadalupe Blanco River Authority about cooperatively preparing a regional HCP. Following these discussions, a preliminary issues document was drafted and discussions regarding an HCP and a potential incidental take permit were initiated with the Service.

Many water users and agencies have conducted studies and evaluations, including computer modeling, to determine the aquifer levels needed to maintain springflow. This has emerged as a critical issue in efforts to manage groundwater for the benefit of listed species. Estimates of aquifer levels needed have been reported over a large range. One estimate says that in a drought of record no more than 165,000 acre-feet per year could be pumped from the Edwards aquifer (Edwards Underground Water District 1992a). In 1989 well discharge was 542,000 acre-feet. Obviously in drought conditions severe reductions in water use will be needed. The mechanism to achieve these reductions will have to be discovered.

The Recovery Plan stresses cooperative development of a regional Aquifer Management Plan, primarily by state and local entities, with the Service lending technical support. It would be most useful if the Service were involved in the process from the early stages, providing assistance to plan developers in assessing the plan's adequacy for protection of affected species and their habitat (task 2.1 and 2.11).

The Recovery Plan gives some preliminary guidance for springflow levels (Table 2) and measures that may be useful and biologically supportable to protect the species (task 2.1 and 2.11). In addition, a comprehensive technical evaluation of springflows, aquifer levels, and conservation measures (e.g., pumping limits) needed for various conditions of rainfall, recharge, weather conditions, and groundwater use is also needed. This evaluation should consider voluntary or mandatory water use reductions and alternative means of providing water regionwide. The Service believes that to undertake this evaluation, it will be necessary to convene a technical team of experts to assist planners in evaluations of hydrology, geology, biology, and economics (task 2.12). It is expected that this evaluation will be modified as more information becomes available.

All Federal agencies have a role in conservation of species of concern, under section 7(a)(1) and 7(a)(2) of the Endangered Species Act. The Recovery Plan encourages efforts by Federal agencies (see task 2.2). Progress has been made in this area, such as recent water conservation efforts and development of wastewater irrigation systems by military bases. An aquifer management plan that will assure adequate springflows and aquifer levels is required to recover these species (see below and task 2.1). Preparation and implementation of plans to assure adequate springflows are best accomplished by state and local agencies. The Recovery Plan calls for actions by Federal agencies to reduce aquifer water withdrawal as much as possible within their authorities to maintain habitat for listed species (task 2.3). Several tasks call for a variety of actions, including continuing to support conservation actions by Federal agencies (task 2.31) and private entities (2.32).

Task 2.33 calls for aggressive pursuit of Federal agency compliance with obligations for informal and formal section 7 consultations. The Service provided notices of the potential effects, the need to consult, and has met with Federal agencies whose actions may directly or indirectly impact the survival of the listed species or adversely affect their critical habitat. The resolution of the problem of maintaining springflows needed for these species to survive is so critical that, in the absence of a regional Aquifer Management Plan enforced by state and local governments, the Service should be prepared to initiate legal action required to maintain springflows at levels that would maintain habitat sufficient to prevent jeopardy to listed species. Task 2.12 requires review of section 10 permit applications, performance and compliance; and review of compliance with formal section 7 agreements by Federal agencies.

Water quality in the Edwards aquifer and the San Marcos and Comal ecosystems is also a major concern with regional implications. The Recovery Plan calls for a regional approach that provides the aquifer with protection from significant sources of pollution and the effects of chronic low-level contamination. Tasks 1.24 and 1.28 provide for an assessment of existing provisions, and task 2.5 recommends the implementation of measures needed to protect water quality in the aquifer.

On a more local level, tasks 1.24, 1.25, 1.26, 1.27, and 3.2 evaluate and task 2.8 seeks to address water quality concerns for the Comal and San Marcos ecosystems. In addition to water quality concerns, tasks 2.4, 2.6, and 2.9 address a variety of local management concerns. Progress has been made on addressing concerns for these systems. The Service is working in cooperation with the city of New Braunfels and others to develop a Comal Ecosystem Management Plan (task 2.42). The city of San Marcos and Southwest Texas State University have funded an effort to develop a similar plan for the San Marcos area (task 2.41). In addition, Texas Parks and Wildlife Department has a study currently underway to examine potential impacts to listed species from the effluent of the A.E. Wood State Fish Hatchery, and a study is underway to examine some potential impacts of effluent from the San Marcos wastewater treatment plant.

Nonnative species have direct and indirect impacts on the habitat and survival of species of concern. Several nonnative species are presently of concern, and the Recovery Plan (see task 1.29) calls for research to learn more about nonnative species impacts and control. Task 2.10 calls for implementation of needed management techniques. Monitoring will also be needed to prevent outbreaks or unacceptable levels of damage from these nonnatives, and this monitoring is included as part of task 3.2. Data on the incidence of clipping of leaves of Texas wild-rice by herbivores in Spring Lake are being collected, and some basic research on ramshorn snails has been conducted in the Comal Springs ecosystem.

Certain recreational activities are of concern because of damage to Texas wild-rice from recreationists and floating mats of vegetation (sometimes cut by local owner/managers to provide better recreational experiences for visitors and users). Task 1.21 calls for an evaluation of the impacts of recreationists to the integrity of the springs and rivers and to listed species. Progress is being made in this area. The Service has recently funded studies examining recreational impacts on Texas wild-rice, and discussions have been initiated with operators of the largest tubing operation in the San Marcos River to examine management options to reduce impacts.

In some areas there may be potential for restoration or enhancement of habitat quality for one or more species of concern. Identification and implementation of habitat restoration and enhancement opportunities are discussed in the Recovery Plan (see task 2.9, conducting restoration directly by resource agencies and others, and task 2.6, working with private landowners to encourage advantageous management). These activities are also supported indirectly through tasks developing local management plans for the Comal and San Marcos Systems (tasks 2.4, 2.41 and 2.42). Progress is being made in this area through development of management plans, and a proposal for manipulation to improve habitat for the San Marcos gambusia.

Most of the tasks reviewed above address general habitat requirements and known threats to habitat. Implementation of these tasks should contribute significantly to increasing stability and maintenance, habitat integrity needed for survival, and recovery of the listed species.

In some cases, information about the species of concern is limited and questions about what is needed to enhance survival and recovery are not yet answered. For some species the exact habitat requirements that determine why they occur in some areas and not others are not well understood, making fine-tuning of habitat management difficult. Task 1.15 provides for the identification of specific habitat characteristics and requirements. The Service and Texas Parks and Wildlife Department are conducting instream flow studies to identify habitat requirements of aquatic plants and animals in the Comal and San Marcos systems. Through section 6, the Service has funded work by Texas Parks and Wildlife Department to investigate habitat requirements for Texas wild-rice. Before management can be implemented for other species, the general life history, survivorship, and potential unique problems such as diseases and parasites must be understood (see tasks 1.11, 1.12, 1.13, 1.14). Monitoring of individuals and populations of some species and their habitat is required for tracking species condition, and the overall impacts of various threats, as noted in task 3.1. Monitoring is needed to assure that no significant decline in their status occurs and to measure success of recovery efforts. Periodic monitoring is taking place for Texas wild-rice and the fountain darter and should continue.

A primary goal of this Recovery Plan is to reduce threats to the species of concern and conserve the species in their native ecosystem. However, in these relatively restricted systems a catastrophic event could cause severe environmental damage and possibly lead to extinction of some species. Consequently, protecting the genetic variation present in existing populations and developing techniques needed for restoration work are high priority recovery tasks addressed through tasks 1.4 and 2.11. This recovery plan requires establishing refugia and captive populations (task 1.4) for all five listed species. Although progress is being made, additional work and research are needed. The Contingency Plan (task 2.11) calls for collection and conservation of individuals of the species of concern in the event a crisis is imminent. The plan will be distributed as a separate document when completed. Reintroduction techniques are fairly well understood for the fountain darter and are the subject of current research underway on Texas wild-rice. Information is still needed for the salamanders and for San Marcos gambusia.

The Service acting alone cannot achieve the conservation and recovery of these species. Conservation of these species and their ecosystems will require the support and participation from a wide variety of people and organizations. In addition, Service policy directs the Service to involve parties in implementation of Recovery Plans. The policy states that implementation should minimize social and economic impacts as much as possible. Consequently, public information, education, and involvement is an important component of this Recovery Plan. Task 2.1 calls for the primary involvement of state and local entities in developing an aquifer management plan. Task 4.2 provides for active encouragement of public involvement in planning and carrying out conservation efforts. Task 4.1 notes that educational materials will need to be produced and distributed for a variety of audiences. Some progress has been made in this area, although more is needed. The Service has a project underway at present in cooperation with Texas Parks and Wildlife Department to produce an information kiosk for the San Marcos River. Another section 6 educational project undertaken cooperatively with Texas Parks and Wildlife Department is producing educational materials on the listed species and their ecosystem. Aquarena Springs (now owned and operated by Southwest Texas State University) installed exhibits that will be helpful in providing information to the public. The Edwards Underground Water District has also produced a variety of educational materials about the aquifer.

PART I

BACKGROUND INFORMATION

A. THE ECOSYSTEMS

The Comal and San Marcos Springs are the largest spring systems in Texas. The source of their flows is the San Antonio Segment of the Edwards (Balcones Fault Zone) Aquifer, which will be referred to in the rest of this plan as simply the Edwards Aquifer. The species covered by this plan are dependent upon the Edwards Aquifer and its associated aquatic habitat in the Comal and San Marcos Springs areas.

Partly because of the constancy of the waters in temperature and flow, the San Marcos and Comal ecosystems, including the spring runs and the San Marcos and Comal Rivers and their impounded headwaters, have one of the greatest known diversities of organisms of any aquatic ecosystem in the southwestern United States. The unique habitats of these systems provide relatively isolated, island-like systems which support a high degree of endemism. The biological uniqueness of these systems has been known for many years. Many species found in the Comal and San Marcos ecosystems are not found elsewhere. Most of the unique species are restricted to the headwaters and the first few kilometers or less of the San Marcos and Comal Rivers. In the San Marcos River, this includes the area above the confluence with the Blanco River, commonly referred to as the upper San Marcos River. The Edwards Aquifer is known to contain a great diversity of organisms that live within it, underground.

These aquatic ecosystems are in danger of losing their unique fauna and flora. A variety of factors threaten the listed species. Local threats to each of the species, as well as broader, regional threats to the ecosystem's continued integrity, are addressed in this plan. Some of the most severe threats are related to both the quality and quantity of water available in the spring systems and in the aquifer. Threats include decreased springflows, impacts resulting from increased urbanization near the rivers, recreational use, pollution, alterations of the rivers, introduction of nonnative species and other concerns.

Presently, four San Marcos, Comal, and aquifer species included in this plan are listed as endangered: the San Marcos gambusia (*Gambusia georgei)*, the fountain darter (*Etheostoma fonticola)*, the Texas blind salamander (*Typhlomolge rathbuni)*, and the Texas wild-rice (*Zizania texana)*. In addition, the San Marcos salamander (*Eurycea nana)* is listed as threatened.

Three species of aquatic invertebrates in the Comal were proposed for listing by the Service on June 5, 1995 (60 FR 107:29537). The species that are proposed are the Peck's cave amphipod (*Stygobromus pecki)*, Comal Springs riffle beetle (*Heterelmis comalensis)*, and the Comal Springs dryopid beetle (*Stygoparnus comalensis)*. The final decision regarding the need to list has not yet been made.

In addition to the listed species, a great diversity of other unique species occur in these aquatic ecosystems. Some of these may also be threatened with extinction, but insufficient information is available to fully assess their status. Some of these species associated with the Edwards Aquifer include the Texas cave diving beetle (*Haideoporus texanus)*, San Marcos saddle-case caddisfly (*Protoptila arca)*, Ezell's Cave amphipod (*Stygobromus flagellatus)*, Texas salamander (*Eurycea neotenes)*, Comal blind salamander (*Eurycea tridentifera)*, robust (=Blanco) blind salamander (*Typhlomolge robusta)*, widemouth blindcat (*Satan eurystomus)*, and toothless blindcat (*Trogloglanis pattersoni)*. Several other invertebrates and vertebrates may also be endemic (that is, found only in a particular locality or region) to these aquatic ecosystems.

This recovery plan covers the five species listed as threatened or endangered and the ecosystems upon which they depend, including the San Marcos and Comal aquatic ecosystems and the Edwards Aquifer. Both the San Marcos and Comal Springs and river systems are dependent upon water from the Edwards Aquifer and thus, represent components of the larger Edwards Aquifer ecosystem. On a smaller scale, both the San Marcos and Comal aquatic systems contain unique flora and/or fauna that do not occur throughout the Edwards Aquifer ecosystem. For purposes of this plan, the San Marcos and Comal systems (including their springs, lakes and rivers) are considered individual ecosystems with the understanding that they are connected to, and an integral part of, the larger Edwards Aquifer ecosystem. A brief comparison of the Comal and San Marcos ecosystems is presented in Table 1. The Edwards Aquifer ecosystem is also important to the bay and estuary ecosystems along the Texas coast. Aquifer water exiting at San Marcos and Comal Springs provides a large proportion of the base flow of the Guadalupe River, particularly in times of low rainfall. The Guadalupe River provides freshwater input to San Antonio Bay on the Texas Gulf Coast and this freshwater input is important for maintaining habitat for species inhabiting the bays and estuaries.

The 1984 San Marcos Recovery Plan was among the first recovery plans to address recovery of multiple species through an ecosystem approach. The importance of conserving the entire spring ecosystem as the only viable approach for recovery of these species was recognized early in the development of that plan. Any recovery plan for these endangered and threatened species that fails to address the continued functioning of the ecosystems will fail to achieve recovery goals set forth for these listed species. Protection of these ecosystems should also help conserve many other unique organisms that reside there, including species that are candidates for listing. These ecosystems also provide a great diversity of uses for humans, from the aquifer and associated streams. Protection of these systems for listed species would also help assure their quality for human use now and for future generations.

This revised plan has been expanded to address importance of the Comal ecosystem as well as the San Marcos ecosystem and to include the Texas blind salamander, a listed aquifer dwelling species. This recovery plan discusses problems each of the listed species is facing and presents a set of actions that, when accomplished, should alleviate threats to each species and maximize potential for continued existence of these species and the ecosystems they depend on.

PHYSIOGRAPHY AND HYDROLOGY

Edwards Aquifer

The Balcones Fault Zone is the principal geological feature characterizing the San Marcos and New Braunfels area. The Fault Zone is a series of faults and fractures that extend east from near Del Rio (Val Verde County) to San Antonio (Bexar County), where it turns northeast through the spring zone. Water flows underground along this fault zone from west to east and then northeast. The Edwards Aquifer underlies this fault zone and has a northern (Barton Springs) and a southern (San Antonio) segment. The aquifer's San Antonio segment extends from Brackettville (Kinney County) to near Kyle (Hays County). This San Antonio segment is the source of water for many major springs along the fault zone including the San Marcos and Comal springs (Figure 1).

Runoff from the southern and eastern portions of the Edwards Plateau flows through an area of about 12,035 kilometers^2 (4,647 miles^2) that is composed of about 9,184 kilometers^2 (3,546 miles^2) of catchment area (often referred to as the drainage basin or contributing zone) and 2,851.6 kilometers^2 (1,101 miles^2) of recharge zone (Guadalupe-Blanco River Authority 1988). Water flowing from the catchment area to the recharge zone recharges the aquifer through the permeable outcrops of Cretaceous-aged limestones found in Hays, Comal, Bexar, Medina, Uvalde, and Kinney counties. This atchment area is also sometimes referred to as the contributing zone or drainage basin. Investigators have estimated that 50-78 percent of the water recharging the Edwards Aquifer comes from the drainage basins west of Bexar County (Guyton and Associates 1979, Wanakule and Anaya 1993, Edwards Underground Water District 1991). The recharge zone is an area of karst terrain where water enters the aquifer. The water is primarily stored in the artesian zone, where impermeable strata overlie the cavernous limestone and trap the water underground. Water confined in the artesian zone flows along the fault zone.

Table 1. Summary of features of the Comal and Upper * San Marcos Ecosystems.

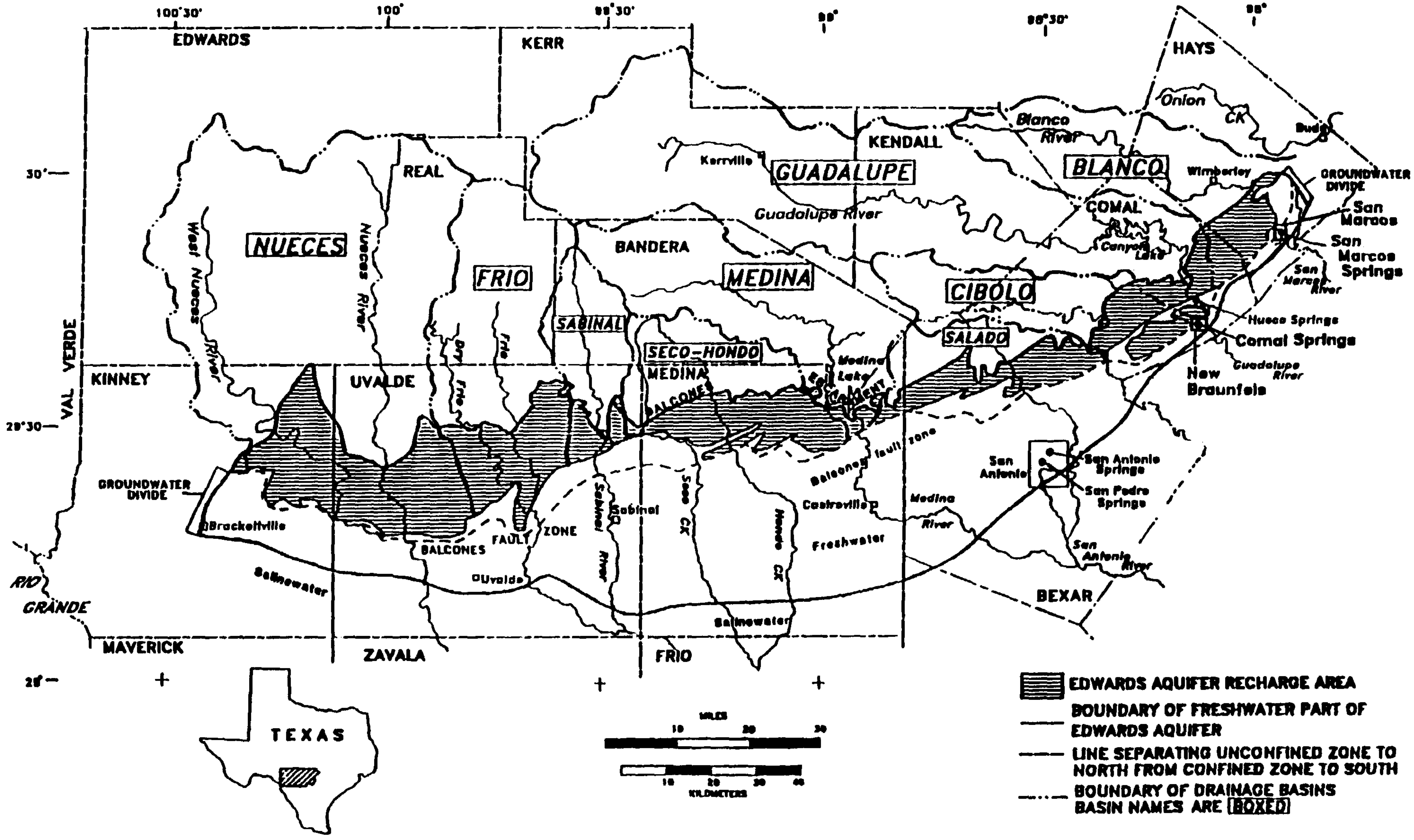
	Comal	**Upper San Marcos**
Listed Species	Fountain darter *(Etheostoma fonticola)*	Fountain darter *(Etheostoma fonticola)* San Marcos salamander *(Eurycea nana)* San Marcos gambusia *(Gambusia georgei)* Texas wild-rice *(Zizania texana)*
Proposed Species	Comal Springs riffle beetle *(Heterelmis comalensis)*	Comal Springs riffle beetle (1 specimen)
Other Species of Interest	Guadalupe bass, *(Micropterus treculi)* (historic only) Comal Springs salamander *(Eurycea sp.)*	Guadalupe bass *(Micropterus treculi)* San Marcos saddle-case caddisfly *(Protoptila arca)* Dusky darter *(Percina sciera apristis)*
Non-native Species of Potential Concern **C = common in system**	Elephant ears, C, *(Colocasia esculenta)* Elodea, *Egeria densa* Hydrilla, *(Hydrilla verticillata)* *Hygrophila polysperma*, (no common name) *Limnophila sessiliflora* (no common name) Blue tilapia, C, *(Tilapia aurea)* Rio Grande cichlid, C, *(Cichlasoma cyanoguttatum)* Common carp, *(Cyprinus carpio)* Amazon molly, *(Poecilia formosa)* Sailfin molly, C, *(Poecilia latipinna)* Waterfowl (various non-native) Giant ramshorn snail, C, *(Marisa cornuarietis)* Other snails, *(Melanoides tuberculata)* and *(M. granifera)* Asian clam, *(Corbicula)* Nutria, C, *(Myocaster coypus)*	Elephant ears, C, *(Colocasia esculenta)* Elodea, *(Egeria densa)* Hydrilla, *(Hydrilla verticillata)* *Hygrophila polysperma*, (no common name) Parrot feather, C, *(Myriophyllum brasiliense)* Water hyacinth, C,*(Eichhornia crassipes)* (in Spring Lake) Blue tilapia, C, *(Tilapia aurea)* Rio Grande cichlid, C,*(Cichlasoma cyanoguttatum)* Common carp, *(Cyprinus carpio)* Amazon molly, *(Poecilia formosa)* Sailfin molly, C, *(Poecilia latipinna)* Waterfowl (various non-native) Giant ramshorn snail, *(Marisa cornuarietis)* Other snails, *(Melanoides tuberculata)* and *(M. granifera)* Asian clam, C, *(Corbicula)* Nutria, C, *(Myocaster coypus)*

* the area commonly referred to as the upper San Marcos River includes the area above the confluence with the Blanco River.

Table 1. Summary of Features of the Comal and Upper* San Marcos Ecosystems (Continued)

	Comal	**Upper San Marcos**
Mean water temp. (°C) at Springs	23.3 (George 1952)	22 (Guyton and Associates 1979)
Average annual springflow (cfs)	284 (1928-1989, Guyton and Associates 1979)	170 (May 1956-Oct 1994, USGS 1995)
Maximum daily mean springflow (cfs)	666 (Dec 22, 1991; EUWD pers. comm)	451 (Mar 12-15, 1992; EUWD pers. comm)
Minimum daily mean springflow (cfs)	0 (June 13-Nov 4, 1956)	45 (Aug 15 & 16, 1956)
Lake Area (acres)	Landa Lake: about 21 acres	Spring Lake: about 10 acres
Riverine Habitat	about 2 miles (3 km)	about 4 miles (6.4 km)

Figure 1. Edwards Aquifer Region (modified from Figure 1 in Maclay and Land, 1988).



Because of the characteristics of the Edwards Aquifer (which include relatively rapid flow through underground caverns), there has been debate among hydrologists regarding whether it should be termed an aquifer or an underground river. This difference in terminology could have ramifications in terms of water-rights law in Texas, the right of the State to regulate the water, and which state agency would have regulatory authority. Recognizing the volume and flow of water through the aquifer and its significance as a natural resource, the Texas Water Commission declared the Edwards Aquifer an underground river (TWC Rules, 17 Tex. Reg. 6601-6620) on September 25, 1992. In May of 1993, Senate Bill 1477 declared the Edwards Aquifer is a distinctive natural resource in the state, to be a unique aquifer, but not an underground stream.

Comal

The Comal Spring system is the largest spring system in Texas. It consists of numerous spring openings, collectively called Comal Springs, that originate from the Edwards Aquifer. These spring openings include Brune's (1981) Springs j, k, and l (referred to herein as spring runs 1, 2, and 3, respectively; Figure 2). These springs provide flow to three short spring runs that empty into the western end of Landa Lake in Landa Park, a municipal recreational area owned by the city of New Braunfels (Comal County, Texas). Another smaller group of springs (east of Brune's Springs a, b, and c (Brune 1981), referred to collectively herein as spring run 4) occurs at the eastern end of Landa Lake near the confluence with Blieders Creek. Blieders Creek is about 11 km (6.8 miles) long and dry except immediately after rains. Numerous small springs and seeps occur in the spring runs, along the banks of Landa Lake, and beneath the Lake.

Landa Lake was created when the original river channel was dammed in 1847 to create a new channel providing water for Merriwether's Mill. Landa Park was established as a privately owned park open to the public in 1898. The city of New Braunfels acquired the park in 1936. At that time the three largest spring runs were channeled by rock work constructed by the Works Project Administration and a children's pool was built at the lower end of spring run 2 (Gregory and Goff 1993).

Water emerging from the various springs passes through Landa Lake before flowing into either the old or new channel of the Comal River (Figure 2). The old and new channels merge about 2.5 km (1.6 miles) downstream from Landa Lake and the Comal River flows generally south another 2.5 km (1.6 miles) before joining the Guadalupe River, making it the shortest river in Texas and the shortest river in the United States carrying an equivalent amount of water (Texas Almanac 1973). A short distance downstream from the headsprings, Dry Comal Creek enters the new channel of the Comal River from the southwest. Dry Comal Creek is also an intermittent stream, but it does provide some recharge.

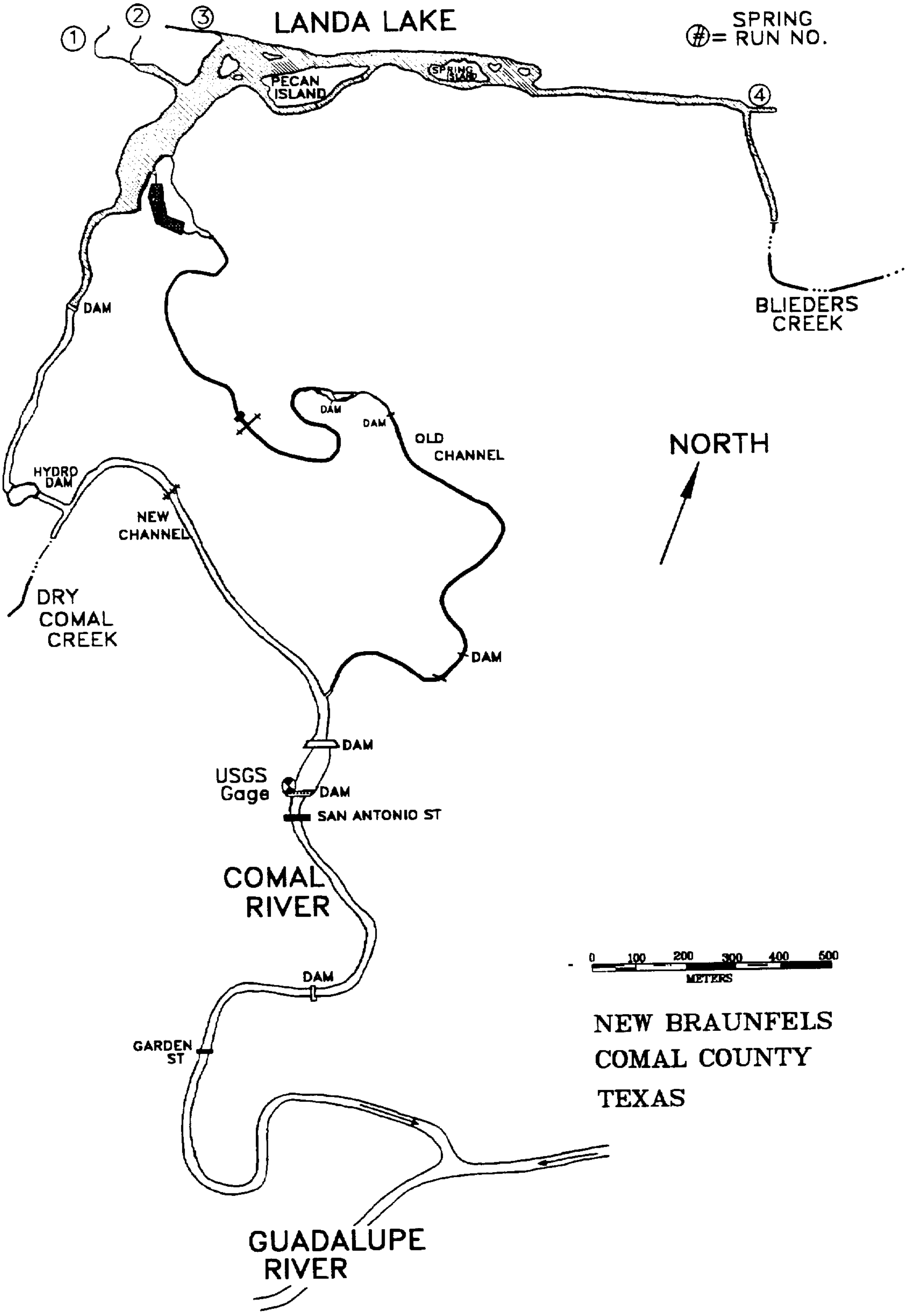
A major fault, the Comal Springs Fault, lies to the west of the Comal Springs tending in a northeast direction with about 243.9 m (800 feet) of displacement. Edwards Group limestones outcrop on the west side of the fault, whereas on the east side, the Edwards has been displaced and lies about 140.2 m (460 feet) below the surface (Edwards Underground Water District 1992a). This outcrop of the karstic water-bearing Edwards limestone on the west side of the fault accounts for the presence of the Comal Springs.

The Comal Springs issue from the limestones of the Edwards Group at the base of the Balcones Escarpment. In the vicinity of the springs, the Edwards Group crops out in a continuous escarpment with about 30.5 m (100 ft) of topographic relief that has been created along the Comal Springs Fault (Guyton and Associates 1979). The spring outlets are located along the base of this escarpment. The three main outlets of Comal

Springs lie at an elevation of about 190 m (623 ft).

Faulting has, for the most part, hydrologically isolated Comal Springs, although large local storms temporarily contribute a small recharge component to spring run 3 (Rothermel and Ogden 1987). Brune (1981) believed the primary recharge area lay as much as 100 km (62 miles) to the west and Guyton and Associates (1979) determined that the recharge area for

Figure 2. Comal Aquatic Ecosystem.



Comal Springs includes a large area of the Edwards Aquifer southwest of Cibolo Creek basin. Studies of the tritium content of the water emerging from Comal Springs indicate that the amount of recharge from local sources is minimal (Guyton and Associates 1979). Maclay and Land (1988) note that based on their simulation studies it appears that most of the flow of Comal Springs is sustained by groundwater from the downthrown side of the Comal Springs fault, where there is flow of groundwater moving northeastward toward the springs.

George, Breeding and Hastings (1952) reported that the mean annual water temperature of Comal Springs is 23.3°C (74°F) and is not believed to fluctuate more than about 0.5°C (1°F).

Flow at Comal Springs has been monitored since the early 1880s. Comal Springs have the greatest mean discharge of any springs in the southwestern United States (George et al. 1952). The average annual discharge from 1928-1989 was 8.04 cms (284 cfs). Maximum daily springflows were 18.86 cms (666 cfs) on December 22, 1991 (Edwards Underground Water District, pers. comm.). The highest monthly flow from Comal Springs was 13.2 cms (467 cfs) in 1973 (Guyton and Associates 1979).

Much lower flows have been recorded during drought years, and in dry years flows from Comal Springs can drop very rapidly. Comal Springs ceased flowing from June 13 to November 4, 1956, during the most severe drought on record (U.S. Army Corps of Engineers 1964). At that time, all major springs in the Balcones Fault Zone had ceased to flow, with the exception of San Marcos Springs, which had decreased its flow substantially (Guyton and Associates 1979). Some of the higher elevation Comal Springs ceased flowing in 1984 and 1990 when water levels in the Bexar County index well (J-17) in San Antonio dropped to within twelve feet of the historic low of 186.7 m (612.5 feet) that occurred in 1956 (Wanakule 1990).

San Marcos

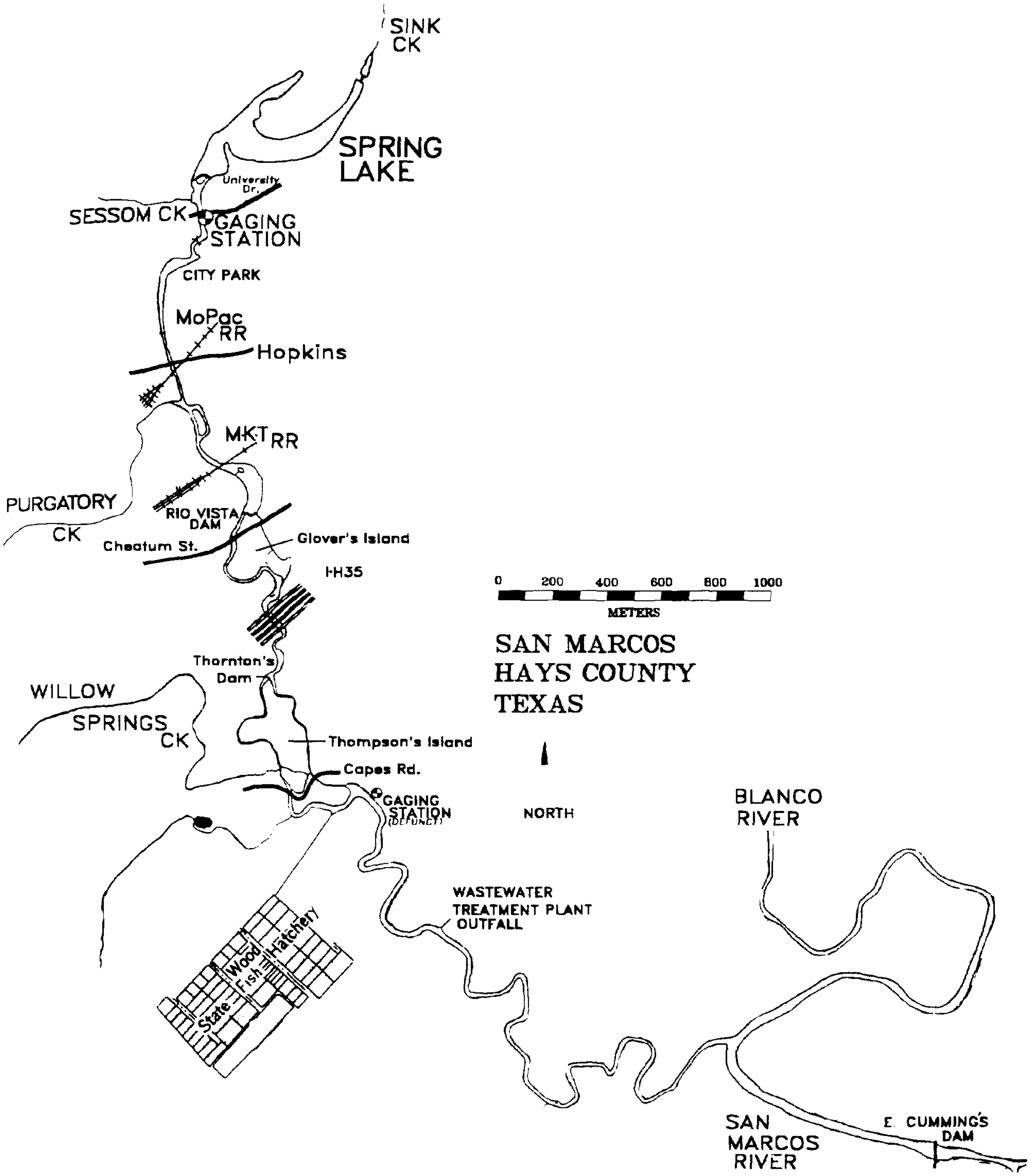
The springs at San Marcos (the second largest spring system in Texas) historically have exhibited the greatest flow dependability and environmental stability of any spring system in the southwestern United States. Records indicate that the San Marcos Springs have never ceased flowing, although the flow has varied and is tied to fluctuations in their source, the Edwards Aquifer underlying the Balcones Fault Zone. The headwaters of the San Marcos River issue from several large fissures and numerous smaller solution openings along the San Marcos Springs fault (Puente 1976). It has been reported that prior to inundation with the formation of Spring Lake, the largest springs emerged with such force that they formed a fountain three feet high (Brune 1981).

Early Spanish explorers estimated that a series of 200 springs made up the main spring area (Brune 1981). Spring Lake, elevation 189 m (620 feet), was created over 50 years ago by the damming of the San Marcos River not far downstream from the springs. Spring Lake, known for the clarity of its water, is the site of a major tourist attraction, Aquarena Springs, Inc., an amusement park featuring glass-bottomed boat rides and a submarine theater. This resort was sold to Southwest Texas State University in 1994.

The San Marcos River (Figure 3) flows primarily southeastward for about 110 km (68.4 miles) before joining the Guadalupe River near Gonzales, Gonzales County, Texas. The upper San Marcos River (which includes the river area above the confluence with the Blanco River) is rapidly flowing and unusually clear. The upper River run is primarily spring-fed and varies from about 5-15 m (16.4-49.2 feet) wide and up to about 4 m (13.1 feet) deep. The section between the Blanco River confluence and the Guadalupe River has fewer attributes of a spring run.

From its headwaters at the springs to near its confluence with the Blanco River, a distance of a few kilometers, the river flows mostly over gravel or gravel/sand bottom (Crowe 1994), with many shallow riffles alternating with deep pools. However, there is variability in the substrate, and in areas with lower flows, silt/mud accumulates. Near banks where erosion has occurred and near stormwater drainage points, silt dominated substrates are also found.

Figure 3. San Marcos Aquatic Ecosystem.



Upstream from the junction of the Blanco River with the San Marcos River, within about a 6.4 km (4.0 mile) river section below the main springs in San Marcos, 4 named and various unnamed creeks, various storm sewers, and one wastewater treatment plant discharge into the river (Figure 3). Sink Creek, largest of the creeks, discharges large quantities of storm runoff from the north into Spring Lake. Spring Lake dam backs water about 1.6 km (1.0 mile) up Sink Creek. Willow Springs and Purgatory Creek are normally dry except during periods of high rainfall.

The exact areas contributing recharge to the San Marcos Springs, and their relative importance, has not been clearly delineated. Guyton & Associates (1979) stated that the majority of recharge for San Marcos Springs is considered to be from an area of the aquifer southwest of Comal Springs that flows under the Comal Springs and is discharged at San Marcos Springs. These flows are derived primarily from the same sources as the Comal Springs, which likely include the recharge area southwest of the Cibolo Creek basin (including the upper part of the San Antonio River basin with Helotes, Leon, and Salado creeks, and the Nueces River basin) with some contribution from a large part of the Cibolo Creek basin (Figure 1).

However, tritium content in the San Marcos Springs water may indicate that some recharge water also originates from other sources such as the Dry Comal Creek basin. The flow from San Marcos Springs also has a component derived from local recharge including recharge from the Blanco River basin, Sink, Purgatory, York, and Alligator creek basins, the Guadalupe River basin recharge area east of the river, the upper part of the Dry Comal Creek basin, and possibly part of the upper part of the Cibolo Creek basin (Guyton and Associates, 1979). Puente (1976) estimated that under normal rainfall conditions 40% of discharge could be derived from local recharge. Maclay and Land (1988), through computer simulation studies, concluded that in southern Hays County groundwater moves northeastward along a narrow strip between Hueco Springs and Comal Springs faults, and discharges at San Marcos Springs. They state that discharges at San Marcos Springs also likely come from water moving southeastward from the recharge area in east-central Hays County.

The flow of San Marcos Springs has been monitored intermittently since 1894 (Puente 1976). Average annual springflow from May 1956- October 1994 was 4.81 cms (170.0 cfs) (USGS 1995). During drought years much lower flows occurred, especially in the mid-1950s during the drought of record. Part of the flows recorded in 1956 may be attributed to water provided by a well near Spring Lake. The lowest recorded monthly flow from the San Marcos River was 1.53 cms (54 cfs) during 1956 (Guyton and Associates 1979). The lowest measured daily flow rate occurred on 15 and 16 August 1956 when the San Marcos River flowed at only 1.29 cms (45.5 cfs). Maximum daily springflows can be greater than the 12.72 cms (451.0 cfs) of 12 March 1992, especially following high local rainfall and runoff (USGS 1995).

The thermally constant water from the San Marcos Springs has long been noted. Guyton and Associates (1979) report an average temperature in the headwaters area of 22.0 °C (71.6 °F), and that the temperature generally fluctuates less than 0.5 °C (1 °F). At the lower end of the spring run habitat only a slightly greater range of variation in temperature (from 25.5 °C [77.9 °F] in August to 20.4 °C [68.7 °F] in February) has been recorded (USGS 1967-1971, Beaty 1972).

Waters tend to be alkaline or neutral due to the limestone aquifer. The pH range of the San Marcos Springs is 6.9 - 7.8 (Texas Water Development Board 1968). The stability of this stream, both in terms of flow dependability and thermal characteristics, provided a unique set of ecological conditions. The unusually high degree of endemism of the San Marcos and Comal biota may be a result of the relatively constant, island-like spring habitats.

B. THREATS TO THE SPECIES AND THEIR ECOSYSTEMS

WATER QUANTITY

A primary threat to all five of these species and their ecosystems is loss of springflows. Springflows at San Marcos and Comal Springs are tied inseparably to water usage from the entire Edwards Aquifer, and use of groundwater in that region decreases flow of water from the springs. Analyses by the Texas Department of Water Resources (TDWR 1977), projecting water usage from the aquifer through the year 2020, indicate that increased groundwater usage is expected well into the 21st century, especially in the San Antonio area. Total withdrawal from the San Antonio area of the Edwards Aquifer has been increasing since at least 1934, when total well discharge was 101,900 acre-feet (EUWD 1989). In 1989, total well discharge was slightly more than 542,000 acre-feet (Longley 1991, EUWD 1992a, 1992b). Municipal water use accounted for 58% of water use from the Edwards from 1981-1988 (Wanakule 1990). The population in Bexar, Comal, Hays, Medina, and Uvalde counties is estimated to increase between 37 and 47% by the year 2010 with a concurrent increase in water demand (Texas Water Development Board 1990, 1992a). Projections of future San Antonio water use and needs have been analyzed by the Texas Water Development Board (1992), Research and Planning Consultants (1994), and others.

Because of the anticipated growth in this region of the Edwards aquifer and the concomitant increase in water use, several estimates have been made concerning the influence of increased well discharge on springflows at Comal and San Marcos.

The Texas Water Development Board has applied its model of the Edwards Aquifer to determine what pumping level would allow Comal Springs to continue to flow (Technical Advisory Panel 1990). The Board found that during a drought similar to that of the 1950s, the maximum pumpage from the aquifer that would allow springflow at Comal Springs to continue is about 250,000 acre-feet per year (less than half the current pumping rate). At this pumping level, Comal Springs could be expected to maintain some annual flow although flows may be intermittent during a recurrence of the drought of record (Technical Advisory Panel 1990). The Panel also predicted that in the year 2000, if pumping continues to grow at historical rates and a drought of record were to occur, Comal Springs would go dry for a number of years (Technical Advisory Panel 1990).

Given various schemes of water usage, the Bureau of Reclamation (U.S. Bureau of Reclamation 1972, 1973, 1974) projects that the probability of continuous flow from the San Marcos Springs by the year 2020 is only 50-75 percent certain. Klemt et al.(1979) project that assuming full projected development with average hydrologic conditions, continuous flow from San Marcos Springs will cease around the year 2010.

Data from the Bureau of Reclamation (U.S. Bureau of Reclamation 1972, 1973, 1974) and others suggest that demands on the Edwards Aquifer, even considering a low (and unlikely) rate of growth for this region, will far exceed the recharge to the aquifer (Longley 1975, McKinney and Watkins 1993, Research and Planning Consultants 1994). Wanakule (1990) states: "The present problem facing the Edwards Aquifer is the threat of overdrafting of the annual average recharge rate (1934-1988) of approximately 635,500 acre-feet." A number of recent studies have modeled springflow at San Marcos and Comal springs (Thorkildsen and McElhaney 1992, McKinney and Watkins 1993, Wanakule and Anaya 1993) and found some regulation of groundwater withdrawal necessary to ensure continuous flow at San Marcos and Comal Springs. Refinement of modeling techniques led to the conclusion, in an updated Texas Water Development Board report (1992) that a sustained pumping limitation of about 165,000 acre-feet per year would be needed to ensure springflows during a repetition of a drought of record. The Edwards Underground Water District (1992a) had a Technical Data Review Panel examine potential problems with the methodology and assumptions used in making current projections, and concluded that additional data would be needed to improve the accuracy of projections for regulatory purposes.

As part of a February 1, 1993, Judgment (as amended on May 26, 1993) in the case of Sierra Club vs. Secretary of the Interior (No. MO-91-CA-069, U.S. Dist. Ct., W.D. Texas), the Court ordered the Service to make certain determinations relative to minimum springflows and aquifer levels necessary for endangered and threatened species. The purpose of these determinations was to provide guidance to Federal agencies and pumpers from the aquifer to assist them in taking appropriate actions to ensure their activities do not take or jeopardize listed species or result in adverse modification or destruction of critical habitat. Take includes "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Take can include significant habitat modification or degradation if it kills or injures wildlife by significantly impairing essential behaviors such as breeding, feeding, or sheltering.

These springflows and aquifer levels were to be based on available information and the Service's best professional judgment. The determinations made by the Service are included in Table 2. These determinations were based on conditions at the time and assume there is no mechanism in place to manage groundwater withdrawal so that the timing and duration of flow levels can be influenced. Determinations also assume there is no effective control mechanism for nonnative species such as the giant ramshorn snail. It may be possible for flow levels to fall below these levels for short periods of time, but not for extended periods without causing take, jeopardy, and/or adverse modification. In some cases these flow levels may also be reduced for short periods if adequate management for controlling duration and timing of low flows and management of nonnative species are in place.

Accurately monitoring the discharge of both Comal and San Marcos Springs is an important task. A variety of methods have been employed for the period of record. Many entities use data

Table 2. U.S. Fish and Wildlife Service determination of minimum springflows needed to prevent take, jeopardy, or adverse modification of critical habitat. All flow rates are given in cubic feet per second (cfs).

Species	Take	Jeopardy	Adv. Mod.
Fountain darter in Comal	200	150	N/A
Fountain darter in San Marcos	100	100	100
San Marcos gambusia	100	100	100
San Marcos salamander	60	60	60
Texas blind salamander	50*	50*	N/A
Damage and Destruction			
Texas wild-rice	100	100	100

* Refers to San Marcos springflow

Some of these levels could be reduced under certain conditions, such as significant control of certain nonnative species and/or implementation of an aquifer management plan. Significant control of nonnative species would be that which would eliminate threats from these species, such as loss or alteration of essential habitat, increased predation, disruption of normal behaviors, or hybridization.

from a monitoring well in San Antonio known as J-17 to track Edwards Aquifer levels. Several investigators have examined the relationship between levels in J-17 and springflows at the Comal and San Marcos Springs (Guyton and Associates 1979, Wanakule 1988). J-17 well levels do not correspond directly (that is 1:1) to springflows, particularly at low flows. The correlation between J-17 well levels and the flow from Comal Springs appears to be better than the correlation between J-17 well levels and the flow from San Marcos Springs. Using wells closer to the springs to estimate spring discharge may be more accurate than relying on J-17 levels.

However, a more direct and accurate method of monitoring Comal and San Marcos springflows is desirable to support recovery efforts. Working cooperatively with the Edwards Underground Water District, the USGS has established a San Marcos gage station near the outflow of Spring Lake at University Drive and has added additional instrumentation along the Comal as well. Previously USGS used a monitoring well off Hunter Road (SW of the City) to estimate San Marcos springflow. The University Drive gage measures San Marcos discharge as the sum of springflow and runoff from Sessom and Sink Creeks. Similarly, the USGS gage for the Comal River measures Comal springflow and runoff from Blieders and Dry Comal Creeks and Panther Canyon. These new gages will give a better estimate of springflow and floodflow conditions. Local wells in Comal and Hays counties that have been used in the past to monitor aquifer levels and estimate springflows provide valuable information about the relationship between differences in aquifer levels in the region and their relationship to springflows, and should continue to be monitored as well.

WATER QUALITY

Water quality declines would likely impact all five listed species included in this plan as well as other species. Water quality includes chemical and physical factors. Some of the chemical constituents that may be important include dissolved ions, trace elements, pH, nutrients, dissolved oxygen, and organic contaminants (e.g., compounds of petrochemical or pesticide origins). Some of the physical factors considered important include water temperature, air temperature, light, turbidity, and sedimentation.

Due to its wide ranging influence on many different biotic and chemical factors (Armour 1991), water temperature is an important consideration. Rivers like Comal and San Marcos typically have a gradient of increasing variability in temperature from the headwaters to the lower reaches. However, human caused factors can affect Comal and San Marcos aquatic systems' temperatures (such as through discharge of water at a temperature other than the ambient water temperature or through decreased aquifer levels resulting in lowered spring discharges and associated increases in temperature fluctuations).

In 1988, The Texas Water Commission, now the Texas Natural Resource Conservation Commission, reported that the San Antonio segment of the Edwards Aquifer, Bexar, Hays, and Comal Counties had the greatest number of land-based oil and chemical spills in central Texas that affect surface and/or groundwater, with 28, 6, and 4 spills, respectively (TWC 1989). The potential exists for catastrophic accidental spills from railroad tank cars, tractor-trailers, or other motor vehicles crossing the San Marcos River on railroad bridges, the interstate highway, or other road crossings. As of July, 1988, Bexar County had between 26 and 50 confirmed leaking underground storage tanks, Hays County had between 6 and 10, and Comal County had between 2 and 5 (TWC 1989), putting these counties among the top five counties in central Texas for confirmed underground storage tank leaks. The TWC estimates that, on average, every leaking underground storage tank will leak about 500 gallons per year of contaminants before the leak is detected. These tanks are considered one of the most significant sources of groundwater contamination in the state (TWC 1989).

Decreased water quality could also result from a reduction in the water level in the aquifer. The Balcones Fault Zone-San Antonio Region is bounded on the south and east by a saline water interface known as the "bad water" line across which the groundwater quality abruptly deteriorates to greater than 1000 mg/L total dissolved solids (TDS). In other words, crossing the bad water line, groundwater goes from fresh to saline or brackish. Lowered water levels due to groundwater pumpage or decreased recharge may result in deterioration of water quality by movement of saline water into the fresh water section of the aquifer. Movement of bad water into the aquifer could have serious impacts on the species of concern, which depend on fresh water, as well as to the suitability for use as a human water supply. Both Comal and San Marcos Springs are very close to the bad water line (TWC 1989, EUWD 1992b) and, although the data are inconclusive at present, both springs could undergo intrusion of saline waters at low aquifer levels.

Lower aquifer levels and springflows may also decrease water quality because of a decreased dilution ability (i.e., less water to dilute any pollutants in the system, resulting in higher pollutant concentrations). This situation would be compounded during drought.

Other threats to water quality occur as a result of human activities in the recharge zone and in the local watersheds. Permitted, non-permitted, and accidental discharges (such as sewage leaks) into waterways are a possible threat that needs to be evaluated and addressed (Emery 1967, Vaughan 1986). Surface runoff, particularly in urban areas, may impact the springs, lakes, and river systems. Stormwater runoff may include such things as pesticides and herbicides, fertilizers, soil eroded from construction activities, silt, suspended solids, garbage, hydrocarbon and inorganic/metal compounds from vehicles and machinery, household solvents and paints, and other urban runoff from point and non-point pollution sources (Urban Drainage and Flood Control District 1992).

Non-point source runoff and chemical contamination are potential sources of water quality degradation. For example, use of an herbicide along bridge pilings and concrete aprons at the IH-35 crossing of the San Marcos River has occurred for years. Moderate to light rainfall could wash this and other contaminants into the river at the type locality of the San Marcos gambusia. Such runoff could impact the San Marcos gambusia, fountain darter, Texas wild-rice, or their habitats. Other species, such as invertebrate prey species and algae on which they feed, could also be affected by runoff of herbicides, pesticides, and other non-point source pollutants.

A report produced by the Edward's Underground Water District (EUWD 1993) summarizes information on increasing development in the Edwards Aquifer recharge zone and the effects of these activities in Bexar, Comal, and Hays counties. The report concluded there was cause for concern that the cumulative impact of pollution resulting from urbanization over the Edwards recharge zone was not being adequately addressed, and that degradation of Edwards Aquifer water could be imminent. The Edwards Underground Water District report also included recommendations for steps that could be taken to prevent pollution of the aquifer.

Rice (1994) examined USGS and State of Texas data for wells sampled between 1982 and 1992 and found that 54 wells in Bexar County have reported mercury and chlorinated solvents. Rice considered the data cause for concern and presented recommendations for preventing groundwater contamination. While only a few wells had contaminant levels above those permitted in drinking water standards, the presence of these contaminant compounds demonstrates the risk of aquifer contamination. If not abated, contamination may increase and threaten the health of humans as well as plant and animal species.

HABITAT MODIFICATION

Human modifications (such as bank stabilization, dams, and landowner maintenance activities in waterways and on adjacent tracts of land) have significantly altered natural configurations and drainage in the San Marcos and Comal systems. These alterations, in turn, have changed the historical magnitude and occurrence of episodic events such as flooding. Indirect impacts from surrounding development and urbanization have also changed these systems. Understanding these changes and their impacts is important to the conservation of the ecosystems and their species.

A series of five flood retardation structures built by the Soil Conservation Service (now known as the Natural Resource Conservation Service) on tributary creeks feeding into the San Marcos River is expected to decrease the severity of flooding in the watershed and to slightly increase the recharge into the aquifer (U.S. Department of Agriculture 1978). However, the effect of these structures on flushing flows and silt accumulation is uncertain. Flooding still occurs and may flush silt and other soft materials from the river bottom, but may not be adequate to maintain natural habitats. A large gravel bar has accumulated below the confluence of Sessom Creek due to construction in the Sessom Creek watershed (Longley, *in litt.*, and USFWS observations). Periodic flooding is a natural event in the San Marcos (and to a lesser extent in the Comal). In addition to silt removal, flooding can maintain habitats for some species by periodically removing vegetation from parts of streambanks and rivers, creating openings in shoreline emergent vegetation and in some substrate areas. Flooding also is known to reduce abundances of introduced nonnative fishes in other southwestern streams.

The species composition, distribution, and density of aquatic vegetation are very important for many of the listed species. These factors influence the quality and quantity of available habitat. Activities that alter aquatic vegetation, directly or indirectly, need to be carefully evaluated and managed to minimize adverse impacts and improve species habitat. Cutting and removing vegetation (algae, mosses, vascular plants) from Spring Lake may harm or kill San Marcos salamanders and fountain darters. This is potentially a serious threat to the San Marcos salamanders, since the algal mats provide a food source, cover and protection from predators (Nelson 1993). Emery (1967), Vaughan (1986), and Rose and Power (1993) have noted that cutting of aquatic vegetation in Spring Lake and other areas threatens Texas wild-rice because floating mats of cut vegetation released into the river shade and entangle Texas wild-rice plants and knock over inflorescences. Vegetation cutting may also threaten other species of concern by direct damage or lowering habitat quality.

NONNATIVE SPECIES

Certain nonnative species (that is, those introduced to an area outside their normal range of distribution; including species native to areas outside the continent often termed exotic species) pose a significant threat to the listed species. Threats occur due to competition over habitat or diet and/or by modifying habitat, such as affected by nonnative elephant ears (*Colocasia esculenta)* and giant ramshorn snails (*Marisa cornuarietis)*. In addition, some species prey on the listed species. Decreased flow may exacerbate the problem posed by nonnative species.

Since introduction of giant ramshorn snails into the Comal and San Marcos ecosystems around 1983, aquatic plants in many areas of Landa Lake have been denuded or grazed to the bottom (Horne et al. 1992, Linam et al. 1993) such that they no longer provided cover for the fountain darter. Giant ramshorn snail populations appear to increase during low flows. This snail poses a significant threat to the Comal aquatic ecosystem. On March 3, 1990, this species was added to the Texas Parks and Wildlife Department's list of "Harmful or potentially harmful exotic shellfish." The giant ramshorn snail is recognized as a voracious herbivore, which is why it became unpopular with aquarists and has been investigated as a biological control agent for aquatic weeds that clog ponds, canals, and waterways (Seaman and Porterfield 1964, Blackburn et al. 1971). Seaman and Porterfield (1964) found that 150 adult snails required less than one week to completely consume masses (1360 g wet weight) of several species of aquatic macrophytes in outdoor concrete tanks. The giant ramshorn snail is common throughout Landa Lake and the Comal River and its population has increased dramatically since its introduction around 1983. Giant ramshorn snails have apparently had a significant impact on Landa Lake and the Comal River ecosystem (Horne et al., 1992). On September 1, 1989, the New Braunfels Parks Director (David Whatley) contacted the Service to inform them that vegetation was disappearing from Landa Lake. From October 1989 through February 1990 extremely dense populations of adult snails and large numbers of egg masses were present in Landa Lake (Linam 1993, and Thomas Arsuffi, SWTSU, pers. comm.). This coincided with low springflows. Areas of the lake that had supported large masses of aquatic macrophytes were completely denuded, leaving areas of bare lake bottom criss-crossed with snail tracks.

Following the giant ramshorn snail population increase in 1989-90, the population subsequently declined, possibly because it had severely depleted its own food and habitat requirements (Thomas Arsuffi, pers. comm.). By April 1990, very few living adult specimens were collected or observed, although a large number of young snails were present (Thomas Arsuffi, pers. comm.). From May to June average springflows dropped below 200 cfs. On July 10, 1990 the New Braunfels Parks Director contacted the Service to inform them that they were having to remove dump truck loads of clipped vegetation from Landa Lake. This second episode of rapid vegetation loss occurred after a shorter period of low flows. Snail censuses in July 1993 and January 1994 during high flow conditions indicate that adult and juvenile ramshorn snails and egg masses are still present in the main body of Landa Lake. They are also still present, although less common, in the spring runs feeding the lake and in the river channel below the lake.

Currently, few giant ramshorn snails are known from the San Marcos ecosystem. However, in the future under low flow conditions the snails may have an adverse effect on Spring Lake and the San Marcos River.

Alteration of plant communities by a nonnative herbivore like the giant ramshorn snail can have a drastic effect on endemic species, such as the fountain darter. Additional studies and monitoring programs for tracking population dynamics and monitoring the effects of ramshorn snails on aquatic vegetation communities should be established for both the Comal and San Marcos aquatic ecosystems. Understanding of giant ramshorn snail life history and demographic characteristics could prove important in developing a management scenario for this pest species.

Elephant ears (*Colocasia esculenta)* are believed to have been introduced into the San Marcos area in the early 1900s (Akridge and Fonteyn 1981) and now form extensive stands at the water's edge in the San Marcos and Comal systems, displacing native species. Elephant ears are present in the area occupied by the San Marcos gambusia and may have decreased habitat suitability and contributed to its decline. The changes in shoreline conditions may also have indirect impacts on other species.

Hydrilla (*Hydrilla verticillata)*, an aquatic plant introduced from the Old World, is naturalized now in many Texas waters. It is abundant in the San Marcos River and Rose and Power (1992) note that "Most of the area historically occupied by wild-rice is now occupied by *Hydrilla* . . . ."

Many fish species have been introduced into the San Marcos and Comal ecosystems (e.g., tilapia, common carp, rock bass, sailfin mollies), and some may compete with the fountain darter and San Marcos gambusia for needed resources (food, breeding habitat) or prey upon the listed fish species. Taylor et. al. (1984) note that introduced fish may also have indirect impacts, inducing changes in habitat characteristics (for example, by removal of vegetation or substrate disturbance) or introducing diseases and parasites. Tilapia have become so abundant in Landa Lake and Spring Lake that in terms of biomass they appear to exceed any of the native sunfish family (blackbass/sunfish species) (Patrick Connor, USFWS, pers. obs.).

Nutria (*Myocaster coypus)*, an introduced mammal native to South America, is also common in the San Marcos and Comal systems. Nutria feed on a wide variety of aquatic vegetation (Burt and Grossenheider 1964) and have been observed feeding on Texas wild-rice (Emery 1967). Investigators feel nutria may significantly damage stands of Texas wild-rice (Rose and Power 1992).

RECREATIONAL ACTIVITIES

The Comal and San Marcos areas are very popular recreation sites that provide a variety of recreational opportunities including swimming, tubing, canoeing, fishing, snorkeling, scuba diving, and glass-bottomed boat tours. These activities and their associated support facilities may directly or indirectly impact the ecosystems and their species. Texas wild-rice plants may be physically damaged by water activity, or its inflorescences may be prevented from emerging so that the plants cannot successfully produce seed (Vaughan 1986, Rose and Power 1992, Bradsby 1994).

Habitat alteration due to recreation activities occurs from direct impacts such as bottom disturbance and vegetation control, or indirectly due to introduction of non–nativebait fish or streamside influences such as increased compaction, erosion, litter, pollution, and runoff from parking areas and support facilities.

Recreational impacts should be carefully evaluated and a comprehensive plan developed to monitor and manage recreational activities so that species needs are provided for and adverse impacts minimized.

OTHER IMPACTS

The New Braunfels and San Marcos areas are growing rapidly (U.S. Bureau of the Census 1982). Over half of the population of Comal County resides in New Braunfels, and the population of New Braunfels has increased from 17,859 in 1970 to 27,334 in 1990 (M. Meek, New Braunfels Chamber of Commerce, pers. comm., 1993). The population of the city of San Marcos, Hays County, Texas rose from 741 in 1870 to 23,420 in 1980 (U.S. Bureau of the Census 1982); no other county along the Balcones Fault Zone had a greater relative growth than Hays County for the period 1960-1980. Between 1980 and 1990, the population of Hays County grew 61.6 percent. As of July, 1992 the Texas State Data Center estimated the population of Hays County at 67,964. The Bureau of Business Research at the University of Texas at Austin estimated that the population of Hays County will reach 83,201 by the year 2000. As of January 1994, the population of the city of San Marcos was estimated at 36,464 (Greater San Marcos Economic Development Council 1994), and this figure excluded their student population.

Edwards (1976) found that increased urbanization caused increased flooding and erosion (due to uncontrolled runoff), pollution, siltation, and a general decrease in species diversity and species numbers in impacted aquatic environments. For these reasons, changes in the upper San Marcos and Comal watersheds should be approached with extreme caution to avoid further degrading of aquatic habitat suitable for these endangered and threatened species.

Predation is currently believed to be a minor threat to the San Marcos salamander. However, fish have been observed preying on salamanders (Tupa and Davis 1976, Nelson 1993) and are suspected to be the main predators of salamanders. Tupa and Davis (1976) suspected that crayfish, which are often found in the salamander's habitat, may also prey on *E. nana*. Given diet similarities it is possible that decapod crustaceans (prawns and crayfish) in general may present a predation threat (David Bowles, TPWD invertebrate biologist, pers. comm., 1995). However, Nelson (1993) found no evidence of crayfish predation on salamanders during her study.

Waterfowl may also present problems for some aquatic species. Rose and Power (1992) noted that waterfowl appear to clip off leaf segments of Texas wild-rice and have significant impacts on experimental plots that are not protected from herbivory. They postulate that waterfowl have increased in numbers and are now permanent residents in the San Marcos area (rather than a migratory and transient population) due to urbanization of the area. Introduced swans (*Cygnus olor)*, domesticated mallard ducks (*Anas platyrhynchos)*, and other ducks in the lake feed on the aquatic moss and *Lyngbya* sp. (Tupa and Davis 1976). These birds roost nightly on the sidewalk alongside the San Marcos salamanders' principal habitat. Their fecal droppings are swept daily into the lake, increasing the nutrient input into this system. This factor, combined with the birds' feeding activities, could reduce the abundance of the aquatic moss and *Lyngbya* sp. where *E. nana* occurs. A reduced abundance of aquatic moss along the bank and on large submerged boulders has been reported by Tupa and Davis (1976).

Broad regional issues of water use and landscape level management influence the systems upon which these species depend. In addition, more local actions of municipalities and landowners have significant potential impacts that must be addressed; and there are some site-specific problems impacting multiple species. Progress on these regional, local, or site-specific issues that impact multiple species has been noteworthy and is discussed below. Progress on more species-specific problems is discussed under the individual Species Accounts section.

C. GENERAL CONSERVATION MEASURES

WATER QUANTITY

The Service has given preliminary guidance on the minimum springflow levels that need to be maintained to protect the species and their habitat (Table 2). In addition, the Service and Texas Parks and Wildlife Department have instream flow and habitat requirement studies underway to help refine habitat requirements and characteristics in both the Comal and San Marcos systems.

There has been considerable activity by many water management agencies and aquifer users that address water quantity issues in developing a regional management plan to ensure adequate springflows to protect the five listed species and ecosystem to which they contribute, covered by this plan. Numerous agencies have examined structural and hydrological characteristics and trends of the aquifer and its watersheds, and there are numerous publications available. These agencies include the U.S. Geological Survey, Edwards Underground Water District, Edwards Aquifer Research and Data Center, Texas Natural Resource Conservation Commission, Texas Water Development Board, U.S. Army Corps of Engineers, Bureau of Reclamation, and the Natural Resource Conservation Service. In addition, land ownership and use along the San Marcos River has been examined (McCoig and Cradit 1986, and Pulich et al. 1994).

Progress has also been made on developing and implementing several other elements or techniques that can contribute to maintaining necessary springflows. The Texas State Legislature has made a significant contribution to this effort by enacting legislation (S.B. 1477, as amended by H.B. 3189 in 1995) creating the Edwards Aquifer Authority. According to that legislation the authority should be able to regulate and control groundwater pumping from the Edwards Aquifer, a primary need identified in the recovery plan. While the implementation of the authority has been challenged as noted above and litigation continues, the Service is hopeful that a State regulatory mechanism will be put in place that provides habitat required to recover the five federally listed species covered by this plan.

New Braunfels, San Antonio, and San Marcos have water conservation ordinances. The city of San Antonio has developed a wastewater re-use plan that may result in conservation of a significant amount of water. Many municipalities and water conservation districts are exploring alternative sources of water.

Federal agencies have also been making a conscious effort to reduce water needed from the aquifer. There have been recent efforts by military bases to conserve water and develop wastewater irrigation systems. The Department of Agriculture is conducting a review of the impact of its programs and practices on irrigation withdrawals.

In addition, many water users and agencies have conducted studies and evaluations (including computer modeling) to examine projected water needs and determine the aquifer levels needed that will translate to maintaining springflow (Longley 1975, McKinney and Watkins 1993, Research and Planning Consultants 1994, Thorkildsen and McElhaney 1992, Wanakule and Anaya 1993, Texas Water Development Board 1992). This has emerged as a critical issue in efforts to manage groundwater for the benefit of listed species, and more work is needed.

Estimates have fluctuated widely, and one estimate predicts that in a drought of record no more than 165,000 acre-feet per year could be pumped from the Edwards Aquifer (Edwards Underground Water District 1992a). In 1989 well discharge was 542,000 acre-feet. Immediate reductions in groundwater use are needed (and in drought conditions severe reductions in water use will be needed).

In June 1994, as a part of the lawsuit proceedings in Sierra Club vs. Babbitt, Judge Bunton ordered court appointed monitor Joe Moore, Jr., to prepare an emergency withdrawal reduction plan by August 1, 1994. The plan was completed and filed on August 1, and was revised in March of 1995. In May of 1995 Judge Bunton named a

5-member committee to develop an alternative voluntary emergency withdrawal reduction plan for 1995. The committee developed a generic, representative ordinance to limit municipal and industrial water use for 1995, which has been largely adopted by the city of San Antonio.

In August of 1994 discussions were initiated by the Court Monitor among the city of San Antonio, the Uvalde Underground Water District, the Medina County Underground Water District, the Edwards Underground Water District, the San Antonio River Authority, and the Guadalupe Blanco River Authority about cooperatively preparing a regional Habitat Conservation Plan. Numerous public meetings were held. Following these activities a preliminary issues document was prepared, and discussions regarding an HCP and a potential incidental take permit have been initiated with the Service. The option also exists that concerned stakeholders may develop and implement one or more smaller regional or local HCPs that contribute to overall aquifer management.

In addition to strategies for conserving water and developing sources off the aquifer to serve projected needs in the area, another approach that has been suggested is to artificially augment the aquifer with water from other sources. McKinney and Sharp (1995) examined five potential techniques for artificially augmenting springflows at Comal and San Marcos Springs. The Service submitted written comments to the Texas Water Development Board (September 1, 1994 and January 23, 1995) indicating that there were hydrological and biological concerns. The Service's comments stated that the augmentation alternatives described involving injection wells, infiltration galleries, aquifer baffles, and direct addition of water to spring-fed lakes are not feasible in terms of providing adequate protection for Federally listed species dependent upon the Edwards Aquifer. While regional and local recharge enhancement opportunities may have some potential benefit, these recharge alternatives cannot be adequately evaluated until data on water quality issues (such as the potential for contamination or the likelihood that enhanced recharge waters will equilibrate to normal aquifer conditions without harm to species) are developed and analyzed. Further, the realistic probability that recharge enhancement can provide significant water to the aquifer should be evaluated. Impacts to fish and wildlife at the point of recharge, from decreased flows in rivers and streams downstream of recharge, and other impacts to drainages that will be deprived of waters normally accruing to them (due to diversion to recharge) must be carefully evaluated as well.

WATER QUALITY

The Edwards Underground Water District (1993) and Rice (1994) have examined water quality threats and existing regulations protecting aquifer water quality and given recommendations for improvements. In addition, Texas Parks and Wildlife Department has a study currently underway to examine potential impacts to listed species from effluent from the A. E. Wood State Fish Hatchery, and a study is underway to examine some potential impacts of effluent from the San Marcos wastewater treatment plant.

Water quality issues are also included in some activities underway to address more local impacts in a comprehensive manner. The Service is working in cooperation with the city of New Braunfels and others to develop a Comal ecosystem management plan (task 2.42). The city of San Marcos and Southwest Texas State University are about to begin developing a similar plan for the San Marcos area (task 2.41). Texas Parks and Wildlife (Spain et al. 1994) completed a preliminary overview of significant management issues for the San Marcos River.

NONNATIVE SPECIES

Progress has been made in some areas. Nutria control measures have been implemented in some areas in the past by Animal Damage Control, and some basic research on giant ramshorn snails has been conducted in the Comal Springs ecosystem area. In addition, data on the incidence of clipping of leaves of Texas wild-rice by herbivores in Spring Lake are now being collected (Power, Southwest Texas State University, pers. comm.).

RECREATION

The Service has recently funded studies examining recreational impacts on Texas wild-rice, and discussions have been initiated with operators of the largest tubing operation in the San Marcos River to examine management options available to reduce impacts from tubing.

HABITAT MAINTENANCE, RESTORATION, AND ENHANCEMENT

Progress is being made in this area through development of local management plans, and a proposal has been developed for habitat manipulation to improve habitat for the San Marcos gambusia.

CAPTIVE PROPAGATION AND CONTINGENCY PLANS

Several cooperating institutions have conducted investigations of captive breeding techniques. Techniques are available for the fish and wild-rice, and some preliminary work has been done for salamanders. The Texas blind salamander appears to breed fairly easily in captivity, but for the San Marcos salamander it has been more difficult to achieve breeding in captivity.

Reducing the probability of loss of the species of concern from catastrophic events led to development of a Contingency Plan providing for collection and captive propagation of individuals of the species of concern in the event a crisis is imminent, as well as more long-term general effort to establish captive populations of the listed species. The Contingency Plan is currently under revision. When completed it will be distributed as a separate document.

EDUCATION AND OUTREACH

The Service has a project underway at present in cooperation with Texas Parks and Wildlife Department to produce an information kiosk for the San Marcos River that includes information on threats from nonnative species. Another section 6 educational project undertaken cooperatively with Texas Parks and Wildlife Department is producing other educational materials on the species of concern and their ecosystem. Aquarena Springs (now owned and operated by Southwest Texas State University) has recently installed exhibits that will be helpful in education of the public. The Edwards Underground Water District has produced a variety of educational materials about the aquifer and water conservation. The Edwards Aquifer Research and Data Center has also developed educational programs about Edwards Aquifer issues.

D. SPECIES ACCOUNTS

San Marcos gambusia (*Gambusia georgei*) - endangered
(*Federal Register* Vol. 45: 47355-47364; July 14, 1980);

fountain darter (*Etheostoma fonticola*) - endangered
(*Federal Register* Vol. 35: 16047; October 13, 1970; *Federal Register* 45: 47355-47364; July 14, 1980);

San Marcos salamander (*Eurycea nana*) - threatened
(*Federal Register* Vol. 45: 47355-47364; July 14, 1980);

Texas wild-rice (*Zizania texana*) - endangered
(*Federal Register* Vol. 43: 17910-17916; April 26, 1978; *Federal Register* Vol. 45: 47355-47364; July 14, 1980)

Texas blind salamander (*Typhlomolge rathbuni*) - endangered
(*Federal Register* Vol. 32: 4001; March 11, 1967)

The recovery priority for all five of these species is 5C. A 5C priority indicates species with a high degree of threat, a low recovery potential, and that are or may be in conflict with construction or development projects or other forms of economic activity.

SAN MARCOS GAMBUSIA (*GAMBUSIA GEORGEI*)

Description

The San Marcos gambusia was described from the upper San Marcos River system in 1969. Of the three species of *Gambusia* native to the San Marcos River, *G. georgei* apparently always has been much less abundant than either the largespring gambusia (*G. geiseri*) or the western mosquitofish (*G. affinis*) (Hubbs and Peden 1969).

The San Marcos gambusia is a member of the family Poeciliidae and belongs to a genus of Central American origin having more than 30 species of livebearing freshwater fishes. The genus *Gambusia* is well defined and mature males may be distinguished from related genera by their thickened upper pectoral fin rays (Rosen and Bailey 1963). Only a limited number of *Gambusia* are native to the United States and of this subset, *G. georgei* has one of the most restricted ranges.

The San Marcos gambusia is subtly different from the western mosquitofish (*G. affinis*). Scales tend to be strongly crosshatched in contrast to the less distinct markings on the scales of *G. affinis*. In addition, *G. georgei* tend to have a prominent dark pigment stripe across the distal edges of their dorsal fins. A diffuse mid-lateral stripe extending posteriorly from the base of the pectoral fin to the caudal peduncle is also often present, especially in dominant individuals. As in *G. affinis*, a dark subocular bar is visible and is elicited easily from frightened fish. Compared to *G. affinis*, *G. georgei* has fewer spots and dusky pigmented regions on the caudal fin. The median fins (i.e., unpaired fins: dorsal, caudal, and anal fins) of wild-caught specimens of San Marcos gambusia tend to be lemon yellow under certain behavioral patterns (when they are not under stress). In a dominant or high male, this color can approach a bright yellowish-orange, especially around the gonopodium. A bluish sheen is evident in more darkly pigmented individuals, especially near the anterior dorsolateral surfaces of adult females.

Gonopodial structures of males classically have been employed in dealing with *Gambusia* systematics. *G. georgei* is unique morphologically from other species in several characters, including the presence of more than five segments in ray 4a (which are incorporated into the elbow) and also by the presence of a compound claw on the end of ray 4p (Hubbs and Peden 1969).

Historic and Present Distribution

The San Marcos gambusia is represented in collections taken in 1884 by Jordan and Gilbert during their surveys of Texas stream fishes and in later collections (as a hybrid) taken in 1925

Table 3. Historical data for known *Gambusia georgei* collections. Data taken from Edwards et al. (1980) and unpublished data.

Year	Number of collections	Number of *G. georgei*	Number of hybrids *	Number of *G. georgei* per collection	% of pure *G. georgei*
1884	1	2	0	2.0	100.0
1925	1	0	1	0.0	0.0
1955	1	1	0	1.0	100.0
1960	2	9	1	4.5	90.0
1961	3	42	1	14.0	97.7
1968	8	119	6	14.9	95.2
1974	1	1	0	1.0	100.0
1978-79	16	18	3	1.1	85.7
1981-83	10	3	17	0.3	15.0
1984	4	0	0	0.0	0.0
1985	2	0	0	0.0	0.0
1989	3	0	0	0.0	0.0
1990-94	6	0	0	0.0	0.0

* hybrids = *G. georgei* x *G. affinis*

(Hubbs and Peden 1969). Unfortunately, records of exact sampling localities are not available for these earliest collections. Collection localities were merely listed as "San Marcos Springs." These collections likely were taken at or near the headsprings area. If true, then *G. georgei* appears to have significantly altered its distribution over time. For the area of the San Marcos River downstream of the headwaters area, there are few records of sampling efforts prior to 1950. However, even in the samples that were taken there are few collections of San Marcos gambusia.

During 1953, a single individual was taken below the low dam at Rio Vista Park; however, since that time, nearly every specimen of *G. georgei* has been taken in the vicinity of the Interstate Highway 35 bridge crossing downstream to the area surrounding Thompson's Island (Figure 3). The single exception to this was a male taken incidentally with an Ekman dredge (sediment sampler) about 1 km below the outfall of the San Marcos wastewater treatment plant in 1974 (Longley 1975).

Historically, San Marcos gambusia populations have been extremely sparse; intensive collections during 1978 and 1979 yielded only 18 *G. georgei* from 20,199 *Gambusia* total (0.09%) (Edwards et al. 1980). Collections made in 1981 and 1982 within the range of *G. georgei* indicated a slight decrease in relative abundance of this species (0.06% of all *Gambusia*) and subsequent sampling has yielded none between 1982 and the present (1995) (Table 3). Intensive searches for *G. georgei* were conducted in May, July, and September of 1990 but were unsuccessful in locating any pure San Marcos gambusia. The searches consisted of a total of 18 hours of effort (>180 people-hours) on three separate days and covered the area from the headwaters at Spring Lake to the San Marcos wastewater outfall. Over 15,450 *Gambusia* were identified during the searches. One individual collected during the search was visually identified as a possible backcross of *G. affinis* and *G. georgei* (USFWS 1990 permit report). This individual was an immature fish with plain coloration.

The pattern of San Marcos gambusia abundance strongly suggests a decrease beginning prior to the mid-1970s. The increase in hybrid abundance between *G. georgei* and *G. affinis* and the decrease in the proportion of genetically pure *G. georgei* is considered evidence of its rarity. As fewer pure individuals encountered each other, the chances of hybridization with the much more common *G. affinis* substantially increased. The subsequent decrease in San Marcos gambusia abundance along with their hybrids suggests the extinction of this species.

Habitat

The San Marcos gambusia apparently prefers quiet waters adjacent to sections of moving water, but seemingly of greatest importance, thermally constant waters. *G. georgei* is found mostly over muddy substrates but generally not silted habitats, and shade from over-hanging vegetation or bridge structures is a factor common to all sites along the upper San Marcos River where apparently suitable habitats for this species occur (Hubbs and Peden 1969, Edwards et al. 1980). Introduced elephant ears have been noted in previously recorded localities for the species. Although the exact nature of the relationship between the occurrence and abundance of elephant ears and the disappearance of *G. georgei* is unknown, some investigators believe these nonnative plants may have modified essential aspects of the gambusia's habitat.

Compared to *G. georgei, G. affinis* tends to show similar preferences for shallow, still waters, but differs strikingly from *G. georgei* in ability to colonize environments with greater temperature fluctuation. These environments include the partially isolated sloughs, intermittent creeks, and drainage ditches found in the upper San Marcos River, and in the nearby Blanco River and lower San Marcos River, as well.

The San Marcos gambusia apparently requires: 1) thermally constant water; 2) quiet, shallow, open water adjacent to sections of moving water; 3) muddy substrates without appreciable quantities of silt; 4) partial shading; 5) clean and clear water; and 6) food supply of living organisms.

Critical habitat has been designated for the San Marcos gambusia as "Texas, Hays County; San Marcos River from Highway 12 bridge downstream to approximately 0.5 miles below Interstate Highway 35 bridge" (45 FR 47355).

Life History/Ecology

Food Habits

The food habits of *G. georgei* are unknown. Presumably, as in other poeciliids, insect larvae and other invertebrates account for most of the diet of this species.

Reproduction

There is little information on the reproductive capabilities of *G. georgei*. Two individuals kept in laboratory aquaria produced 12, 30, and 60 young, although the largest clutch appeared to have been aborted and did not survive (Edwards et al. 1980).

Hybridization

Hybridization between *G. georgei* and *G. affinis* was first noted by Hubbs and Peden (1969) and the production of hybrid individuals between them has continued for many years without obvious introgression of genetic material into either of the parental species. Given the history of hybridization between these two species, this factor was not thought to be of primary importance in considerations of the status of *G. georgei*. It was thought that so long as the proportion of hybrids remained relatively low compared to the abundance of pure *G. georgei*, few problems associated with genetic swamping or introgression would occur (Hubbs and Peden 1969, Edwards et al. 1980). However, the series of collections (Edwards, pers. comm.) taken during 1981-83 indicate that hybrid individuals may have become many times more abundant than the pure *G. georgei*. It is possible that hybrid individuals may now be competing with *G. georgei*, placing an additional stress on the small native population of San Marcos gambusia.

Conservation Measures

In 1976, prior to listing, the Service contracted for a status survey to improve our understanding of the species, particularly its habitat needs. The Service also promoted bringing individuals into captivity for breeding and study. Many researchers have been involved and have devoted considerable effort to attempts to locate and preserve populations.

Captive breeding was attempted. Individuals taken during the 1976 study were held and bred at the University of Texas at Austin by Dr. Clark Hubbs in 1979, and fish from that captive population were used to establish a captive population at the Service's Dexter National Fish Hatchery in 1980. Both captive populations later became contaminated with another *Gambusia* species. The fish hybridized and the pure stocks were lost.

Following publication of the status report and listing of the species in 1980, the Service contracted with Dr. Bob Edwards for examination of known localities, and collection of fish to establish captive refugia. In 1981, 1982, 1983, and 1984 Dr. Edwards tried to relocate populations and reestablish a culture of individuals for captive refugia. Too few pure San Marcos gambusia and hybrids were found to establish a culture, although Dr. Edwards attempted to do so with the few fish available. In the mid 1980s personnel from the Fish and Wildlife Service National Fish Hatchery in San Marcos also searched unsuccessfully for the species in attempts to locate individuals to bring into captivity. In 1990 the Service organized three intensive searches, conducted by Service biologists and volunteers, to search for the species again. Unfortunately, none were found.

Academic researchers, Texas Parks and Wildlife Department scientists, and the Service continue to search for the gambusia during all collection and research with fishes that is done on the San Marcos River.

FOUNTAIN DARTER (*ETHEOSTOMA FONTICOLA*)

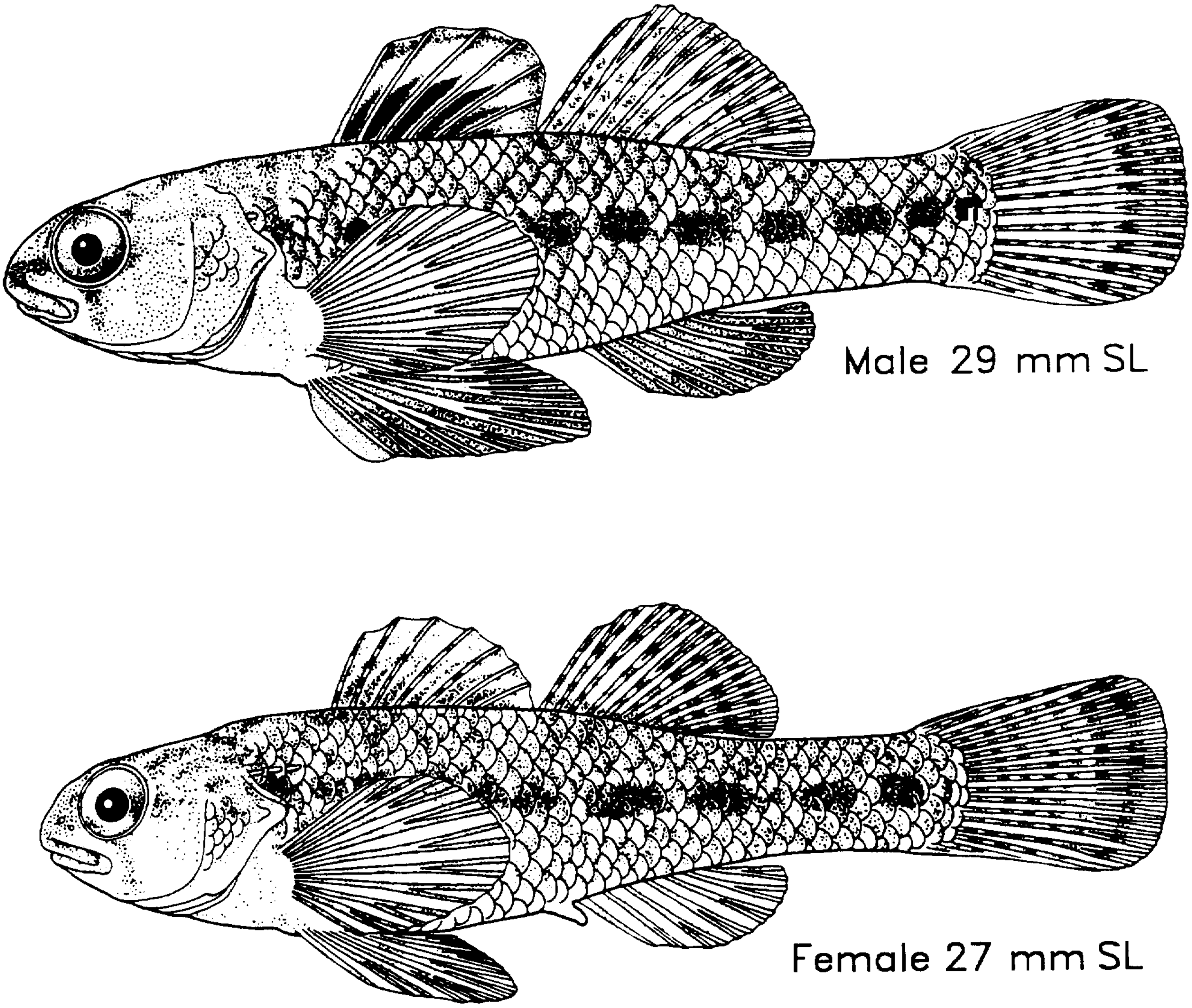
Description

Recognition of the fountain darter began with the inadvertent description of this species as *Alvarius fonticola* from specimens collected from the San Marcos River just below the confluence of the Blanco River in 1884 (Jordan and Gilbert 1886). The authors noted at that time that the species was abundant in the river. An additional specimen reported from the Washita River drainage of Arkansas by Jordan and Gilbert was undoubtedly misidentified (now presumed lost, and discussed below under "Historical Distribution"). Gilbert (1887), in the intended original description, redescribed the species and noted its occurrence only in the San Marcos River System.

Evermann and Kendall (1894) included an illustration of the species by E. Copeland which was designated the lectotype by Jordan and Evermann (1886). Because the "type" referred to by Jordan and Evermann was a lot containing four specimens, Collette and Knapp (1966) selected a lectotype from the U.S. National Museum collections of *Etheostoma fonticola* originally referenced by Gilbert (1887). The remaining three specimens included in this collection are now paralectotypes (Burr 1978).

Etheostoma fonticola (Figure 4) is the smallest species of darter, usually less than 25 mm (1 in.) standard length (SL), and is mostly reddish brown in life. The scales on the sides are broadly margined behind with dusky pigment. The dorsal region is dusted with fine specks and has about eight indistinct dusky cross-blotches. A series of horizontal stitch-like dark lines occur along the middle of the sides, forming an interrupted lateral streak. Three small dark spots are present on the base of the tail and there is a dark spot on the opercle. Dark bars appear in front of, below, and behind the eye. The lower half of the spinous dorsal fin is jet-black; above this appears a broad red band, and above this band the fin is narrowly edged with black. Male fountain darters differ from females in four morphological characters: banding pattern, spinous dorsal fin coloration, genital papillae, and pelvic and anal fin nuptial

Figure 4. Adult fountain darters. Drawing by Alice A. Prickettt from Bulletin Alabama Museum Natural History (Burr 1978).



tubercles (Jordan and Gilbert 1886; Gilbert 1887; Jordan and Evermann 1896, 1900; Strawn 1955, 1956; Collette 1965; Schenck and Whiteside 1977b, Burr 1978).

Although the fountain darter has been characterized as the most advanced (specialized) darter, the basis for this was an analysis of a very limited subset of traits, which appear to be highly influenced by environmental factors, such as temperature (Bailey and Gosline 1955, Collette 1962). The subgenus *Microperca*, to which *E. fonticola* belongs, is still thought to be the most derived (specialized) subgenus of *Etheostoma*. The evolutionary history of this group is presumed to involve an early separation of the presently recognized *E. proeliare* and *E. microperca* groups followed by a later isolation of a subset of an *E. proeliare*-like ancestor. This *E. proeliare*-like ancestor survived and became the presently recognized *E. fonticola* in only the San Marcos and Comal Rivers (Bailey and Gosline 1955; Collette 1962, 1965; Page and Whitt 1972; Collette and Banarescu 1977; Page 1974, 1977; and Burr 1978).

Historical Distribution

The original range of *E. fonticola* includes the San Marcos and Comal Rivers in Texas (Jordan and Gilbert 1886, Gilbert 1887, Evermann and Kendall 1894, Jordan and Evermann 1896, Jurgens 1951, Ball et al. 1952, Hubbs et al. 1953, Hubbs 1954, Kuehne 1955, Strawn 1955, Hubbs 1957, Hubbs and Strawn 1957b, Schenck and Whiteside 1976). In 1884, Jordan and Gilbert (1886) collected the type specimens of *E. fonticola* in the San Marcos River from immediately below the confluence of the Blanco River. Fountain darters have been found intermittently between downstream of Cumming's Dam and Martindale. A single specimen was taken near Ottine. Evermann and Kendall (1894) collected 43 specimens of *E. fonticola* in the Comal River in 1891, the first collection record for that locality. Jurgens (1951) collected fountain darters below the ice house dam, by the old USO pool, and below a cotton gin near the State Hatchery. Hubbs and Strawn (1957a) collected this species from the Comal River in 1954, the last collection record for that locality of the original population, before its apparent extirpation there and subsequent reintroduction into the Comal system.

During March 1973 through February 1975, Schenck and Whiteside (1976) spent 300 person-hours sampling the Comal River but collected no *E. fonticola*. They proposed three possible reasons why *E. fonticola* was absent from the Comal River. First, the Comal River was treated with rotenone in December 1951. Many specimens of desirable fishes, including *E. fonticola*, were seined and held in a protected area until the rotenone dissipated (Ball et al. 1952; C. Hubbs, University of Texas at Austin, pers. comm.). This procedure reduced the number of *E. fonticola* but apparently did not cause their immediate elimination since this species was last collected in the Comal River in 1954. Second, the most likely cause, Comal Springs ceased flowing from June until November, 1956, which probably caused drastic temperature fluctuations in the remaining pools of water. Since *E. fonticola* occupies areas with constant water temperature, temperature fluctuations (broader due to cessation of Comal Springs) may have contributed to the loss of this population. Other factors resultant from reduced springflow that may have contributed to the Comal population loss are: decreased habitat/water quality and increased predation of fountain darters during low flows. Third, but less likely, a flood from Blieders Creek inundated the entire Comal River in the spring of 1971 and may have caused their elimination.

A report of *E. fonticola* in the Washita River, Arkansas, (Jordan and Gilbert 1886) is the only record of fountain darters outside of Texas. These specimens, now lost from the Smithsonian collections, are presumed to be *E. proeliare*, which were misidentified due to the early confusion in the taxonomy and systematics of the subgenus *Microperca* to which both *E. proeliare* and *E. fonticola* belong.

From 1974 until 1981 a stock of E. fonticola taken from the San Marcos River near the IH-35 crossing was cultured at the Federal facility at Dexter, New Mexico, to ensure against a catastrophic loss of this species. This stock has since been discontinued; however, a new culture was established at the San Marcos National Fish

Hatchery and Technology Center, now part of the National Biological Service, in 1988.

Present Distribution

The present distribution of *E. fonticola* in the San Marcos River is from Spring Lake (inclusive) to an area between the San Marcos wastewater treatment plant outfall and the confluence with the Blanco River (Figure 3), (USFWS 1994 permit report; Casey Berkhouse, NBS, pers. comm.). The fountain darter is also found virtually throughout the Comal River to its confluence with the Guadalupe River (USFWS 1994 permit report).

B.G. Whiteside and J.R. Schenck released 457 adult *E. fonticola*, which were collected from the San Marcos River (mostly from below Rio Vista Dam), into the Comal system. During February 1975 through March 1976 about 400 fish were released into the headsprings area of the Comal River, Landa Park, New Braunfels, Texas, and about 50 fish were released into the old channel area that flows through the golf course. Schenck and Whiteside (1976) found five off-spring a short distance below the headsprings area on June 18, 1976. An established reproducing population now occupies the entire Comal aquatic ecosystem from Landa Lake (inclusive) to the vicinity of the Comal/Guadalupe River confluence (Figure 2).

Habitat

The fountain darter requires: 1) undisturbed stream floor habitats (including runs, riffles, and pools), 2) a mix of submergent vegetation (algae, mosses, and vascular plants) in part for cover, 3) clear and clean water, 4) a food supply of living organisms, 4) constant water temperatures within the natural and normal river gradients, and 5) most importantly, adequate springflows.

In general, *E. fonticola* prefers vegetated stream-floor habitats with a constant water temperature. Higher densities of the fish are found in mats of the filamentous green algae (*Rhizoclonium* sp.) and the moss *Riccia*. It is occasionally found in areas lacking vegetation. Fountain darters have also been observed among leaf litter in the Comal River (Thomas Brandt, NBS, pers. obs.).

Critical habitat has been designated for the fountain darter as "Texas, Hays County; Spring Lake and its outflow, the San Marcos River, downstream approximately 0.5 miles below Interstate Highway 35 bridge." A field identifier of the downstream boundary is the defunct U.S. Geological Survey stream gage.

Life History/Ecology

Food and Feeding Habits

Based on percent frequency of occurrence of food items in fountain darter stomachs sampled from the San Marcos River, fountain darters <19.2 mm (0.75 in.) SL feed primarily on copepods; darters between 19.2 and 29.5 mm (0.75-1.15 in.) SL feed mainly on dipteran and ephemeropteran larvae, and darters >29.6 mm (1.15 in.) SL prefer ephemeropteran larvae. Food habit studies are currently underway for fountain darters in the Comal ecosystem.

Food habits of fountain darters in Spring Lake differ from the food habits of darters in the San Marcos River. Casual observations indicate that the overall invertebrate community in Spring Lake is different from the community in the river, which could explain the observed differences in food habits of darters in these two areas on the basis of availability of food items.

Fountain darters feed primarily during daylight and demonstrate selective feeding behavior. Those held in an aquarium feed on moving aquatic invertebrates while disregarding immobile ones, suggesting that these darters respond to visual cues. Fountain darter fry raised in captivity appear to prefer cladocerans when offered a choice of other microcrustaceans, protozoans, and rotifers. When the fry reach 8 mm (0.3 in.) in length they select copepods. Fry up to 13 mm (0.5 in.) in length consume organisms from 0.2 to 0.4 mm (.008-.016 in.) long.

Population Estimates

Schenck and Whiteside (1976) estimated the total number of *E. fonticola* in the San Marcos

River to be about 103,000. L.A. Linam (1993) estimated the San Marcos River fountain darter population (excluding Spring Lake) to be 45,900, with a confidence interval (90%) ranging from -15,900 to 107,700. This could indicate a real decrease in fountain darter numbers in the San Marcos over the past 18 years, or the difference in the population estimates may just reflect differences in the methods used to estimate population size. However, Dr. Bobby Whiteside (Southwest Texas State University, San Marcos, pers. comm.), believes that the numbers of fountain darters in the San Marcos River have decreased over the past 20 years that he has been collecting in this stream (though he has no quantitative data to demonstrate this). In 1991, Janet Nelson conducted scuba-aided underwater surveys in Spring Lake and estimated at least 16,000 fountain darters at the springs openings and another 15,000 in the green algae habitat (Longley 1991).

G. Linam et al. (1993) sampled 7 transects in Landa Lake and the Comal River in 1990 and reported a population estimate of about 168,078 darters above Torrey Mill Dam, with a confidence interval (95%) ranging from 114,178-254,110.

Reproduction

The reproductive activities of fountain darters were first described by Strawn (1955, 1956) who noted that *E. fonticola* are headwater darters that breed in the relatively constant temperature of the San Marcos River. He further recorded in his publications that fountain darters appear to spawn year-round and that the parents, after depositing eggs in vegetation, provided no further care to the young. After hatching, the fry were never free swimming, in part due to the reduced size of their swim bladders as in other darters. Dowden (1968) found fountain darter eggs attached to moss and to algae and these eggs hatched in aerated aquaria. Strawn (1956) also included a photograph of a breeding male in its nuptial coloration in his discussion of the reproduction of this species. Males develop nuptial tubercles on their pelvic and anal fins (Collette 1965) and the sexes differ in this respect. Tubercles on darters are thought to stimulate gravid females or to assist in maintaining the spawning position within the vegetation (Collette 1965). Sex determination of *E. fonticola* in the wild (325 males and 234 females) revealed a sex ratio of 1.39:1 (Schenck and Whiteside 1977b).

Schenck and Whiteside (1977b) reported that natural populations of fountain darters have two temporal peaks of ova development, one in August and the other in late winter to early spring. Therefore, fountain darters apparently have two major spawning periods annually. The monthly percentages of females with ovaries containing at least one mature ovum also demonstrate the two annual spawning peaks. However, females containing at least one mature ovum have been collected throughout the year, further suggesting year-round spawning. The ovary weight/body weight relationship and the testis width/square root of total length relationship also indicate the two peak spawning periods (Schenck and Whiteside 1977b).

Fountain darters have been artificially hybridized with a number of other species including: *E. caeruleum, E. chlorosomum, E. euzonum, E. juliae, E. lepidum, E. spectabile, Percina caprodes,* and *P. sciera*. Procedures for artificially stripping eggs and milt of fountain darters and a discussion of the artificial hybridization and the resulting low survival of the various hybrid combinations appear in Strawn (1956), Hubbs and Strawn (1957a,c), Hubbs (1958, 1959), Hubbs and Laritz (1961), Hubbs (1967), and Distler (1968).

Most darters spawn in the spring or early summer. However, populations of *E. lepidum* and *E. spectabile*, which live in areas with slight annual water temperature variation, extend their breeding periods considerably (up to 10-12 months) (Hubbs and Strawn 1957b, Hubbs et al. 1968). The extension of the breeding season of *E. spectabile* throughout the summer is also known for a population inhabiting the Guadalupe River below Canyon Reservoir where releases from the bottom of the reservoir moderate water temperatures, especially during summer months (Marsh 1980). Since *E. fonticola* also lives in a relatively constant temperature environment, it is not especially surprising to find that this species spawns throughout the year as was originally suggested by Strawn (1956).

The mean diameter of mature ova (1.10 mm or 0.04 in.) from *E. fonticola* apparently is not correlated with length of the fish. Based on 74 *E. fonticola* that contained mature ova, the mean fecundity was 19, which is less than in other darters. This low fecundity is probably compensated for by repeated spawnings of small groups of eggs throughout the year. It is not known how many ova are spawned annually by each *E. fonticola.* Male fountain darters produce little milt and that which is produced tends to be transparent (Hubbs and Strawn 1957b, Hubbs 1958).

Culture techniques have been developed for the fountain darter at the Aquatic Station, SWTSU, and the San Marcos NFH&TC. The fountain darter will spawn and produce offspring when held at temperatures between 6° and 27° C (42.8-80.6°F). (These offspring were moved to room temperature after being spawned.) If photoperiod is held at 12 light and 12 dark, the fountain darter will spawn year-round. The number of eggs produced by a single female per day can vary between 0 and 60. Fountain darters held at 21°C (69.8°F) reached sexual maturity about 180 days after hatching. Darters as old as 39 months produced viable offspring. The critical thermal maximum for fountain darters was 34.8°C (94.6°F)(Brandt et al. 1993).

Conservation Measures

In 1993, the U.S. Fish and Wildlife Service and several cooperators began studies in the Comal Springs ecosystem designed to study habitat use and to model instream flow requirements for the fountain darter and the Comal Springs riffle beetle. Results of this study are not yet available, but are expected to provide additional population and density estimates for these two species. In 1994, the USFWS and cooperators initiated a similar study in the San Marcos system.

The U.S. Geological Survey is in the process of collecting water temperature, DO, pH, and specific conductivity (an indicator of salinity) data in both Comal and San Marcos aquatic ecosystems. These data will be valuable in modeling water temperature at various spring and river discharges.

A number of other studies and conservation efforts are underway or have taken place for this species. Genetic studies of the fountain darter populations in the San Marcos and Comal ecosystems are being done by D.C. Morizot at the University of Texas M.D. Anderson Cancer Center. These studies are designed to determine the pattern and extent of genetic variation within and among fountain darter populations in the Comal and San Marcos ecosystems and the experimental fountain darter stock at the San Marcos NFH&TC. This research will provide valuable information for culture and conservation of the fountain darter. An interim progress report submitted in May 1993, indicated no evidence of hybridization of fountain darters with greenthroat (*Etheostoma lepidum)* or orangethroat darters (*Etheostoma spectabile).* Of 11 polymorphic loci examined, no alleles were present in the hatchery strain that were not also present in wild-caught darters. However, 46% (19 of 41) of the alleles detected in the total wild-caught darters were not present in the hatchery strain. It appears that there has been some loss of genetic variability in the hatchery strain and/or the original collection did not adequately represent all the variability in the wild, producing a founder effect. This is not particularly surprising as the hatchery strain was established for preliminary studies of a different nature and not for use as captive stock for reintroduction or restoration work. The hatchery strain was established with twenty or fewer fish that were not intended as a representative sample, and was maintained with uncontrolled breeding. These results do underscore the need for careful management of the genetic characteristics of captive populations. Finally, several genetic markers were detected in the Comal population that were not found in the San Marcos population sample. There are several possible explanations for this result and further studies should help to clarify this observation.

A preliminary study has been conducted to determine the toxicity of effluent from the San Marcos wastewater treatment plant and the herbicide Rodeo® to fountain darters. A statistical procedure referred to as the inhibition concentration (IC) provides a point estimate of the toxicant concentration that would cause a given percent reduction in a biological measurement of the test organisms, including reproduction, growth, fertilization, or mortality. An IC_{25} for growth would represent the effluent concentration at which a 25 percent reduction in growth occurs. Results indicate that the IC_{25} of wastewater plant effluent on growth for fountain darters is 19.1 percent effluent (Greg Smith, Great Lakes Environmental Center, Columbus, Ohio, *in litt.*, 1993). However, data are available for only one effluent sample. Further research on the toxic effects of both pure and complex toxicants on fountain darters and their symbionts is needed.

SAN MARCOS SALAMANDER (*EURYCEA NANA*)

Description

Taxonomy

The San Marcos salamander (*Eurycea nana)* is a member of the family Plethodontidae (lungless salamanders). The various species of *Eurycea* are known as brook salamanders. *E. nana* is a neotenic form and retains its external gills (the larval condition) throughout life. The salamander does not leave the water to metamorphose into a terrestrial form, but becomes sexually mature and breeds in the water. The specific name *nana* is from the Greek *nanos* or Latin *nanus*, meaning dwarf, referring to the small adult size (up to 59.6 mm [2.32 in.] total length) of these salamanders (Brown 1967).

On June 22, 1938, C.E. Mohr collected a series of 20 specimens from San Marcos Springs. The specimens were sent to Sherman C. Bishop who described *E. nana* as "a small, slender, neotenic species uniformly light brown above with a dorsolateral row of pale spots on either side of the mid-line; yellowish white below; with 16 or 17 costal grooves. *E. nana* differs from *E. neotenes*, the only other species of the genus from the general locality, in its smaller size, its uniformly light brown dorsal coloration relieved only by a few small light spots, and in its more slender form and longer, more slender toes" (Bishop 1941).

Bogart (1967) studied the life histories and chromosomes of Texas *Eurycea* on the Edwards Plateau. Based on chromosomal studies (karyotypes), he included in *E. nana* populations from the following localities in addition to San Marcos Springs: Sabinal River, 8.9 km (5.5 mi) north of Vanderpool, Bandera County; Mountain Home, headwaters of the river feeding into the fish hatchery in Mountain Home, Kerr County; and Kerrville, 8 and 11 km (4.9 and 6.8 miles) west of Highway 16 beside RR 1273, Kerr County.

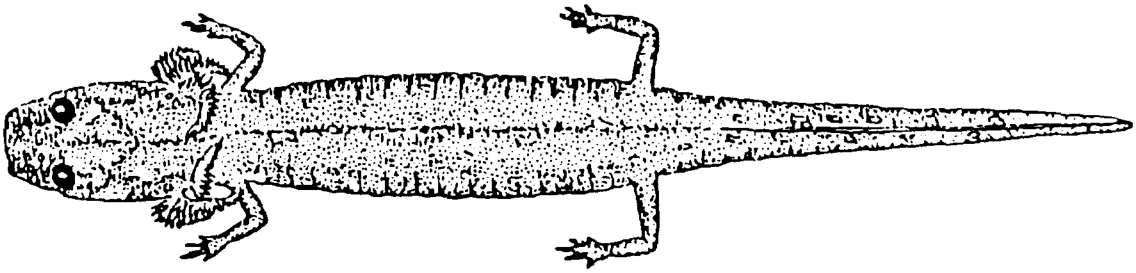
Sweet (1978) indicated that a population of *Eurycea* inhabiting Comal Springs in New Braunfels is very similar to *E. nana* and probably conspecific. However, recent biochemical, molecular and morphometric studies (Chippindale et al. 1992, 1993, 1994) indicate that the salamander at Comal Springs is clearly a different species than *E. nana*. The Comal Springs population is currently included in the large, diverse, *Eurycea neotenes* species group.

Work by Chippindale et al. (1992, 1993, 1994) also provides evidence that populations of *Eurycea* on the Edwards Plateau in locations other than San Marcos are not *E. nana*. Their work indicates that these other populations are geographically and genetically isolated, and represent distinct taxa, probably distinct species. *E. nana* then, is represented only by the populations in the San Marcos Springs area.

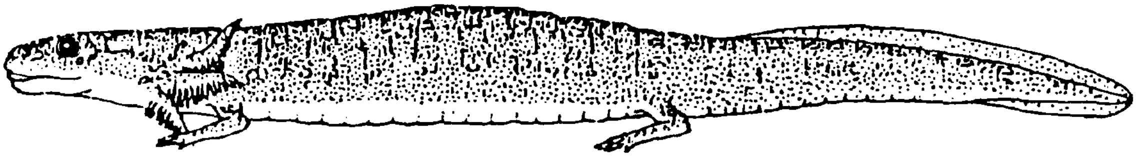
Morphology

Prominent external features of the small, slender salamander are moderately large eyes with a dark ring around the lens, well developed and highly pigmented gills, relatively short, slender limbs with four toes on the forefeet and five on the hind feet, and a slender tail with well developed dorsal fin (Figure 5). Compared to other neotenic *Eurycea* from Texas, the San Marcos salamander is smaller and more slender, different in coloration, has larger eyes relative to the size of its head, a greater number of costal grooves, and fewer pterygoid and premaxillary teeth. Detailed morphological descriptions of this species are found in Bishop (1941, 1943), Baker (1957, 1961), Mitchell and Reddell (1965), Schwetman (1967) and Tupa and Davis (1976).

Figure 5. Drawing of *Eurycea nana* (modified from Schwetman 1967).



Dorsal View



Lateral View

Historical and Present Distribution

On November 24, 1975, a sampling program was started on the largest fissures that constitute San Marcos Springs (Longley 1978), and the sampling was continued in recent years by Nelson (1993). The sampling involved placing a 500-micrometer (0.02 in) mesh net over the outlet from one of the major springs in Spring Lake. This outlet was dubbed "Pipe Spring" since it had been diverted via pipe into the show area of Aquarena's Submarine Theater. This outlet is also frequently called Diversion Spring. The concrete base over the spring opening had been undercut by action of floods in recent years and this allowed material from the lake bottom near the spring to be drawn into the outflow from the spring by a venturi (suction). Small organisms such as *E. nana* work their way between the rocks surrounding the spring opening until they are caught in the flow from the spring and then carried into the net along with subterranean organisms. In Longley's (1978) study, *E. nana* were found in most samples. All age classes were common, but juveniles were most often collected.

Other studies used the above technique to sample Diversion Spring and other techniques to sample spring outlets throughout Spring Lake (Tupa and Davis 1976, Nelson 1993). *E. nana* was found in most samples taken from "Deep Spring" in Spring Lake. Tupa and Davis (1976) found *E. nana* in the dense mats of filamentous alga (*Lyngbya* sp.) along the shallow area adjacent to the northern bank of Spring Lake, especially in the uppermost region of the lake in front of the Aquarena Springs Hotel. Nelson (1993) found the salamanders distributed throughout Spring Lake among the rocks near spring openings, in the algal mats where Tupa and Davis found salamanders, and in the rocky areas just downstream from the dams. Unlike Tupa and Davis (1976), Nelson (1993) used SCUBA to observe salamanders in Spring Lake, which may explain the different distributions seen in these studies.

The combined results of these three studies show that *E. nana* occurs near all the major spring openings scattered throughout Spring Lake and is quite abundant at some of these springs (Nelson 1993). *E. nana* is found in the San Marcos River just below Spring Lake for about 150 m (492 feet).

Habitat

The San Marcos salamander occurs in Spring Lake where rocks are associated with spring openings, and in rocky areas up to 150 m (492 feet) downstream of the dams at Spring Lake (Longley 1978, Tupa and Davis 1976, Nelson 1993) (Figure 3).

The salamander is also found in shallow spring areas on the uppermost (northernmost) portion of Spring Lake on a limestone shelf in an area immediately in front of Aquarena Springs Hotel. The substrate in this area is sand and gravel interspersed with large limestone boulders. Concrete banks in front of the hotel and boulders in shallow (1-2 m or 3.3-6.6 feet) water support a lush growth of an attached aquatic moss (*Leptodictyium riparium).* Interspersed with the moss and blanketing the shallow sandy substrate are thick filamentous mats of a coarse, filamentous blue-green alga (*Lyngbya* sp.*)*, the dark reddish-brown color of which almost perfectly matches the dark dorsal coloration of the San Marcos salamander.

Spirogyra sp. and a few other larger filamentous green algae species, as well as the carnivorous angiosperm known as bladderwort (*Utricularia gibba)*, are present in small amounts in the aquatic moss. A wide variety of rooted aquatic macrophytes occur on the periphery of the salamander habitat at 1-3 m depths. The macrophytes include arrowhead (*Sagittaria platyphylla)*, parrot's feather (*Myriophyllum brasiliense)*, water primrose (*Ludwigia repens)*, and wild celery (*Vallisneria americana).* In deeper water, Carolina fanwort (*Cabomba caroliniana), Hydrilla* (*Hydrilla verticillata)*, and elodea (*Egeria densa)* become the dominant macrophytes of the mud and detritus-laden benthic region.

The salamanders are abundant within the wiry mesh of the aquatic moss and the filamentous mats of *Lyngbya* sp. in the shallow headwaters area. Sandy substrates devoid of vegetation and muddy silt or detritus-laden substrates with or without vegetation are apparently unsuitable habitats for *E. nana.* Specimens occasionally are collected from beneath stones in predominantly sand and gravel areas. In view of the abundance of predators (primarily larger fish, but also crayfish, turtles, and aquatic birds) in the immediate vicinity of the springs, protective cover such as that afforded by the moss and cyanophycean bacteria (=blue-green algae) is essential to the survival of the salamander. This vegetation also supports a plentiful food supply for the salamander.

Flowing water is apparently a prerequisite for suitable *E. nana* habitat, as no specimens were found in still water areas of the lake or river. The flowing spring waters in the principal habitat are slightly alkaline (pH 7.2), stenothermal (narrow range of temperatures) at 21-22°C (69.8-71.6°F), and clear. Around springs, the oxygen content of the water is about 4 mg/L or greater (about 40-50 percent saturated with oxygen). Methyl orange alkalinity in the area where *E. nana* occurs (due entirely to bicarbonates) measured 220-232 mg/L and the specific conductance measured 510-535 micromhos/cm in the habitat (Tupa and Davis 1976). In preliminary observations in captivity, these salamanders appear to become stressed at temperatures above 30°C (86°F). Oxygen consumption by *E. nana* was greatest at water temperatures of 25°C (77°F) as compared with 20 or 30°C (68 or 86°F)(Norris et al. 1963). Critical thermal maximum (CTM) investigations by Berkhouse and Fries (1995) determined that juveniles had a lower CTM, 35.8°C (96.4°F) than adults (37.2°C or 99°F).

In summary, the San Marcos salamander apparently requires: (1) thermally constant waters; (2) flowing water; (3) clean and clear water; (4) sand, gravel, and rock substrates with little mud or detritus; (5) vegetation for cover; and (6) an adequate food supply.

Critical habitat has been designated for the San Marcos salamander as: "Texas, Hays County; Spring Lake and its outflow, the San Marcos River, downstream approximately 50 m (164 feet) from the Spring Lake Dam."

Life History/Ecology

Food Habits

Salamanders in laboratory aquaria feed on amphipods and young brine shrimp. Stomach content analyses of 80 preserved specimens revealed the salamander's diet in its natural habitat included amphipods and tendipedid (midge fly) larvae and pupae; other small insect pupae and naiads and small aquatic snails were found in lesser numbers. Small amounts of *Lyngbya* sp. and grains of sand occasionally were present, apparently as incidental items ingested along with principal food items. Feeding behavior observed in the laboratory indicated that the salamanders did not actively pursue their prey. Salamanders remained stationary until the prey items were near their head, then abruptly snapped forward while opening their mouths to engulf food items. This information suggests they respond either to visual or vibrational cues from living prey.

Reproductive Characteristics: Male *E. nana* reach sexual maturity (possess at least one full darkly-pigmented lobe in each testis) after attaining a snout-vent length of 19 mm (0.741 in.) or 35 mm (1.37 in.) total length. All males with snout-vent lengths greater than 23.5 mm (0.92 in.) or 40-45 mm (1.56-1.76 in.) total length were mature, possessing darkly-pigmented testes with one to three lobes (Tupa and Davis 1976). In an investigation by Mackay (1952), sperm were found in the testes of all mature males collected from October to May and in the Wolffian ducts of certain males from October to June (except for January and March). This study did not include the months of July and August. Mackay found large numbers of spermatozoa in the Wolffian ducts in November; ducts were in a distended condition in June, leading her to postulate a breeding season in June and possibly another in the fall.

Salamanders had the following four classes of ova in the oviducts: very small clear ova, small opaque-white ova, small yellow ova, and large yellow ova. Females carrying large yellow ova (1.5-2.0 mm [0.06-0.08 in.] diameter) were considered gravid and presumably ready for oviposition. Large yellow ova were present in females with snout-vent lengths greater than 20.0 mm (0.78 in.) or 35 mm (1.37 in.) total length). Females with a snout-vent length ≥ 26 mm (1.01 in.) carried 1 to 19 large yellow ova. Large yellow ova were present in some females in nearly every month of the year (Tupa and Davis 1976).

Courtship and egg deposition by *E. nana* has not been reported, and no eggs have been collected from the habitat. However, courtship, oviposition, and hatching have been observed for the closely related Comal Springs salamander. Eggs of this species were deposited singly on plant material, stones, and the bottom of a glass bowl about 24 hours after courtship. Eggs hatched 18-23 days later (Bogart 1967, Schleser et al. 1994). Jordan et al. (1992) were successful in inducing the Comal Springs salamander to spawn, but hatching did not occur. The Comal Springs salamander has reproduced successfully several time in artificial spring upwellings at the Dallas Aquarium (Schleser et al. 1994). Most, if not all, *Eurycea* breed in running water of brooks, caves, or springs. In most cases, adherent eggs are deposited singly on the bottom and sides of stones, or on aquatic vegetation.

A total of seven small juveniles of *E. nana* still possessing yolk on the venter were collected in February, May, and June 1968. Juveniles of less than 12 mm (0.47 in.) total length were collected from February through October (Tupa and Davis 1976). Bogart (1967) found very small *E. nana* in September, December, March, April, and June, but noted they were most common in the late spring and early summer. He postulated that the salamander breeds most of the year with a peak in late spring.

The structure of the *E. nana* population is remarkably uniform throughout the year. In all seasons juvenile specimens (snout-vent lengths usually less than 15 mm [0.54 in.]) of undetermined sex represented about 45 percent of the total population. Larger juveniles (about 15-20 mm [0.59-0.78 in.] snout-vent length) of undetermined sex represented about 30-40 percent of the population. Mature males (snout-vent lengths 19 mm [0.74 in.] and greater) represented about 10-15 percent and gravid females (snout-vent lengths 20 mm [0.78 in.] and greater) about 4 percent of the total (Tupa and Davis 1976). Most evidence suggests reproduction occurs throughout the year with a possible peak about May and June.

Population Estimates

Tupa and Davis (1976) estimated the number of *E. nana* in the floating algal mats at the uppermost portion of Spring Lake to be between about 17,000 and 21,000 individuals. Nelson (1993) followed the same procedure used by Tupa and Davis (1976) and estimated that the mats were inhabited by about 23,000 salamanders. Nelson (1993) also searched rocky substrates around the spring openings throughout Spring Lake and estimated an additional 25,000 *E. nana* in this type of habitat. She also estimated the population below Spring Lake associated with rocky substrates to be about 5,200 individuals. These estimates give a combined population total for Spring Lake of 53,200. Nelson's population estimates of the rocky substrate habitat are believed to be low (Nelson 1993 and Longley, *in litt.*, 1994), since salamanders are known to wriggle down into interstitial spaces in the habitat. Captive salamanders from Comal springs are found as far as four feet down in simulated spring habitats (Longley, *in litt.*, 1994).

Other Known Biological Aspects

The San Marcos salamander is capable of altering its dorsal coloration from light tan to dark brown in accord with the lightness or darkness of the substrate. This color change is accomplished by migration of pigment in melanophores, giving them these structures the appearance of expanding or shrinking (Schwetman 1967).

The salamander's external gills expand and appear bright red from increased blood flow in cool water of low oxygen content. The bushy red gills are prominent on individuals when collected from the springs, but they show marked reduction, almost to the point of apparent resorption when specimens are kept in well-oxygenated aquaria (Tupa and Davis 1976).

Associated Species

Fountain darters occupy some of the same habitats as *E. nana* (Tupa and Davis 1976), and display many of the same feeding and protective concealment habits of the salamander. Unlike other fishes in the area but like the salamanders, fountain darters are found within the aquatic moss growths and *Lyngbya* mats, as well as beneath and alongside stones. Like the fountain darters, the salamanders in the lake habitat eat amphipods (Tupa and Davis 1976).

Associated with the salamander and fountain darter in the moss and algal vegetation are crayfish of varying sizes, two species of small freshwater shrimp (*Palaemonetes* spp.), many tendipedid larvae, a variety of other insect larvae, a very large number (particularly in the moss) of amphipods (*Hyalella azteca)*, water mites, and many small aquatic snails. Leeches (*Placobdella* sp. and others) and planarians (*Dugesia* sp.) are also numerous, especially in samples taken over rocky substrates (Tupa and Davis 1976).

Most larger associated species are predators and occur in the vicinity of the salamander habitat. These include several species of sunfishes (family Centrarchidae) and cichlids (family Cichlidae), which feed on insect larvae, amphipods, terrestrial isopods, aquatic snails, freshwater shrimp, fountain darters, and San Marcos salamanders. Turtles such as Texas river cooters (*Pseudemys texana*) and stinkpots (*Sternotherus odoratus*) occasionally are present in the salamander habitat as are yellow bullheads (*Ameiurus natalis*) and largemouth bass (*Micropterus salmoides*) (Tupa and Davis 1976). Nonnative blue catfish have been introduced into Spring Lake and may prey on *Eurycea*. The exotic blue tilapia are a common part of the Spring Lake and San Marcos fish fauna as well. Blue tilapia are omnivorous and may prey on *Eurycea.*

Conservation Measures

Experiments are underway at the Dallas Aquarium to develop captive breeding techniques for *E. nana* in the event that the natural population at San Marcos Springs is lost, using techniques patterned after those used for breeding the Comal salamander. Efforts to induce propagation at the San Marcos NFH&TC, which also housed *E. nana* in simulated spring environments, were unsuccessful (Brandt et al. 1993).

TEXAS WILD-RICE (*ZIZANIA TEXANA*)

Description

Taxonomy

Texas wild-rice was first collected by G.C. Neally in August 1892 and was originally identified as *Z. aquatica* (U.S. National Herbarium sheet 979361). The next collection was by Ena A. Allen on July 10, 1921 (U.S. National Herbarium sheet 1611456). This sheet was labelled as *Z. texana*, apparently by A.S. Hitchcock, some time after its collection. W.A. Silveus, an attorney and amateur botanist from San Antonio, first recognized Texas wild-rice as a distinct species. The type collection (W.A. Silveus 518, both the holotype and isotype are housed at the U.S. National Herbarium) was probably made on April 3, 1932. Silveus sent the specimen along with a letter to Agnes Chase of the U.S. National Herbarium on April 4, 1932. The plant was formally described and named as *Z. texana* by Hitchcock (1933). All specimens were collected from the San Marcos River. (The above information was taken from Terrell et al. 1978).

In a monographic work on the genus *Zizania*, Dore (1969) labelled *Z. texana* a "dubious species." Dore felt that Texas wild-rice was most closely related to *Z. aquatica* var. *aquatica*. He attributed the "perennial" nature of Texas wild-rice to the "constant year-round temperature of the artesian waters in which it grows," and the prostrate habit was due to the force of the current. Dore felt that the distinction of *Z. texana* from *Z. aquatica* would require careful field appraisal.

Dore also noted that collectors might mistake *Zizaniopsis miliacea* for *Zizania texana,* as Dore was sent rhizomes of the former when requesting material of the latter (Terrell et al. 1978). However, these two genera are different in several reproductive and vegetative characters and are easily distinguishable. The most diagnostic of these characters is that *Zizaniopsis miliacea* does not have male and female flowers on separate branches as does *Zizania texana* (Figure 6).

Terrell et al. (1978) examined the three American taxa of *Zizania*, including cultivating them in common garden conditions (cultivation side-by-side to be certain differences are intrinsic and not environmentally induced). They concluded that *Z. texana* was a distinct species based on several characters. In addition, neither of the other North American taxa occur near Texas wild-rice, so there is little or no chance for confusion. Northern wild-rice (*Z. palustris*) appears several hundred miles to the north and northeast (Missouri, Kansas, and Arkansas). The nearest populations of southern wild-rice are in Louisiana, some 400 miles to the east.

Southern wild-rice is a much more robust plant than Texas wild-rice, attaining heights up to 4 m (13 ft.) and having only its lower culms immersed in water; the rest of the plant is erect and emergent. In addition, the leaves of southern wild-rice are 3-5 times as broad as those of Texas wild-rice. In southern wild-rice the upper inflorescence branches are long and widely spreading, while those of Texas wild-rice are shorter, more erect, and appressed. Southern wild-rice has lemmas and paleas that are thin and papery while those of Texas wild-rice are somewhat leathery (Terrell et al. 1978).

Northern wild-rice is somewhat smaller in stature and more closely resembles Texas wild-rice. Distinguishing characters are that the spikelet is generally longer [up to 20 mm (0.8 in.) long in northern wild-rice, while Texas wild-rice seldom exceeds 12.5 mm (0.5 inch)], the paleas and lemmas of northern wild-rice are distinctly leathery, and the lemmas of northern wild-rice have prickle hairs in lines rather than randomly scattered as in Texas wild-rice (Terrell et al. 1978). The northern wild-rice plants are generally more emergent than Texas wild-rice under typical growing conditions, though in some conditions Texas wild-rice will become more emergent.

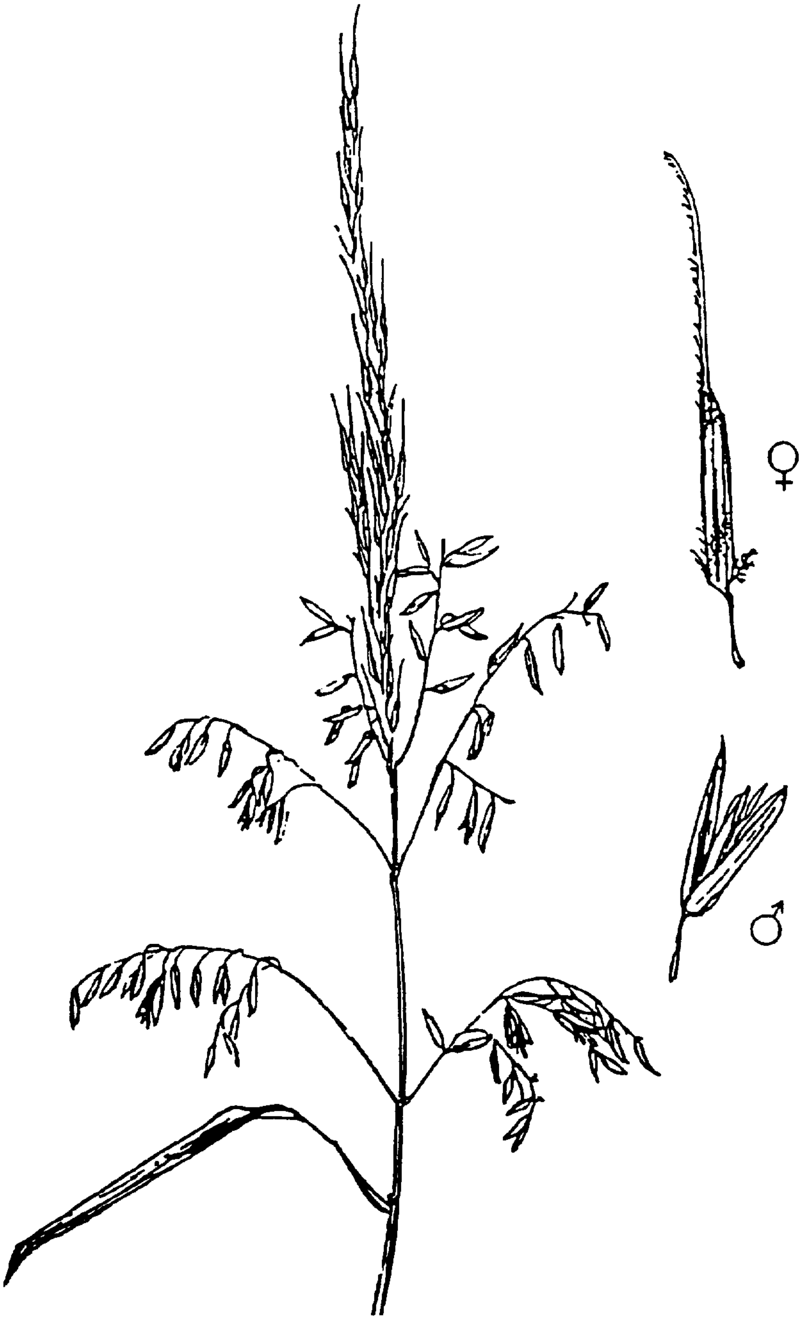
The mature caryopses (seeds) of Texas wild-rice are only 50-70% as long as the lemma and palea, whereas in both northern and southern wild-rice nearly the entire spikelet is filled by the caryopses at maturity (Terrell et al. 1978).

Morphology: Texas wild-rice is an aquatic, monoecious, perennial grass. The plant is generally 1-2 m (3.3-6.6 ft.) long (up to 4 m or 13 ft.) and usually immersed and prostrate in the swift-flowing water of the San Marcos River. In slow water the inflorescence, as well as the upper culms and leaves, becomes emergent. The culms are long decumbent, stoloniferous, and root only at the lower nodes. The leaves are linear, elongate, green, 12-110 cm (4.7 - 43.3 in.) long, and 5-25 mm (0.2 - 1.0 in.) wide. The inflorescence is a narrow panicle, 16-31 cm (6.3 - 12.2 in.) long, and 1-10 cm (0.4 - 3.9 in.) wide. Flowering occurs primarily in the spring and fall although it may occur throughout the year in warm weather. The spreading staminate branches occur below the appressed pistillate branches. Spikelets consist of a single naked floret and lack glumes. The staminate spikelets are 6-11 mm (0.24 - 0.43 in.) long, 1.2-2 mm (.05 - .08 in.) wide, with white stamens, and hang down when mature. The pistillate spikelets are 8-12 mm (0.32 - 0.4 in.) long, 1.2-1.8 mm (0.05 - .07 in.) wide, erect, and awn-tipped. The awns are scabrous with scattered prickle hairs, and 10-35 mm (0.39 - 1.38 in.) long. The seeds (as obtained from cultivation) are cylindrical, 4.3-7.6 mm (0.17 - 0.30 in.) long, 1-1.5 mm (0.04 - 0.06 inch) wide, 1/2 to 3/4 as long as the lemma and palea, and black, brown, or greenish. The chromosome number is n=15. (Compiled from Silveus 1933, Hitchcock 1950, Correll and Correll 1975, and Terrell et al. 1978).

Past and Present Distribution

When first described in 1933, Texas wild-rice was abundant in the San Marcos River, including Spring Lake and its irrigation waterways (Terrell et al. 1978). By 1967 Emery found only one plant in Spring Lake, none in the uppermost 0.8 km (0.5 mile) of the San Marcos River, only scattered plants in the lower 2.4 km (1.5 miles), and none below this (Emery 1967). Beaty (1975) reported a coverage of about 240 m^2 (2,580 ft^2). However, the survey methodology Beaty used is not known. In 1976 Emery again checked the abundance (Emery 1977). He found no plants in

Figure 6. Texas wild-rice. Inflorescence and male and female florets. Drawing courtesy of Texas Parks and Wildlife Department.



Spring Lake. Using a floating frame one square meter to measure the area of vegetative dominance, he calculated 1,131 m^2 (12,161 ft^2) of Texas wild-rice in the San Marcos River, primarily concentrated in the extreme upper and lower segments of the area known as the upper San Marcos River.

Subsequent data were gathered by Vaughan (1986) for several years using Emery's measuring technique. The overall areal coverage in 1986 was 454 m^2 (4881 ft^2), less than half Emery's 1976 figure.

The Texas Parks and Wildlife Department has monitored area coverage since June 1989 (Table 4), and coverage has ranged from 1,005.4 m^2 (10,823 ft_2) to 1,592.4 m^2 (17, 142 ft^2)(average 1,374.3 m^2 or 14,794 ft^2) (1989-1994). Emery's methodology was employed for the first few plants, but was abandoned due to technical difficulties. Length and width was measured on the remaining plants, and percent coverage was estimated within the resulting rectangle. Areal cover was equal to L x W x % cover.

Texas Parks and Wildlife studies have established that the current distribution of wild rice extends from the uppermost part of the San Marcos River just below Spring Lake dam (where neither Emery nor Vaughan had reported Texas wild-rice) and throughout the critical habitat down to an area slightly below the wastewater treatment plant, except for the river portion between the Rio Vista railroad bridge and the dam above Cheatham Street (Figure 3).

Habitat

The plants form large clumps rooted in the limestone sand and gravel river bottom, which overlays Crawford black silt and clay (Vaughan 1986). According to Silveus (1933), Texas wild-rice occurred in Spring Lake and its irrigation waterways. Silveus also noted that although he expected originally to find the species growing along the margins of the stream, he found the plants occurring in the swiftly flowing currents some distance from the bank (after Terrell et al. 1978), similar to current conditions. While exotic elephant ears occupy river margins rather than the regions with swift current, hydrilla (which has also been introduced in recent times) forms extensive stands in some swift areas of the river today. The consequences of this to Texas wild-rice are unknown, but it is possible that hydrilla is competing with Texas wild-rice or altering its essential habitat.

Experimental studies (Vaughan 1986) showed that Texas wild-rice grew poorly in Spring Lake at water depths greater than 2 m (6.6 ft) due to decreased light intensity and shading from other aquatic vegetation. Rose and Power (1992) noted robust growth at 1.6 m (5.25 ft.) in experimental reintroduction work. In Vaughan's experiments, plants did not survive in moist or alternating wet/dry experimental conditions, only in constantly inundated conditions. Plants grown in an artificial raceway environment (Vaughan 1986) produced seed at water depths ranging from 20-60 cm (7.9 - 23.6 inches). Other species of wild-rice require very shallow water for germination (Vaughan 1986).

Power (1990) found that under experimental conditions Texas wild-rice seeds germinated more readily under low oxygen conditions and that buried seeds (buried in either clay or sand) germinated more readily than seeds at the substrate/water interface. Rose and Power (1993, 1992) collected seeds from Texas wild-rice in culture and conducted experiments on seed storage and germination. Their studies indicated that fewer seeds germinate as storage time increases and, of seeds that germinate, fewer have successful seedling development (Rose and Power 1993 and *in litt.*).

Critical habitat has been designated for Texas wild-rice as "Texas, Hays County; Spring Lake and its outflow, the San Marcos River, downstream to its confluence with the Blanco River."

Life History/Ecology

Associated Species

In the upper portion of the San Marcos River, Texas wild-rice occurs with pondweed (*Potamogeton illinoensis*), wild celery (*Vallisneria americana*), arrowhead (*Sagittaria platyphylla*), hydrilla (*Hydrilla verticillata*), hornwort (*Ceratophyllum demersum*), elodea (*Egeria densa*), and water primrose (*Ludwigia repens*) (Terrell et al. 1978, Vaughan 1986). In the lower portion of the river, Texas wild-rice is most often found in isolated clumps (Terrell et al. 1978, Vaughan 1986). Elephant ears (*Colocasia esculenta*) (elephant ear) has invaded the river edge, and is narrowing the river and crowding the other aquatic species in many places. Common tree species that shade the river, include sycamore (*Platanus occidentalis*), pecan (*Carya illinoensis*), *Populus deltoides* (cottonwood), sugar hackberry (*Celtis laevigata*), baldcypress (*Taxodium distichum*), black willow (*Salix nigra*), American elm (*Ulmus americana*), Chinese tallow tree (*Sapium sebiferum*), and live oak (*Quercus fusiformis*) (Vaughan 1986). Whether or not survival of Texas wild-rice is influenced by the degree of shading by the tree canopy is unknown.

Reproduction

Texas wild-rice produces new plants either via seeds or stolons. When reproducing sexually the long rigid decumbant culm (which can reach lengths of 3.6 - 4 m (12 feet) or more) bends upward at its nodes, emerges above the current, and produces a 3.2 to 4.7 cm (8 to 12 inch) flowering panicle (Beaty 1975). Asexual reproduction occurs where shoots arise at the ends of stolons. While asexual reproduction has been noted and some plants have produced culms for inflorescences, plants have not successfully been producing (or setting) seed in the San Marcos River (J. Poole, Texas Parks and Wildlife and P. Power, Southwest Texas State University, pers. comm.). Emery and Guy (1979) studied reproduction in Texas wild-rice and reported the species is predominantly outbreeding and wind-pollinated. They found no indication of apomixis (selfing) or any reproductive anomaly. Pollen and megaspore development as well as pollination and early embryo development appear normal. Pollen fertility is good (81.6%), and they concluded the failure of wild-rice to produce seed in the wild is probably not due to any genetic, cytological, or embryological problems, but rather to some extrinsic factor or factors. Plants grown in raceways at Southwest Texas State University's Aquatic Station successfully bloom and set seed, and seed have been observed to drop in place and subsequently germinate (P. Power, pers. comm.).

Conservation and Research Efforts

Texas wild-rice has been cultivated numerous times with varying results. Terrell et al. (1978) took three small clumps of Texas wild-rice to Beltsville, Maryland, in September 1973. The plants were grown in tap water and kept at a constant temperature of about 23°C (73.4°F). Only one of the plants survived. This individual produced about 80 seeds. The plant later died from two-spotted mites. Some of the seeds germinated, but none grew more than a few centimeters before dying, including ones grown in San Marcos River water.

Emery moved four clones of Texas wild-rice from the San Marcos River to the constant temperature, spring-fed raceways at Southwest Texas State University (Terrell et al. 1978). The plants became emergent and produced over 1,500 seeds during the summer of 1975. After being kept in 3°C (37.4°F) spring water for 105 days to break dormancy, the seeds were germinated in petri dishes filled with tap water. Seven to 10 days after germination, seedlings were transplanted to pots containing river gravel, and immersed beneath a few centimeters of water. By August 1976 about 500 clumps of Texas wild-rice had been produced (Emery 1977 and *in litt.*, Terrell et al. 1978).

Vaughan (1986) grew Texas wild-rice in the raceways at Southwest Texas State University as well as at various depths in Spring Lake and in various soil types and water regimes in fish-culture ponds at the San Marcos NFH&TC. Growth rate was higher in the raceways than in the San Marcos River itself, possibly due to increased light and temperature. Plants grown at different depths in Spring Lake showed the effects of irradiance and depth. Low growth rates occurred at the greatest depths (more than 120 cm (47 inches)). Soil type (either Crawford silt clay from the banks of the river or Quaternary limestone sediment from the river bottom) had no significant effect on growth rate or survivorship. However, moisture regime led to dramatic results. Mortality was 100% in both the dry (an intermittently wet terrestrial site) and the moist (a constantly moist but not inundated site) regime. Plants grown in 20 cm (7.9 inches) of water or more were significantly larger than those grown in 20 cm (7.9 inches) or less. Thus both water depth and amount of light appear significant in the growth of Texas wild-rice.

Efforts made to grow Texas wild-rice outside the San Marcos River have been unsuccessful. Current Service policy would not support introduction of listed species outside their historic range. However, before Texas wild-rice was listed Beaty (1976) attempted to grow plants in Salado Creek in Bell County. The plants established and produced inflorescences, but local recreational activities plus periodic removal of aquatic vegetation from the stream, destroyed all plants. Emery transplanted more than 100 clones of Texas wild-rice into various central Texas sites, including the Comal River in New Braunfels. However, flooding washed the plants away before they could become established, and a planting in Spring Lake was eaten by nutria (Beaty 1976, Emery 1977 *in litt.*).

Rose and Power (1992, 1993) transplanted young Texas wild-rice plants raised from seed into Spring Lake. One hundred and eighty-three young plants raised in raceways were planted in Spring Lake near the dam (about 3m [8.4 ft] deep) in December 1992, and March and July 1993. Five hundred transplants were planted on the northwest side of the lake in 1994. Although both reintroduction sites showed a slight increase in stem density during 1994, they later showed a decline. The reintroduction may be jeopardized by competition with other aquatic vegetation and shading by cut vegetation floating downstream (Rose and Power 1993). Monitoring has not been conducted for a long enough period to ascertain trends or predict long-term success.

Texas Parks and Wildlife Department and the Service (through the section 6 program) initiated a study in June 1989 to determine areal coverage of Texas wild-rice on a yearly basis and to monitor the plants on a monthly basis to detect major changes in coverage. Monthly observations are no longer taken, but Texas Parks and Wildlife has continued annual measurements of the areal extent of stands (Texas Parks and Wildlife Department, *in litt.* 1994, see Table 4). Fluctuations in areal coverage of individual stands and within individual river segments have been noted and need to be carefully analyzed to tie such variations to other changes occurring in or influencing the river.

Another joint section 6 study funded by the Service and Texas Parks and Wildlife is also nearing completion. This study examined habitat parameters in the wild for areas where Texas wild-rice is growing and contrasted them with conditions in other areas where Texas wild-rice is absent.

Herbivory has been noted incidentally by several workers. Beaty (1976) and Poole (pers. comm.) have observed nutria eating plants of Texas wild-rice, and Rose and Power (1992, 1993) have observed waterfowl feeding on the plants. More recently Power has begun quantitative monitoring of herbivory on leaves of reintroduced plants.

The potential impacts of recreationists, particularly tubers and swimmers, has been a concern. The Service has recently funded research to examine the frequency and magnitude of impacts from recreational users of the San Marcos River on Texas wild-rice.

TEXAS BLIND SALAMANDER (*TYPHLOMOLGE RATHBUNI*)

Description

The Texas blind salamander was first described by Stejneger (1896), after the type specimen No. 22686, USNM (U.S. National Museum). The type specimens of the Texas blind salamander were collected in 1895 at the Federal Fish Hatchery in San Marcos, Texas, where they were expelled from an artesian well drilled to supply water to the hatchery (Longley 1978). Since that time there has been some disagreement among experts about whether the species belongs in the genus *Typhlomolge* or *Eurycea*. Wake (1966 after Chippindale et al. 1993) and Potter and Sweet (1981) have supported recognition of *Typhlomolge*, while Mitchell and Reddell (1965) have supported inclusion within *Eurycea*. Chippindale et al. (1994), based on studies using morphometric, biochemical, and molecular techniques have concluded that the species is properly included within the genus *Eurycea*, but have not yet formally published their treatment.

Table 4. Areal coverage (m^2) of Texas wild-rice from 1976 to 1994 (Vaughan 1986, Texas Parks and Wildlife Department 1992, and Jackie Poole, TPWD, in litt.)

Segment*	1976	1978	1983	1984	1985	1986	1989	1990	1991	1992	1993	1994
A	0	0	0	0	0	0	23.1	77.46	63.39	34.24	38.67	35.31
B	0	0	0	0	0	0	83.48	162.43	237.81	184.7	267.37	455.71
C (one)	554	463.5	251	228	217	209	324.64	477.96	392.02	449.22	540.70	442.64
D (two)	0	0	0	0	0	0	0	0	0	0	0	0
E (three)	55	26	29	27	19	19	81.34	72.4	109.81	71.88	76.68	67.84
F (four)	164	no data	119	83	103	92.5	276.57	241.9	271.42	357.88	429.45	270.50
G (five)	68	33	37	8	8	7.5	18.58	18.83	12.88	12.65	20.25	16.91
H (six)	0	0	0	0	0	0	11.4	11.81	8.66	10.15	1.32	4.46
X (seven)	0	0	0	0	0	0	1.04	0	0	0	0	0
I (eight)	9	no data	4	3	4.5	4	12.87	5.56	1.4	0.21	0.32	0.17
J (nine)	49	no data	46	48	68	55	91.08	120.48	117.01	117.7	96.56	76.23
K (ten)	233.5	no data	55	15	69.5	67	77.87	191.07	171.52	122.16	120.58	129.54
L	0	0	0	0	0	0	2.84	0.43	0.29	0.33	0.52	1.52
M	0	0	0	0	0	0	0.53	0	0	0	0	0
Total	1132.5	Incomplete	541	412	489	454	1005.36	1380.31	1406.21	1361.12	1592.42	1500.83

* Segments refer to particular sections of the San Marcos River. Texas Parks and Wildlife Department (1992) used letters. Vaughan used numbers.

Following are descriptions of the segments:

A = Icehouse dam to University Drive (Icehouse dam = Spring Lake dam)
B = University Drive to Hopkins Road railroad bridge (Hopkins Road RR bridge = MOPAC RR bridge)
C = Hopkins Road railroad bridge to Rio Vista railroad bridge (Rio Vista RR bridge = MKT RR bridge)
D = Rio Vista railroad bridge to dam above Cheatum St. (= Cheatham) (Dam above Cheatum St. = Rio Vista dam)
E = Dam above Cheatum Street to low point on south side of Glover's Island
F = Low Point on south side of Glover's Island to just above South I-35 access road
G = Just above South I-35 access road to Thompson Island Dam (Thompson Island dam = Thornton dam)
H = Thompson Island Dam to east-west channel through Thompson Island
X = Hays County Road to mill (east channel) (Hays Co. Road = Capes Road)
I = East-west channel through Thompson Island to Hays County Road
J = Hays County Road to just below east and west channels' confluence
K = Just below east and west channels' confluence to high tension wire
L = High tension wire to sewage treatment plant outfall
M = Sewage outfall to Blanco River confluence

Longley (1978) prepared a report that summarized the available information on this species. Most of the following information on this species comes from that report.

The Texas blind salamander is a smooth, unpigmented (appears white) troglobitic (cave-adapted) species. The maximum total length noted during Longley's (1978) study was 12 cm (4.7 in.). The head is large and broad; eyes are reduced (visible as two small dark spots deep beneath the skin); limbs are slender and long; four toes occur on the fore legs; and five toes occur on the hind legs. The species does not have reliable external characters that can be used to determine sex.

Historical and Present Distribution

All collections or sightings of the Texas blind salamander occur in Hays County, Texas (Figure 7). *Typhlomolge rathbuni* was first collected from the artesian well at the Federal Fish Hatchery in 1895. Since then, the species has been found at several other locations including Ezell's Cave, San Marcos Springs, Rattlesnake Cave, Primer's Fissure, Southwest Texas State University's artesian well, and Frank Johnson's well (Russell 1976, Longley 1978). The species was previously known to occur in Wonder Cave but searches in 1977 did not locate any specimens (Longley 1978). The total distribution of this species may be as small as 10 km^2 (25.9 mi^2) in a portion of the Edwards Aquifer beneath and near the city of San Marcos.

Habitat

Typhlomolge rathbuni is an obligate troglobitic species that occupies the subterranean waters of the Edwards Aquifer in Hays County, Texas. It is neotenic (non-transforming) and aquatic throughout its life and lives in water-filled, cavernous areas in the San Marcos area of the Edwards Aquifer. Observations in caves with access to the water table indicate that this salamander moves through the aquifer by traveling along submerged ledges and may swim short distances before spreading its legs and settling to the bottom of the pool (Longley 1978). Due to the relatively constant 21°C (69.8°F) temperature of subterranean waters in the Edwards Aquifer, *T. rathbuni* is believed to be adapted to this temperature regime and may be sensitive to changes in water temperatures. However, additional research is necessary to determine critical temperature minima and maxima for different life stages of this species (Longley 1978).

Life History/Ecology

Little is known of the life history of *T. rathbuni* since its subterranean existence makes it difficult to study in its natural environment.

Food Habits

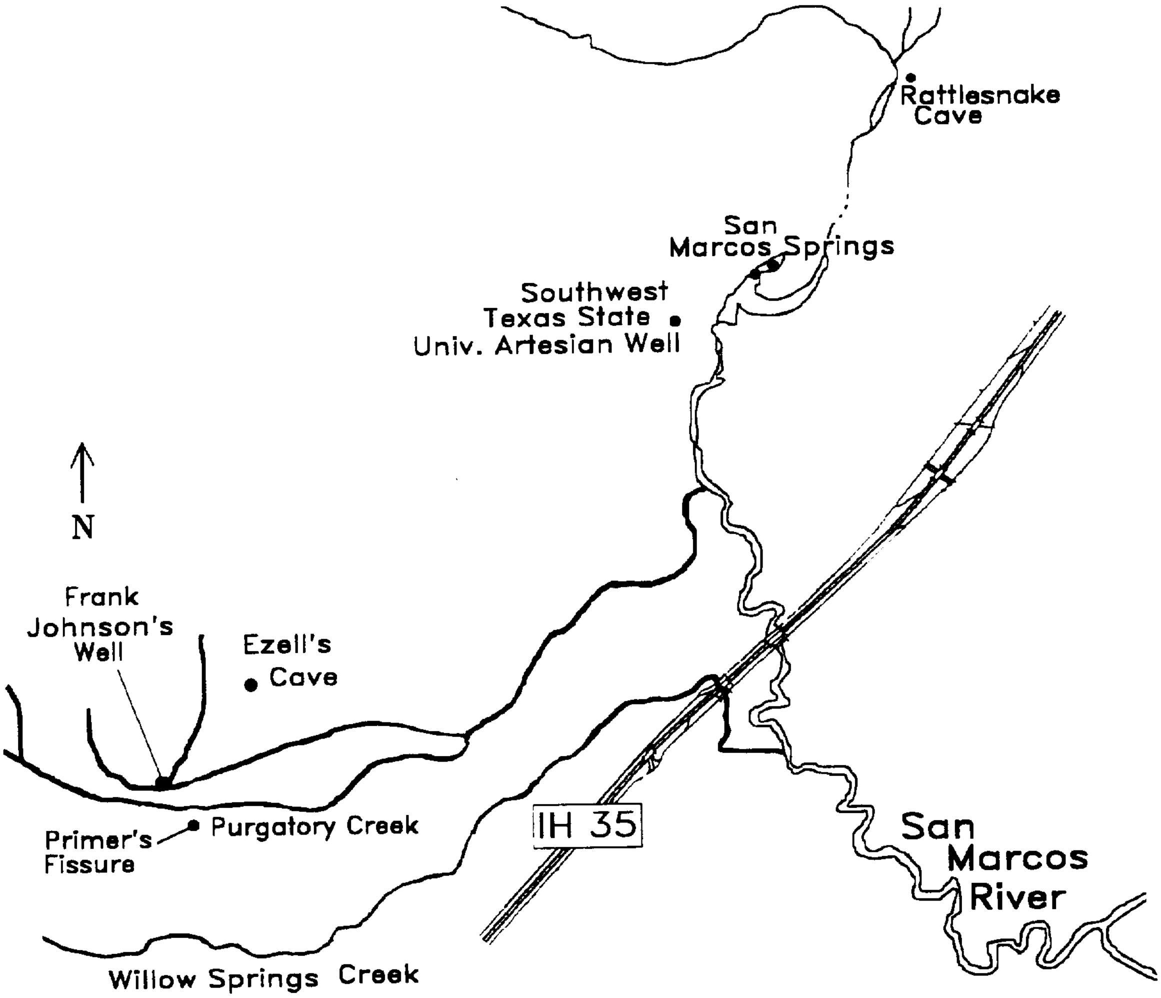
Observations on captive individuals indicate that *T. rathbuni* feed indiscriminantly on small aquatic organisms and do not appear to exhibit an appreciable degree of food selectivity. Young *T. rathbuni* feed well on copepods. Larger salamanders are documented to eat amphipods, blind shrimp (*Palaemonetes antrorum*), daphnia, small snails, and other invertebrates. Cannibalism has also been documented (Longley, *in litt.*, 1994).

Reproductive Characteristics

Due to the presence of juveniles throughout the year, *T. rathbuni* appears to be sexually active all year, which is expected since there is little seasonal change in the aquifer (Longley 1978). Gravid females have been observed each month of the year (F.E. Potter, pers. comm., in USFWS 1980). One gravid female contained 39 eggs (Longley 1978). There appears to be a correlation between size (age class), number of testicular lobes, and number of times sperm has been produced (Longley 1978).

Typhlomolge rathbuni reproduced for the first time in captivity at the Cincinnati Zoo (Maruska 1982). Three different spawning events occurred between December 1979 and January 1980. Clutch size ranged from 8 to 21 eggs per spawning. The eggs were unpigmented and were attached to pieces of gravel singly or in clusters of 2 or 3 eggs. Light intensity did not appear to affect embryonic development. However, relatively

Figure 7. Collections and sighting location of the Texas blind salamander.



constant water temperature similar to that within the aquifer (21°C [69.8°F]) is necessary for normal egg development.

The Dallas Aquarium has also induced *T. rathbuni* to breed in captivity (David Schleser, Dallas Aquarium, pers. comm., 1994). Two individuals were apparently engaged in courtship behavior on May 11, 1994, and repeated this activity on May 15. The first clutch of 13 eggs was deposited singly on the limestone rocks in the aquarium on May 21-22. The eggs hatched within 12 to 16 days of oviposition, and the larvae began feeding within 1 month after hatching. Successful reproduction continues to occur at the Dallas Aquarium.

Conservation Measures

The Nature Conservancy (TNC) purchased Ezell's Cave in 1967. In 1972, Ezell's Cave was designated as a National Natural Landmark by the National Park Service.

Personnel at the Cincinnati Zoo and the Dallas Aquarium have successfully propagated *T. rathbuni* in captivity. The Dallas Aquarium is developing a captive breeding program for this species. Photodocumentation of embryologic and larval development will provide information on the reproductive ecology of the Texas blind salamander (Schleser, *in litt.* 1994). The Service has also recently provided funding for the San Marcos NFH&TC to collect *T. rathbuni* for distribution to one or two additional facilities to increase the chances for successful captive propagation.

E. RECOVERY STRATEGY

To conserve these species and meet the objectives of this recovery plan, consistent with the purposes of the Endangered Species Act, the ecosystems upon which these species depend must be conserved. These ecosystems include the Edwards Aquifer and the systems associated with Comal and San Marcos Springs (including spring runs, lakes, and rivers). One of the most serious threats to the continued existence of these species and their ecosystems is decreased water levels in the Edwards Aquifer and loss of adequate springflows required to maintain aquatic habitat in the Comal and San Marcos Springs and associated riverine systems. Current water withdrawals are mostly unregulated and based on right of capture. To recover the five species covered by this plan, a mechanism for maintaining existing aquatic habitats must be in place. In 1993, the Texas legislature passed S.B. 1477 creating an Edwards Aquifer Authority to regulate groundwater withdrawal. The legislation was challenged due to Voting Rights Act concerns, which were resolved by the legislature in 1995 with amendments (H.B. 3189). The legislation has subsequently been challenged by the Medina and Uvalde County Underground Water District, and was ruled unconstitutional. The state plans an appeal, and it is likely that litigation will continue. The Authority's ability to regulate will depend on resolution of these concerns.

In addition, to conserve these species and their habitat, aquifer levels and springflows must be maintained. A variety of tools for achieving reduced groundwater withdrawal from the aquifer are available. Some possibilities include conservation and reuse; creation of a water marketing system; development of alternative sources of water for human use; and modification of delivery mechanisms or water use practices. The overall environmental impacts of all of these alternatives should be considered. Because there are a significant number of users dependent on the aquifer and aquifer waters that flow downstream, creation of this plan should involve representation from multiple user groups (including Federal and non-Federal entities) to assure equitable consideration of various human needs (social and economic) while implementing recovery of federally listed plant and animal species that depend on the Edwards Aquifer and associated aquatic systems.

During the interim period while long-term water management plans are being developed and put in place, it may be possible to grant one or more incidental take permits for levels of take that do not jeopardize the species or preclude recovery actions. Such a permit can be granted under section 10(a)(1)(b) of the ESA. One component needed to qualify for such a permit is an adequate Habitat Conservation Plan (HCP). Short-term measures developed by the above planning activities may form a basis for developing an incidental take permit application.

The Service should provide guidance and support for the planning and permitting process. Guidance on the permitting process, logistics, documentation and responsibilities should be given as well as encouraging applicants to initiate informal discussions with the Service at an early stage. The Service should provide early assistance to answer questions and provide direction about elements needed for a successful application, as well as strategies and approaches that may be available.

In addition the Service needs to develop, through an interdisciplinary approach, refinements of springflow levels previously provided and guidance on reductions in groundwater use and aquifer levels that are needed to support the species and their habitat.

Judging from recent events in the courts it appears possible that a state or local agency with the authority to regulate groundwater use may not be established in a timely manner. In the event that an adequate regional management plan is not developed and implemented, the Service should assist in developing a conservation strategy for Federal agency conservation actions to maintain flows from Comal and San Marcos Springs that promotes recovery of the five listed species covered by this recovery plan.

In addition to addressing the major threat of loss of water quantity to threatened and endangered species, consideration needs to be given to providing adequate water quality. Potential and existing sources of water quality impacts to the aquifer and the Comal and San Marcos systems need to be identified and addressed, including such things as point and non-point source pollution; activities in the contributing and recharge zones; potential movement of the bad-water line; and use of pesticides, herbicides, and other chemicals.

In addition to addressing the broad, regional threats facing these species and their ecosystems, the recovery strategy also needs to address the more local and site-specific threats. These threats include such things as presence of nonnative species, impacts from recreation, and local sources of water quality impacts and habitat alterations (for example, leaking tanks and septic systems, siltation from local construction site runoff). A number of tasks to address these threats have been outlined in this recovery plan, among them are development of local spring and river management plans, control and/or removal of select nonnative organisms, and work with local landowners and users. Work with local landowners should include efforts to address site-specific threats as well as to enhance and/or maintain habitat for the species. For example, in the case of the San Marcos salamander, maintaining natural algal and plant communities in Spring Lake and adjacent portions of the San Marcos River is important.

Because of their limited range and the potential for catastrophic events (such as oil or hazardous material spills, severe droughts) or other uncontrollable factors these species will continue to be at risk of extinction. Therefore, though the main strategy of this plan is to reduce that risk and conserve the species in their native ecosystems, this plan includes captive propagation as a tool to provide additional assurance that the species will be conserved for the long-term. Genetically representative captive populations should be established and carefully maintained so that suitable stocks are available for reintroduction or supplementation purposes if needed. Captive populations alone do not constitute recovery nor meet the purpose of the Endangered Species Act "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." Therefore, their use should be considered a precautionary measure, for dire circumstances only, and the primary focus should be placed on conservation of these species' ecosystems.

Until captive propagation programs are in place, an up-to-date contingency plan should be in place that outlines a strategy for bringing representative samples of each listed species into captivity temporarily in the event of a dire reduction in springflows.

Conservation of these species and their ecosystems will necessitate support and participation of a wide variety of people and organizations, with varying levels of knowledge and backgrounds. Therefore, public information and education is an important component of this recovery strategy.

Additional research is needed in some areas, particularly regarding the species' specific habitat requirements, assessing threats and how to address them, and captive breeding and reintroduction techniques.

These species' populations, habitats, and threats should also be monitored to assess population trends and assure that no significant decline in their status occurs. Monitoring is also needed to protect the species from an irreversible decline and to provide information for periodic evaluation of the effectiveness of recovery actions.

PART II

RECOVERY

A. OBJECTIVE AND CRITERIA

The objective of this Recovery Plan is to secure the survival of these endangered or threatened species in their native ecosystems. Maintenance of water levels in the Edwards Aquifer and flows that maintain the San Marcos and Comal River ecosystems is vital to the survival of these species. Protection of these ecosystems will also aid in conservation of numerous candidate species.

Local threats to each of the species, as well as broader, regional threats to the ecosystems' continued integrity, are addressed in this plan. Only by addressing *both* types of threats and directing conservation activities toward remedying both can the goals of this plan be attained. Recovery criteria for each species follow.

RECOVERY CRITERIA

San Marcos Salamander, San Marcos Gambusia

Because of the limited distribution of the San Marcos salamander and the San Marcos gambusia, and the potential for a catastrophic event that could eliminate these species, the potential for full recovery leading to downlisting or delisting of these species is low. Elements that threaten the continued survival of these two species must be controlled before downlisting or delisting these species could occur. However, much can be done to increase the chances of long-term survival of the San Marcos salamander and the San Marcos gambusia (if the latter species still exists). The objective of this plan for these two species is the continued existence of healthy, self-sustaining populations of these species in their native ecosystems. Criteria for whether this objective is being obtained are whether the following conditions have been achieved:

1. Adequate flows and water quality are assured to continue from the San Marcos Springs and downstream through the San Marcos River, even in a drought of record, at a level that will sustain these species.
2. Captive, breeding populations for each species are maintained in such a way that genetic integrity of each species is insured and there is suitable stock for reintroductions or supplementations should a catastrophe eliminate or drastically reduce numbers in their native ecosystem, and reintroduction techniques that are likely to be successful have been developed.
3. Local threats have been successfully removed or minimized (e.g., impacts from nonnative species, recreation, habitat alteration, or local water quality problems).
4. Healthy, self-sustaining populations of each species are established throughout their historic ranges, and these populations are being maintained. Whether this has been attained should be evaluated based on the criteria that follow for each species:

San Marcos Salamander

Estimated conditions indicating healthy, self-sustaining populations of the San Marcos salamander were obtained from Tupa and Davis (1976) and Nelson (1993).

- Sampling should occur at least once a year following the methodology used by Nelson (1993), in the appropriate substrates.
- The following minimum density estimates of salamanders in the rock substrate at Diversion and Deep springs and algal mats at the upper end of Spring Lake in front of the hotel should be observed.

in algal mats:	116/m^2	(1249 ft^2)
in Diversion Spring:	25/m^2	(269 ft^2)
in Deep Spring:	8/m^2	(86 ft^2)

- Juvenile (<20 mm snout-vent length) salamanders should make up at least 75 percent of the total salamander population.

- Suitable rocky substrates (sand and gravel interspersed with large limestone boulders and devoid of muddy or detritus-laden substrates) should occur at the sampling sites with the minimum areal coverage listed below.

algal mats:	317 m^2	(3408 ft^2)
Diversion Spring:	14 m^2	(151 ft^2)
Deep Spring:	19 m^2	(206 ft^2)

San Marcos Gambusia

Estimated conditions indicating healthy, self-sustaining populations of San Marcos gambusia are listed below.

- A ratio of pure San Marcos gambusia to hybrids of 10:1 or fewer hybrids (that is 10% or fewer hybrids).

- If the species can be found, additional indicators for criterion #4 (such as status of habitat and population numbers and distribution) will be determined.

RECOVERY CRITERIA

Fountain Darter

Because of the limited distribution of this species the potential for full recovery and delisting is low. The fountain darter will be considered for downlisting, from endangered to threatened, when the following conditions have been achieved:

1. Adequate flows and water quality are assured to continue from the San Marcos and Comal Springs downstream through their respective rivers and channels, even in a drought of record, at a level that will sustain the species.

2. Captive, breeding populations of both the Comal and San Marcos populations are being maintained in such a way that genetic integrity of each species is assured and there are suitable stocks for reintroductions or supplementations should a catastrophe eliminate or drastically reduce numbers in their native ecosystems.

3. All measures identified in this plan to remove or minimize "local" threats have been successfully implemented (e.g., impacts from nonnative species, recreation, habitat alteration, or local water quality problems).

4. Healthy, self-sustaining populations of both populations exist throughout their historic ranges in both the Comal and San Marcos systems and are being maintained. Whether this has been attained should be evaluated based on the criteria that follow:

    - Monitoring of fountain darters and submergent vegetation in both the San Marcos and Comal systems should be conducted annually to verify acceptable populations are being maintained.

    - Methods used to sample fountain darters should be similar to those used by the USFWS in their Comal and San Marcos habitat and flow requirements study, i.e., use of drop nets and underwater observation.

    - Fountain darter numbers and densities by microhabitat type should occur in densities similar to or greater than that described by the USFWS in the Comal in 1993 and in the San Marcos in 1994 (work in progress: Habitat and Flow Requirements Study for the Comal and San Marcos Systems. USFWS Austin Ecological Services Office).

- Areal coverage of submergent vegetation by species (including filamentous algae, mosses, and higher plants) should be monitored annually (in July or August) and should not be significantly different from the submergent plant community described in 1993 and 1994 as characterized in studies conducted by the USFWS, TPWD, and cooperators.

The estimated date for attaining the downlisting criteria of the fountain darter is 2025. This estimate is based on a review of the recovery tasks needed and a reasonable time period in which tasks could be achieved. This estimate assumes support will be available to accomplish all tasks in a timely manner.

RECOVERY CRITERIA

Texas Wild-rice

Because of the limited distribution of this species the potential for full recovery and delisting is low. The Texas wild-rice will be considered for downlisting, from endangered to threatened, when the following conditions have been achieved:

1. Adequate flows and water quality are assured from the San Marcos Springs and downstream through the San Marcos River, even in a drought of record, at a level that will sustain the species.
2. Captive, reproducing populations are being maintained in such a way that genetic integrity of the species is secured and there is suitable stock for reintroductions or supplementations should a catastrophe eliminate or drastically reduce numbers in their native ecosystem, and reintroduction techniques that are likely to be successful have been developed.
3. All measures identified in this plan to remove or minimize local threats have been successfully implemented (e.g. impacts from nonnative species, recreation, habitat alteration, and local water quality problems).
4. Healthy, self-sustaining, and reproductive populations are established throughout the historic range, and these populations are being maintained. Whether this has been attained should be evaluated based on the criteria that follow:
    - Wild-rice plants should be present with at least the following areal coverage and distribution:

Spring Lake:		1500 m^2	(16,148 ft^2)
Segment	A:	1400 m^2	(15,071 ft^2)
	B:	5000 m^2	(53,825 ft^2)
	C:	1000 m^2	(10,765 ft^2)
	D:	100 m^2	(1,077 ft^2)
	E:	500 m^2	(5,383 ft^2)
	F:	900 m^2	(9,689 ft^2)
	G:	100 m^2	(1,077 ft^2)
	X:	50 m^2	(538 ft^2)
	H:	30 m^2	(323 ft^2)
	I:	50 m^2	(538 ft^2)
	J:	400 m^2	(4,306 ft^2)
	K:	700 m^2	(7,536 ft^2)
	L:	100 m^2	(1,077 ft^2)
	M:	100 m^2	(1,077 ft^2)
Total:		11,930 m^2	(128,426 ft^2)

Segments are delineated in Table 4. These figures are calculated to achieve an average cover of 75% of the potential wild-rice habitat believed to be present in each segment. This percent cover is typical of that found in healthy, vigorous stands of rice monitored over the last several years.

Flowering, fruiting with production of viable seed, and seed germination in stands, with establishment of vigorous juvenile plants should be documented to occur in at least 5 percent of the stands each year for a 5-year period.

These criteria provide some degree of assurance that plants are successfully completing their natural life cycle and opportunity for cross pollination exists. However, these criteria cannot ensure that juvenile plants are actually maturing and reproducing successfully. Neither would these criteria detect such problems as late onset of juvenile mortality or sterility. To document survivorship and viability of plants germinated from seed, it would be necessary to track individual seedlings to verify that wild seedlings produce viable seed. However, techniques for this sort of detailed tracking of individuals of wild-rice within stands have not yet been developed. If such techniques can be developed in the course of monitoring research, documentation that plants derived from seed are surviving and reproductively successful should be added to the downlisting criteria.

The estimated date for attaining the downlisting criteria of Texas wild-rice is 2025. This estimate is based on a review of the recovery tasks needed and a reasonable time ›d in which they could be achieved.

RECOVERY CRITERIA

Texas Blind Salamander

Because of the limited distribution of the Texas blind salamander, the potential for full recovery and delisting is low. However, much can be done to increase the chances of long-term survival of this species. The Texas blind salamander will be considered for downlisting, from endangered to threatened, when the following conditions have been achieved:

1. Adequate water levels in the aquifer are assured to continue natural springflows, even in a drought of record.

2. Adequate water quality in the aquifer is assured to sustain this species.

3. Captive breeding populations of this species are maintained in such a way that genetic integrity of the species is secured and there are suitable stocks for reintroductions or supplementations should a catastrophe eliminate or drastically reduce numbers in their native ecosystem, and reintroduction techniques that are likely to be successful have been developed.

4. All measures identified in this plan to remove or minimize local threats have been taken (e.g., localized water withdrawals, destruction or pollution of local recharge features and caves, local pollution sources, etc).

5. Healthy, self-sustaining populations of this species exist throughout the species' historic range and are being maintained, as indicated by the following measures:

    - Sampling should occur at least once a year and include the use of collection nets over the spring outlets (see Nelson 1993) and baits (organic matter such as potato peels) to attract amphipods and *T. rathbuni* in the caves.

- *T. rathbuni* should be present during the course of search efforts lasting three weeks each at three or more of the following five locations: Ezell's Cave, Rattlesnake Cave, San Marcos Springs, Primer's Fissure, and the artesian well on SWTSU campus. At least one of the three locations where *T. rathbuni* is found should be at one of the two cave locations.

- Salamanders less than 3 cm (0.09 in.) total length should make up at least 50% of the total salamander population from samples taken in the cave and artesian well locations and at least 90% of the population sampled at the spring locations. These estimates are based on data obtained by Longley (1978) and are believed to be representative of healthy, self-sustaining populations.

Reclassification criteria are preliminary and may be revised on the basis of new information. Adequate flows for all species covered in this plan will be considered to be those given in Table 2 that avoid "take" of the listed animals and "damage and destruction" of the Texas wild-rice, unless a permit has been issued for some incidental take. However, in no case should flows that would jeopardize any of the listed species or adversely modify critical habitat be considered adequate. Numbers in Table 2 may be modified by the Service based on new information.

B. STEP-DOWN OUTLINE OF RECOVERY ACTIONS

The following outline lays out a plan for obtaining the objectives of this recovery plan. More detail on specific tasks is given in Section C. Though the Service is responsible for developing this recovery plan, it cannot be implemented in its entirety without assistance from other stakeholders. Responsible parties to assist in implementing the tasks in this plan have been identified in the implementation schedule (Part III). This plan does not commit any "responsible party" to carry out a particular recovery task or expend funds. Likewise, the implementation schedule does not preclude or limit others from participating in the recovery of the species covered in this plan.

1.0 Specific research and information needs

- 1.1 Identify individual and population needs and habitat requirements
    - 1.11 Determine food habits
    - 1.12 Identify diseases and parasites
    - 1.13 Determine reproductive parameters
    - 1.14 Determine survivorship patterns
    - 1.15 Identify habitat characteristics and requirements (including flow, temperature, and channel conformation requirements, and other parameters)
    - 1.16 Conduct searches to locate San Marcos gambusia
- 1.2 Determine the nature and extent of local threats
    - 1.21 Determine impacts from tourism enterprises and recreational use of the springs, lakes, and rivers upon the listed species
    - 1.22 Compile information on the characteristics of the San Marcos watershed
    - 1.23 Compile information on the characteristics of the Comal watershed
    - 1.24 Compile data pertaining to pesticide and herbicide use in the San Marcos and Comal watersheds, including drainage into caves containing the Texas blind salamander
    - 1.25 Identify and determine effects of pollutants from point source discharges and other discharges on listed species and their habitats
    - 1.26 Assess water quality in the San Marcos aquatic ecosystem and determine possible sources of negative impacts
    - 1.27 Assess water quality in the Comal aquatic ecosystem and determine possible sources of negative impacts
    - 1.28 Assess adequacy of existing aquifer water quality protection provisions
    - 1.29 Determine negative impacts by nonnative species and develop control mechanisms where necessary
- 1.3 Determine aquifer characteristics and recharge patterns and zones that influence flow from San Marcos and Comal Springs
- 1.4 Develop captive breeding and reintroduction techniques for all species

2.0 Manage, maintain, and enhance the species' populations and habitats throughout their present and historic ranges

- 2.1 Working with affected stakeholders, implement an Aquifer Management Plan to ensure sufficient habitat (aquifer levels and springflows) are provided to recover the five listed species.

- 2.11 Working with stakeholders, develop and promote a comprehensive short and long-term regional plan for aquifer management that considers all users
- 2.12 Provide Service guidance and support for the regional aquifer management planning effort

2.2 Encourage Federal agencies to undertake or actively promote conservation activities under section 7(a)(1) of the ESA

2.3 Develop a Federal agency conservation strategy in the event that task 2.11 is not implemented or is ineffective in ensuring necessary springflows

- 2.31 Continue to support proactive Federal agency conservation actions
- 2.32 Continue to support private proactive conservation actions
- 2.33 Aggressively pursue Federal agency compliance with obligations for informal and formal consultations under section 7(a)(2) of the Act
- 2.34 Examine the potential effectiveness of State and Federal legal action, and prepare to initiate such action if an emergency appears imminent

2.4 Develop and implement local spring and river management plans

- 2.41 Develop and implement Management Plan(s) for the San Marcos system
- 2.42 Develop and implement Management Plan(s) for the Comal system

2.5 Implement measures necessary to protect water quality in the aquifer

2.6 Encourage management of spring, lake, river, and cave habitats by private individuals and others

2.7 Establish and maintain captive stocks at appropriate facilities

2.8 Reduce pollution loadings to San Marcos and Comal aquatic habitats and caves with Texas blind salamanders

2.9 Restore damaged habitats and enhance marginal habitats

2.10 Control and/or remove select nonnative organisms from the San Marcos and Comal aquatic ecosystems

2.11 Maintain and implement a contingency plan to bring species into captive refugia if an emergency exists

2.12 Provide regulatory protection

3.0 Monitor populations, habitats, and threats

- 3.1 Monitor populations and habitats
- 3.2 Monitor threats

4.0 Public information and education

- 4.1 Produce educational materials and inform a variety of audiences
- 4.2 Encourage public participation in conservation efforts

C. NARRATIVE OUTLINE FOR RECOVERY ACTIONS

1.0 Specific research and information needs.

Additional information and data are needed to assist in completing certain recovery actions.

1.1 Identify individual and population needs and habitat requirements.

The biological, physical, and chemical attributes affecting and influencing the survival of the five protected species covered by this plan are not well understood, although efforts toward a greater understanding of these parameters are a major thrust of previous, on-going, and planned research. A great deal of progress has been made in several of these task areas, and several additional studies are currently underway. These are discussed in detail under the General Conservation Measures section and under each species account's Conservation Measures section.

1.11 Determine food habits

The food habits of the fountain darter and the San Marcos salamander have been examined, and the food habits of the Texas blind salamander have been observed in captivity. However, the foods taken by the San Marcos gambusia have not been determined. An examination of the food requirements of these species should be made. This research should describe the distribution of preferred and highly desirable food items on a seasonal basis. The availability of food items or nutrients also should be quantified seasonally. This information will be helpful when managing the species and/or the ecosystems.

1.12 Identify diseases and parasites

Little information on diseases and parasites of the five listed species is available. The effects of these on population survival could be adverse. Populations should be periodically surveyed for the incidence of disease and parasites. If significant, or potentially significant, additional work will be needed. Impacts and control mechanisms need to be determined in advance of outbreaks so that corrective management strategies may be implemented if a debilitating parasite infestation or an uncontrolled disease outbreak occurs. Conditions that may foster stress and disease outbreaks should also be described so that such conditions can be avoided.

1.13 Determine reproductive parameters

A study of the reproductive cycles and patterns for the species should be accomplished to better understand the natural fecundities of the species and factors influencing the number of offspring each species can produce. From this information it may be possible to optimize conditions, thereby improving natural reproductive rates of these listed species. This information will also be helpful in evaluating recovery criteria and recovery status of populations. Work currently underway examining reproduction is discussed under individual species accounts.

1.14 Determine survivorship patterns

The factors influencing the survivorship of each of the protected species are inadequately understood. Information concerning survivorship is needed, as is information on optimal conditions for enhancing survivorship of these species. Studies should include analyses of factors potentially limiting survival, such as predation, competition, and water quality. The role of predators on the survival of the protected species has not been studied in detail, although fountain darters have been found in stomach contents of largemouth bass (*Micropterus salmoides*) taken during winter months. Additional information that may be useful for fountain darters includes the density and types of vegetation needed for (1) survival of darters from various types of predators and (2) prey base for darters. For Texas wild-rice these studies should also evaluate the fate of seeds produced and the role of seeds in contributing to reproductive adults in the system. These studies will provide information needed for managing the species and for restoration and reintroduction work. As our understanding of the species biology and the environmental variables that influence survivorship improve, tools such as population viability analysis (PVA) may provide useful insight needed for management and planning purposes.

1.15 Identify habitat characteristics and requirements (including flow, temperature, and channel conformation requirements, and other parameters)

Although general characteristics of the habitats used by these species are known, more specific information is needed. Studies should be conducted to determine the specific aspects of the environmental parameters influencing the survival of these species to best manage these populations. Studies of the relationship between instream features and species habitat are ongoing and are detailed under the General Conservation Measures section.

1.16 Conduct searches to locate San Marcos gambusia

Individuals of this species must be located before some other tasks can begin. San Marcos gambusia have not been located in the San Marcos River for over 10 years. However, a new approach is proposed conducting directed habitat manipulation/restoration (as advocated under task 2.9) in areas where the species was formerly found. By recreating what are believed to be optimum conditions it is hoped that any existing individuals may be attracted and concentrated, to increase chances for detection and survival.

1.2 Determine the nature and extent of local threats

Attempts should be made to identify the source and extent of local threats, so that significant threats can be addressed.

1.21 Determine impacts from tourism enterprises and recreational use of the springs, lakes and rivers upon the listed species

Use of the San Marcos River by swimmers, tubers, canoeists, and others is significant and is believed to impact listed species directly and indirectly. Tourism enterprises may have impacts from activities related to their operations. Recreation has increased dramatically over the years (Bradsby, 1994). The Comal River is also heavily used for recreation. The extent of the effects of these uses on the San Marcos and Comal aquatic ecosystems is unknown. However, it is believed that at least part of the reproductive difficulties of the Texas wild-rice stems directly from human use of the San Marcos River for recreational activities as emerging seed heads are knocked over or damaged by recreationists. Recreational impacts on the protected species (either directly or through adverse impacts to their habitats) in the San Marcos and Comal aquatic ecosystems should be determined and potential means to avoid adverse effects developed. This information should be useful in developing management plans under task 2.4 and in working with landowners and users as part of task 2.6. Work underway examining these impacts is detailed under individual species accounts.

1.22 Compile information on the characteristics of the San Marcos watershed

Even though the San Marcos ecosystem is principally a springrun, runoff from the surrounding watershed strongly influences the water quality and biota of the river. Consequently, knowledge of the characteristics of the watershed is necessary for its management. A description of the watershed should include the size, topography, slope, runoff patterns, soil types and characteristics, land use patterns and acreages, and climatic characteristics.

1.23 Compile information on the characteristics of the Comal watershed

A description of the Comal watershed, similar to that called for in task 1.22 for the San Marcos, is also needed.

1.24 Compile data pertaining to pesticide and herbicide use on the San Marcos and Comal watersheds, including drainage into caves containing the Texas blind salamander

Pesticides, herbicides, and other chemical compounds could negatively impact the San Marcos and Comal aquatic ecosystems' biota in degrees of severity ranging from subtle to catastrophic. Information should be compiled pertaining to chemical related fish or plant kills. The use and potential impacts of agricultural and non-agricultural herbicides and pesticides in the upper San Marcos and Comal watersheds should be evaluated, including attention to inage that may impact caves with the Texas ind salamander.

1.25 Identify and determine effects of pollutants from point source discharges and other discharges on listed species and their habitats

Point source discharges include wastewater and stormwater outfalls, commercial discharges, parking lot drainage discharges, detention pond discharges, seepage discharging from dumps, etc. Discharges into the Comal and San Marcos River systems may introduce pollutants that are harmful to listed species, and may cause changes in the physical characteristics of depth, flow, and sediments that may directly or indirectly alter habitat. For example, records show the historic range of both the fountain darter and Texas wild-rice extends below the outfall of e San Marcos wastewater treatment plant. ough it is unclear how they were distributed in this area or how abundant they may have been in the past, today fish are not abundant and wild-rice has not been found recently below the outfall. The city of San Marcos is considering expanding the wastewater treatment plant from the current flow of 6.25 MGD to 9 or 10 MGD. Needed research is underway to determine some of the effects of the sewage effluent. Other discharges also occur into the San Marcos and Comal ecosystems and these should be evaluated for their impacts on the species and their habitats. For example, the A.E. Wood State Fish Hatchery is currently examining the potential impacts of their operation to listed species in the San Marcos.

1.26 Assess water quality in the San Marcos aquatic ecosystem and determine possible sources of negative impacts

Key components of water quality should be sampled at points throughout the San Marcos aquatic ecosystem. Information compiled as part of task 1.22 should assist in determining sampling points. Sampling should also be designed to determine the source of any significant negative impacts.

1.27 Assess water quality in the Comal aquatic ecosystem and determine possible sources of negative impacts

A study similar to that called for in task 1.26 for the San Marcos ecosystem should also be conducted in the Comal ecosystem. Information from task 1.23 should be useful in determining sampling points.

1.28 Assess adequacy of existing aquifer water quality protection provisions

A review of all aquifer water quality protection provisions and an evaluation of their adequacy should be conducted. An evaluation of possible sources of catastrophic contamination should also be conducted. This analysis should identify all potential sources possible, the likelihood of the catastrophe, the extent of ecosystem damage likely to occur (such as where it would hit - at the spring openings, downstream, etc.). Provisions for protecting against both catastrophic and chronic water quality problems should be included. Recommendations should be made for any shortcomings found. Preliminary work done examining this issue is noted under the General Conservation Measures section.

1.29 Determine negative impacts by nonnative species and develop control mechanisms where necessary

A relatively large number and variety of nonnative species have been introduced into the San Marcos and Comal aquatic ecosystems. Some of these introduced species are affecting listed species; however, the level and significance of these interactions are unknown in many cases. Some nonnative species may be competitors or predators or otherwise negatively impact the listed species through habitat modification or other influences. It is important to understand the effect these nonnative plants and animals are having on the protected species so that necessary remedial actions can be determined and implemented. In addition, information that may be useful in developing control strategies needs to be obtained. Some life history information on nonnatives, especially those parameters such as critical life stages, overlap in habitat use, foods, and other factors that may affect the survival and recovery of listed species will need to be collected. Attention should be given to those nonnative species most likely to be impacting listed species, such as the giant ramshorn snail, elephant ears, tilapia, and nutria. Emphasis should be placed on developing control techniques for those nonnative species that pose a significant threat. Work currently underway examining impacts of nnonnativespecies is discussed in the General Conservation Measures section.

1.3 Determine aquifer characteristics and recharge patterns and zones that influence flow from San Marcos and Comal Springs

Because the San Marcos and Comal aquatic ecosystems are tied intimately to the flow of the San Marcos and Comal Springs, respectively, and the springs to the Edwards Balcones Fault Zone aquifer, additional information detailing the hydrologic characteristics and trends of the aquifer is essential. Numerous agencies, including the U.S. Geological Survey, Edwards Underground Water District, Edwards Aquifer Research and Data Center, Texas Natural Resource Conservation Commission, Texas Water Development Board, U.S. Army Corps of Engineers, Bureau of Reclamation, Natural Resource Conservation Service, and various other organizations and groups, have conducted and are continuing to conduct investigations into the functioning of the aquifer and its watershed, as noted in the Introduction. Additional information on the functioning of the aquifer in the San Marcos and Comal regions and specifically studies that deal with those factors that can influence the flow from the San Marcos and Comal Springs are needed to evaluate any of the flow-related recovery actions. This information should also be helpful in evaluating the potential for contamination of the springs.

1.4 Develop captive breeding and reintroduction techniques for all species

Captive breeding and reintroduction techniques have been developed for the fountain darter. In addition, captive breeding of various gambusia species has been successfully undertaken; however, no additional work on the San Marcos gambusia will be possible until the species is found (see task 1.16). No one has been successful at captively breeding the San Marcos salamander. Texas blind salamanders breed in captivity readily, though the young are very fragile and require a good deal of attention (Streett Coale, Dallas Aquarium and Ed Maruska, Cincinnati Zoo, pers. comm., 1995). Additional research is underway for both of these species. Research developing methods for seed storage (short and long-term) is a high priority for Texas wild-rice as aquatic species are known to have special needs for temperature, moisture, oxygenation, etc. These techniques need to be worked out as soon as possible given potential for catastrophically low flows. Cultivated plants and seed could be used for research purposes (if the research contributes to the species conservation) as well as reintroduced into the San Marcos River in carefully chosen sites. Though work is underway to develop reintroduction techniques for Texas wild-rice more work is needed to increase chances of success. Similarly, for the other species where reintroduction techniques have not been developed (salamanders and San Marcos Gambusia) additional work is needed.

2.0 Manage, maintain, and enhance the species' populations and habitats throughout their present and historic ranges

Recovery of these five species will require efforts aimed at specific aspects of each species' biology in conjunction with efforts addressing the continued need to maintain habitat in the Edwards Aquifer and to secure flows from the San Marcos and Comal Springs. Natural populations of the Texas wild-rice, San Marcos gambusia, and San Marcos salamander occur only in the San Marcos aquatic ecosystem. The fountain darter inhabits both the San Marcos and Comal aquatic ecosystems. The fountain darter population in the Comal River is believed to stem from a successful reintroduction of this species from stocks obtained from the San Marcos River after its apparent extirpation from the Comal River. This population is given the full protection of the Endangered Species Act, just as the population in the San Marcos is. Both populations are important for the survival and recovery of the fountain darter. For the Texas blind salamander, which lives in the aquifer, accomplishing the recovery objectives will focus on maintaining adequate water quality and quantity in the aquifer, which is also important for the other four species.

2.1 Working with affected stakeholders, implement an Aquifer Management Plan to ensure sufficient habitats (aquifer levels and springflows) are provided to recover the five listed species.

Local, state, and Federal entities and the public should work together to develop and implement a plan that maintains adequate habitats (aquifer levels and springflows) in the Edwards Aquifer, Comal, and San Marcos Springs to sustain native plant and animal populations and provides for human needs. Some mechanism for maintaining aquifer levels sufficient to maintain essential to assure success of this plan in maintaining adequate springflows, otherwise all the efforts of the involved parties could be offset by parties who choose not to participate in the implementation of the plan. Accomplishment of this initiative will require the cooperation of all parties who have the ability to control groundwater withdrawals. Through cooperation progress toward recovery can be made while social and economic values of the aquifer are also conserved.

The Texas State Legislature has made a significant contribution to this effort by enacting legislation (S.B. 1477, as amended by H.B. 3189 in 1995) creating the Edwards Aquifer Authority. However, the ability of the Edwards Aquifer Authority to control groundwater withdrawals has been legally challenged by the Medina and Uvalde County Underground Water District(s), and the resulting dispute has made the prospects for State control of water withdrawals from the Edwards Aquifer uncertain.

Until such time that the Service revises or refines the springflow numbers provided to the Court in the case of Sierra Club vs. Secretary of the Interior (No. MO-91-CA-069, U.S. Dist. Ct., W.D. Texas) (see "Threats" and Table 1 for these flows), adequate springflows should be considered to be those above which take of listed species would occur, unless a permit is issued to allow some incidental take. In any case, flows should be maintained above the level where adverse modification of critical habitat would occur or where jeopardy to the species would result.

To achieve maximum reliability and minimize potential adverse environmental and economic impacts, the plan should not rely heavily on any single strategy. The plan should be multifaceted, using a diversity of techniques and approaches. The plan may include such things as conservation and reuse measures, limits on groundwater withdrawal, emergency groundwater use reduction plans with springflow "trigger levels" under given conditions (such as low precipitation), creation of a water rights marketing system, changes in delivery systems or management practices, use of groundwater models, and development of alternative sources of water for human use.

State and local entities should be the primary parties involved in developing this Water Management Plan, with public participation. However, some Federal agencies also contribute to Edwards Aquifer water withdrawal, directly or indirectly. In addition, representatives of Federal agencies can help insure compliance with Federal regulations, and have valuable technical expertise and resources to offer. Under section 7(a)(1) of the ESA, Federal agencies are supposed to use their authorities to further the purposes of the ESA, and involvement in a planning effort of this nature would be an appropriate activity for many Federal agencies.

Consideration should be given, while developing this plan, to potential impacts to other sensitive species and ecosystems, in addition to those covered by this recovery plan. Strategies should be examined for implications to the long-term protection of water quality in the overall Edwards Aquifer. Evaluation of efforts to minimize economic and social effects should examine distant, indirect, and long-term impacts in addition to local, direct, and short-term impacts.

2.11 Working with stakeholders, develop and promote a comprehensive short- and long-term regional plan for aquifer management that considers all users

Activities needed to protect the habitat for listed species are similar to those needed to protect human needs for abundant clean water. Local and regional economies are closely tied to the quality and quantity of water available. This similarity of interests provides an opportunity to create a productive problem-solving coalition to conserve the natural resources needed to ensure a viable future both for the biological communities supporting the species of concern and for the local human community.

Leaders representing diverse users of the Edwards Aquifer should work together with biological and technical experts to develop and actively promote an aquifer-wide management plan. This group should provide the leadership necessary to help all water users understand the need to save water and motivate users to achieve the necessary reductions in use of Edwards Aquifer waters.

The plan should include strategies capable of achieving significant reductions in groundwater use that can be implemented quickly and should address immediate needs, as well as short-term strategies that may take longer to produce significant results but can help reduce dependency on the aquifer within a time-frame and long-term strategies that provide permanent solutions and accommodate future plans for the region.

Using a diversity of techniques will help to meet all of these needs. Immediate strategies might include campaigns to reduce landscape watering and household water use and a carefully staged emergency reduction plan tied to aquifer levels (that is capable of achieving sharp reductions when necessary). Short-term strategies might include retrofitting programs for existing plumbing and water delivery systems, increasing efficiency of irrigation equipment, promotion of xeriscaping, development of wastewater reuse systems, water use audits and design improvements for industrial processes, funding programs for assistance to present users for water efficiency improvements, and development of small-scale catchment systems for buildings. Long-term solutions might include techniques like revisions of water marketing systems, and development of multiple alternative water sources. There are undoubtedly other strategies that can be employed as well, and the examples above should not be considered limiting.

While long-term strategies are being initiated short periods of lower springflows might unavoidably occur. If flow levels drop below take levels an incidental take permit under section 10(a)(1)(B) of the ESA would be needed to permit some level of "take" that does not jeopardize the species. The Aquifer Management Plan should include all provisions necessary to qualify for a 10(a)(1)(B) permit, including providing a comprehensive habitat conservation plan (HCP). Other requirements will include measures to assure the successful implementation of the plan (such as, a mechanism for State and local enforcement of groundwater use restrictions, financial instruments, management agreements, etc.). The court monitor has begun work on preparation of a preliminary issues document (detailed under the General Conservation Measures section). Refinement of this document into a draft HCP, its acceptance by the Service, and granting of an incidental take permit would provide significant relief from uncertainty for the participants. Such a permit could limit liability and legal action that might otherwise occur if take occurs during the implementation of conservation measures.

The Aquifer Management Plan and any regional or locally developed HCP should identify responsible parties and their roles. The plan should be clear about how actions called for will be implemented and when (for example, under what flow and storage conditions, weather patterns, etc.).

Significant progress toward developing and implementing a diverse regional plan has been made, but there is still a need to complete a comprehensive plan for assuring adequate springflows. A team approach is needed to coordinate diverse activities, share information and resources, and plan cooperatively and comprehensively to develop and implement solutions region-wide. The working group can build on experience and accomplishments to date to achieve better cost-effectiveness and more widespread benefits.

Work done to date (outlined in the General Conservation Measures section), such as the Court Monitor's emergency reduction plan and the attorney-devised municipal water emergency reduction plan, provide a model for additional work. Coordination and extension of individual municipalities efforts to create water conservation ordinances, wastewater re-use plans, and to develop alternative sources of water could cost-effectively increase benefits for the entire region.

2.12 Provide Service guidance and support for the regional aquifer management planning effort

The Service should take a more proactive role in support of regional planning efforts.

Because one of the goals/objectives likely to be included in aquifer management is the development of an endangered species permit application, the Service should be involved early on in the process, providing guidance for HCP applicants for this region. This guidance should assist in developing a successful, multiparty, regional application with maximum benefit. Conservation needs for this area include a number of complex technical problems, and more guidance is needed than might be required for most permits. This guidance should include explanations of the logistics of the process, responsibilities of the applicants (including necessary financial commitments), and the types of documentation that are needed. In addition, while it is not the responsibility of the Service to draft the habitat conservation plan supporting the application for a permit, the Service should provide some technical direction and guidance for a regional HCP or other HCPs to assist in the development of an acceptable application package. The Service should provide direction concerning the level of take that might be addressed through such a permit, a reasonable time-period for the permit to cover, the elements that the Service feels would have to be included, conservation opportunities or strategies that might be fruitful, issues that must be addressed, and supporting analyses needed in the plan. In addition applicants should be encouraged to initiate informal discussions with the Service as early as possible in the development process to achieve maximum efficiency and benefits.

The Service, working with affected stakeholders, needs to develop better guidance about reduction in groundwater use that would be sufficient to insure that human use does not cause springflows to fall to levels that would compromise the survival and recovery of the species of concern or cause jeopardy. It is important to develop operational criteria for the short-term. It is also important to continue to collect additional information so that models can be refined and provide more reliable analyses that will allow long-term criteria to be developed.

There has been considerable diversity in opinions on levels of groundwater use that would preserve needed springflows under various conditions. To provide needed technical guidance will require an interagency team of biologists, geologists, hydrologists, economists, and water resource planners. This group should examine baseline information and existing models and build upon other efforts to date (such as emergency water reduction plans) to develop better guidance on aquifer levels needed under varying conditions to support the survival and recovery of the species.

In addition, the Service should continue to give advice on potential direct and indirect impacts of proposed conservation actions on fish and wildlife resources. For example, there may be impacts to cave species if recharge enhancement causes flooding or scouring of these caves or subterranean voids, recharge could cause contamination harmful to subterranean aquatic species, using alternative water sources could influence the maintenance of adequate freshwater inflows to bays and estuaries, and the use of alternative water sources may impact species in the rivers between the springs and the bays (such as Cagle's map turtle). These concerns about other direct and indirect impacts should be addressed.

The Service should provide guidance and support for water management planning efforts to ease the vulnerability of the Edwards aquifer resources, as part of ongoing integrated efforts to assist both State and Federal water planning and management agencies. Water management planning in Texas should require integrated planning for both regional and river basin efforts (including specific interbasin transfer issues as well as more widespread planning efforts such as the Trans-Texas Program). These evaluations help water planners in evaluating feasibility of plans, incorporating conservation actions, and in minimizing social and economic impacts of recovery activities.

2.2 Encourage Federal agencies to undertake or actively promote conservation activities under section 7(a)(1) of the ESA

These conservation activities could take the form of technical assistance or implementation of specific tasks that directly benefit the aquifer or its listed species and their habitats.

All Federal agencies, especially those whose activities affect, directly or indirectly, the quantity or quality of water in the Edwards Aquifer and associated spring ecosystems, should take actions within their authorities to conserve the listed species and the ecosystems upon which the species depend. Section 7(a)(1) of the ESA says all Federal agencies shall use "their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species...".

Other Federal agencies may have statutory authority under laws other than the ESA that give them opportunities to assist in the protection of the listed species and their ecosystems. There are complementary functions in protecting human health and in conserving habitat for listed species, for example. The EPA has authority under the Clean Water Act, Safe Drinking Water Act, FIFRA and CERCLA for actions that can benefit endangered species as well as protect human health. Similarly the Department of Agriculture's mandates for preventing pollution from agricultural practices would benefit endangered species sensitive to such pollutants. Situations where there are authorities granted to an agency under its primary mission that may also benefit endangered species should be considered by these agencies in setting up programs to benefit listed species. By working cooperatively, agencies can ensure minimal harm and maximum potential benefits from their activities in the course of performing their duties under both their enabling legislation and the ESA.

Examples of Federal agencies that could provide technical information or expertise include USFWS, USGS, USDA, the U.S. Army Corps of Engineers, the Bureau of Reclamation, and the National Biological Service. Their assistance could be invaluable in the conservation planning process. Many of these agencies, and others, can also undertake recovery tasks with direct benefits.

An example of a Federal agency taking [illegible] to benefit the conservation of the ecosystems would include the Department of Defense. San

Antonio military bases are currently implementing a wastewater reuse system for landscape watering and an aggressive campaign to reduce water consumption in their facilities. Similarly, the Department of Agriculture might be able to stimulate and promote increasing the use of water efficient irrigation equipment.

Agencies taking beneficial actions need recognition and support. Agencies identified as having the potential to take proactive conservation measures should be contacted and encouraged to do so.

2.3 Develop a Federal agency conservation strategy in the event that task 2.11 is not implemented or is ineffective in ensuring necessary springflows.

A cooperative approach, with a State and local plan developed primarily by the primary aquifer users is preferable to Federal regulatory action. Local users, leaders and agencies may have valuable background and expertise that will be helpful in developing and implementing a balanced, long-term solution that achieves conservation objectives and minimizes social and economic impacts. In addition, for such a plan to be effective, State and local enforcement of groundwater use limits should be in place. Federal agency representatives should continue to work with State and local managers and regulators and support their efforts. However, if an adequate state or local solution is not implemented, Federal agencies must do what they can to assure that springflows are protected.

2.31 Continue to support proactive Federal agency conservation actions.

These are described in task 2.2.

2.32 Continue to support private proactive conservation actions.

The Service and other Federal agencies should continue to encourage and assist individual agencies, organizations, municipalities, etc. in their efforts to reduce groundwater withdrawals. Examples of this might be community efforts to reduce landscape watering and promote xeriscape landscaping, development of wastewater reuse plans, and public education campaigns.

2.33 Aggressively pursue Federal agency compliance with obligations for informal and formal consultations under section 7(a)(2) of the Act

According to section 7 of the ESA, Federal agencies must insure that any action that they authorize, fund, or carry out in the Edwards Aquifer region is not likely to jeopardize the continued existence of any listed species. All Federal agencies have an obligation to comply with section 7(a)(2) requirements of the ESA and should initiate consultation with the Service for all actions that may affect listed species.

The Service should continue to follow up on notifications they have provided to Federal agencies whose actions may directly or indirectly impact the survival of the listed species or adversely affect their critical habitat.

If no adequate and enforceable Aquifer Management Plan is developed by State and local entities (task 2.1), these Federal agencies may ultimately have to withhold permits or funds for actions likely to jeopardize the species. The point at which any permits or funds may have to be withheld or modified would be determined by these Federal agencies during interagency section 7 consultations, with the issuance of a biological opinion pursuant to section 7(b).

2.34 Examine the potential effectiveness of State and Federal legal action, and prepare to initiate such action if an emergency appears imminent

The State created the Edwards Aquifer Authority to regulate and enforce groundwater use of the Edwards Aquifer region. Due to the current State litigation over the EAA, it is not known when the EAA may function. State approved groundwater districts have the authority to regulate and enforce groundwater use limits (including taking appropriate legal action) (Ellis, 1995). The Service should be prepared to support State, regional, or local authorities who may initiate legal action if necessary and obtain injunctions against water users to prevent springflows from falling to levels that would jeopardize the species. Because of the time it would take for the aquifer to respond to cutbacks, these injunctions would have to be in place far enough in advance to guarantee curtailment of groundwater use in time to prevent jeopardy. Consideration should be given to filing injunctions when "take" levels are reached, unless it's determined that this is not soon enough to prevent jeopardy. Current Service estimates should be used for take and jeopardy levels (Table 2).

2.4 Develop and implement local spring and river management plans

Work with specific cities and towns, their local landowners, and/or the local general public to develop plans, including management guidelines. These plans should incorporate both general and site-specific management guidance for restoring, protecting, and maintaining the health of the local ecosystems for the listed species and addressing local threats to the species. Plans should also include the lakes at the headwaters of both the San Marcos and Comal rivers and examine recharge and cave features in the area that may be significant for subterranean species. Maintaining the health of these ecosystems also promotes the health and well-being of the local community since it maintains water quality for human uses as well. Plans should address potential problems like recreational activities and their impacts, point and non-point source pollution, nonnative species, siltation, silt or gravel removal, and vegetation management. Plan objectives should be to avoid impacts whenever possible, or minimize them to an insignificant level. Working cooperatively with land managers, approaches can be developed that minimize social and economic costs for users and managers and preserve sustainable social and economic benefits from the resource. Plans should include guidance wherever possible on how local entities can conduct their desired activities (such as vegetation control, sediment removal, bank stabilization, recreation, etc.) without negatively impacting listed species. In some cases funding assistance may be available for management projects that result in an improvement of habitat for the species of concern.

2.41 Develop and implement Management Plan(s) for the San Marcos system

Develop and implement a plan, as described under 2.4, for the San Marcos Springs and River and Spring Lake. This task may entail developing separate plans for different parts of the system due to multiple landowners. Guidelines developed for the plan might include (but are not limited to) issues that need to be addressed like use of the San Marcos River by recreationists, aquatic plant management, control of nonnative species, bank stabilization, litter control, point source discharges, etc. Guidance should be developed to protect the listed species and their habitat from unintentional harm by the public. Hopefully, public cooperation will aid in conservation of these species and the public will not be inordinately restricted in their use of the aquatic ecosystems.

Examples of areas where developing management guidelines to protect the species would be helpful include aquatic plant management in Spring Lake, where vegetation cutting, control and removal needs to be planned in a way that is compatible with the needs of fountain darters and San Marcos salamanders, as well as Texas wild-rice. Similarly, management techniques might be developed to protect the species and their habitats from impacts from recreationists (e.g., tubers, canoeists, swimmers, and fishermen). Methods to manage impacts to streamside areas and sensitive zones in the river may be developed to protect fountain darters and wild-rice. It may be possible to re-route recreationists to avoid impacts in certain areas/sections of the San Marcos River during critical or sensitive periods in the life history of these species.

A project undertaken by Dr. Glenn Longley (SWTSU) under the Section 6 Program to develop management recommendations should provide some useful information to assist in accomplishing this task. The city of San Marcos and Southwest Texas State University are exploring a partnership to develop a detailed management plan. The Lions Club (owners of a major tube rental operation) and the Service have initiated discussion examining possible recreational impacts by tubers and management options.

2.42 Develop and implement Management Plan(s) for the Comal system.

Develop and implement a plan, similar to that described under 2.41, for the Comal Springs and River and Landa Lake. This may entail developing separate plans for different parts of the system due to multiple landowners. Work on this task was initiated in 1995 through a partnership involving the city of New Braunfels, the Service, the National Fish and Wildlife Foundation, the Guadalupe Blanco River Authority, the Lower Colorado River Authority, New Braunfels Utilities, and the Nature Conservancy to develop a management plan for the public areas of the Comal system.

2.5 Implement measures necessary to protect water quality in the aquifer

Based in part on information obtained in task 1.28, as well as any other available information, measures should be implemented to protect water quality in the aquifer. A preliminary assessment of adequacy of existing regulations to protect the aquifer and a preliminary examination of contamination in the San Antonio area have been done, and both include recommendations for improvement, as discussed in the General Conservation Measures section. This work should be expanded. In addition, river basins outside the San Marcos and Comal contribute recharge waters to the Edwards Aquifer. While these areas are predominantly rural at present, an evaluation should be made to determine if there is a need for site-specific management plans to reduce potential water quality concerns for these systems as well.

2.6 Encourage management of spring, lake, river, and cave habitats by private individuals and others.

Through ownership of adjacent lands, early water rights agreements, and other legal agreements the San Marcos and Comal ecosystems have a mixture of public and private ownership and influence. Many private owners, exercising good stewardship, can help preserve the San Marcos and Comal aquatic ecosystems. If uninformed, however, serious negative impacts could result, often unintentionally. Landowners with recharge features, cave habitats, shoreline properties, etc. should be encouraged to prevent pollution, destruction, or other adverse modifications of these features. A program should be developed to provide information and assistance, and develop a cooperative effort with landowners and others to ensure the integrity of these ecosystems. Efforts should also be made to gain the cooperation of recreational users of the San Marcos and Comal aquatic ecosystems since they have a large influence on the biota of the ecosystems.

2.7 Establish and maintain captive stocks at appropriate facilities

Because of the limited range of the listed species, a catastrophe could be disastrous for each of them. Genetically representative captive stocks of each species (including candidates where feasible) should be kept in at least two facilities. Protocol should be developed for maintaining these stocks in such a way that there would be suitable stock for reintroduction or supplementations if needed. This would entail careful attention to the genetic make-up of the captive stock, control of disease in captivity, etc.

2.8 Reduce pollution loadings to San Marcos and Comal aquatic habitats and caves with Texas blind salamanders

Water quality continues to be a concern in the San Marcos and Comal Rivers due to urbanization in the surrounding areas. Catastrophic single events as well as chronic and persistent pollution incidents are increasingly likely to occur. These must be minimized to increase the chances of long-term survival of the listed species. For example, new means of handling wastewater, stormwater and street runoff (especially from IH-35 bridges in San Marcos), and other pollutant sources may be needed. Railroad crossings pose a threat to water quality from catastrophic and small spills, and current efforts in the city of San Marcos to reroute rail traffic should be supported. In San Marcos, stormwater runoff and occasional spills of sewage from both the wastewater treatment plant and from leaky collection systems currently are discharged into the San Marcos River. As the city has become increasingly urbanized, these problems have increased in frequency and severity. Information gained from tasks 1.22, 1.23, 1.24, 1.25, 1.26, 1.27, and 1.28 should be useful in carrying out this task.

2.9 Restore damaged habitats and enhance marginal habitats

To enhance the species' populations and habitats and to accomplish the goal of maintaining the species throughout their historic range will require some restoration of damaged habitats and improvement of marginal habitats. For example, for Texas wild-rice the area from Spring Lake to Rio Vista dam provides the largest amount of potential habitat, though significant potential habitat exists below the dam as well and there is even a small amount (about 100 m^2 or 1076.5 ft^2) of potential habitat at present below the San Marcos wastewater treatment plant. For the San Marcos gambusia restoration of the shaded but open substrate habitat of the San Marcos River downstream from the IH-35 crossing of the river should be attempted. For the fountain darter, among other areas, the potential for restoration and enhancement of habitat downstream of the San Marcos wastewater treatment plant should be evaluated.

2.10 Control and/or remove select nonnative organisms from the San Marcos and Comal aquatic ecosystems

Nonnative organisms, with their actual and potential effects on the listed species, are not a natural influence on the listed species or their ecosystem(s). A program of selective removal and/or other control mechanisms, based on information gained in 1.29 and any other available information, should be initiated to insure that impacts to the listed species from these nonnatives are removed or reduced to an insignificant level. Efforts to reduce the likelihood of further plant or animal introductions should also be made.

Low flow conditions may provide an opportunity for control of some nnonnativespecies more easily or effectively, especially if non-destructive techniques can be developed. At low flows nonnative species may be more exposed and concentrated and easier to eliminate, and some nonnative species are believed to have their greatest detrimental impacts during low flows. However, this is also the time that any remaining individuals of listed speci will be most stressed and vulnerable. A full evaluation of potential adverse impacts to the physical and biological constituents of the system would need to be done before proceeding with control of nonnatives during low flow conditions. This is needed to ensure that listed species are not harmed and that system recovery is not impaired, delayed, or precluded.

2.11 Maintain and implement a contingency plan to bring species into captive refugia if an emergency exists

A contingency plan was developed for removing additional individuals of listed species for maintenance and captive propagation. The contingency plan is currently being revised, and will include all of the listed species as well as some other unique or rare species of concern. The goal of the plan is to provide secure, genetically representative material of wild populations. T revised plan includes some proactive measures subterranean species where action must be initiated before flows fall. This plan should be considered a last-ditch effort, to prevent extinction of the species and provide material for restoration efforts. At present, for some species our ability to cessfully restore populations to the system n captive material is limited because reliable captive breeding and reintroduction techniques are not yet worked out. The contingency plan and captive propagation cannot provide for the recovery of the species as directed under the ESA. While captive propagation may provide for survival of species in the short-term, it does not meet the full purpose of the ESA, which is to protect the ecosystem upon which these species depend. This plan should be updated as needed and incorporate the latest information on genetics, disease control, and other factors related to captive propagation for reintroduction purposes. The plan should clearly identify who will do what, when, and how.

2.12 Provide regulatory protection

The protective provisions in the Endangered Species Act and regulations should be enforced, as well as any other regulatory protec- provisions, including State and local ones. Provisions in the ESA include "take" prohibitions, among others. Enforcement of these provisions involves such things as section 7 consultations with Federal agencies; and review of section 10 permit applications, performance, and compliance; and Fish and Wildlife Service law enforcement.

According to section 7 of the ESA, Federal agencies must insure that any action they authorize, fund, or carry out in the Edwards Aquifer region is not likely to jeopardize the continued existence of any listed species. Thus, to ensure their actions do not cause jeopardy these Federal agencies may ultimately have to decide whether to withhold permits or funds for actions likely to jeopardize the species, if no adequate and enforceable Aquifer Management Plan is developed (see task 2.33). If an effective Aquifer Management Plan is implemented, this could enable continuation of Federal activities hout jeopardizing the continued existence of the species. The point at which any permits or funds may have to be withheld, or other actions need to be taken, will be determined by these Federal agencies during interagency section 7 consultations.

Regulatory agencies and law enforcement divisions should be provided with current information concerning the identification and ecological requirements of each of the species so that negative impacts to these species from individuals or projects can be identified and abated.

3.0 Monitor populations, habitats, and threats

To assess trends in population dynamics of the five listed species and to assess the effectiveness of recovery actions, each of the five species and their habitats should be monitored and their distribution and populations censused on a regular basis. None of these species is expected to be delisted in the foreseeable future. Therefore, to protect the species from an irreversible decline, monitoring efforts for threats and the species' habitats, should also be undertaken.

3.1 Monitor populations and habitats

Because each species is unique with its own particular set of population parameters, the specific protocol involving each species should be unique to the particular population in question. Populations of the San Marcos gambusia need to be located before they can be monitored (see Task 1.16). Texas wild-rice, San Marcos salamander, Texas blind salamander, and fountain darter (both in San Marcos and Comal) should be monitored at least annually. More specific information on sampling procedures is contained in Part II.A. in the discussions on recovery criteria. As recovery actions proceed and more data are acquired, these recommended schedules may be modified. In monitoring each species, appropriate methods should be used to minimize interference. This is especially important with regard to the San Marcos gambusia, as this species is critically in danger of extinction, if it still exists.

3.2 Monitor threats

This task should include such things as monitoring aquifer levels and springflows, water quality, and condition of the species' habitat (such as vegetation and substrate), as necessary to detect threats before they result in significant and/or potentially irreversible impacts to the species. Other threats also need to be monitored, and may include such things as nutria giant ramshorn snail, and tilapia populations, levels of recreational use in certain areas, amount and areas of runoff impacts, and siltation. Monitoring of the populations and habitats conducted as part of task 3.1 may also serve as an alert to threats affecting the species and their ecosystems.

4.0 Public information and education

It is imperative that the public become aware of and sensitive to the need to protect these unique and fragile aquatic systems, and the problems associated with ensuring the survival of the Edwards Aquifer and the San Marcos and Comal aquatic ecosystems and their unique flora and fauna. Means should be developed to inform the public and to gather public support for protecting these endangered and threatened species and their ecosystems. Materials produced for this objective should be directed toward increasing the public's general awareness of the listed species and their plight, actions that would result in their conservation, and the human benefits and costs of protecting or not protecting the ecosystems upon which these species depend. The social and economic benefits of good stewardship should be illustrated. Attention should be given to the big picture and showing the interrelatedness of the spring systems to everything from the contributing zone of the Edwards Aquifer, to the quality of local drinking water, to the continued support of economies dependent on these river systems, and to the bays and estuaries downstream.

4.1 Produce educational materials and inform a variety of audiences

A variety of approaches should be used, (including multi-media) so that all segments and age groups of the public are aware of and informed of the message discussed under 4.0. Audiences targeted should include policy makers, as well as school children. Information should be included on what's needed for species conservation, including major actions like groundwater pumping limits, as well as those things individuals can do themselves (like conserving water and not releasing nonnative species into the systems). Economic and social consequences of failing to protect the aquifer and its species should be included. Projects to achieve this might include factual briefing materials for public policy makers and regulators, information packets for teachers, information kiosks for recreationists, brochures, museum and aquarium displays and interpretive materials about the species and their vulnerability, etc. Live displays of the species are very effective and should be allowed if it is determined that they will be providing information to a significant audience, and will be properly cared for. Live display material should come from propagated stocks wherever possible, but collection from the wild might be permissible if collection of a few individuals will not do unacceptable harm to the species in the wild.

4.2 Encourage public participation in conservation efforts

For conservation of the listed species to occur, the public must be involved in recovery activities. Support programs for environmentally sensitive activities associated with the Edwards Aquifer and the San Marcos and Comal aquatic ecosystems need to be developed and/or continued. These could be of the form of "Aquifer/River Awareness" events specifically designed to enhance the public's awareness and empathy toward the conservation needs of the species and their ecosystems. A citizens' committee could be established to coordinate local efforts, provide input and direct citizen attempts in fostering awareness for the uniqueness of these aquatic ecosystems. In addition, the public may also be invited to participate on Implementation Planning Teams to identify specific ways to accomplish certain significant recovery tasks, while minimizing economic and social costs. The plans called fo task 2.4 may also be good vehicles for participa tion of local landowners and other interested parties.

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PART III

RECOVERY PLAN IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs for implementing this recovery plan. It is a guide for meeting the objectives discussed in Part II of this plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when complete, should accomplish the objectives of this plan. The Service has identified agencies and other potential "responsible parties" to help implement the recovery of these species. This plan does not commit any "responsible party" to actually carry out a particular recovery task or expend the estimated funds. Likewise, this schedule does not preclude or limit other agencies or parties from participating in the recovery program.

The total estimated cost of recovery, according to each priority, is provided in the Executive Summary, not in the implementation schedule. In the implementation schedule (Part III) the estimated monetary needs for all parties involved in recovery are identified for the first 3 years only. Estimated funds for agencies include only project specific contract, staff, or operations costs in excess of base budgets. They do not include budgeted amounts that support ongoing ordinary responsibilities.

In this recovery plan, several tasks outlined are driven by multiple social and economic needs in addition to endangered species recovery. For example, developing alternative water supplies to meet the projected future needs of cities and towns over the Edwards Aquifer area is a task that must be implemented to provide for future community security and growth as well as endangered species recovery. Protection of water quality in the aquifer and in the Comal and San Marcos ecosystems is necessary to protect human as well as endangered species interests. Implementation costs of some tasks or task elements may actually be largely offset (or even cost-saving) for the entities implementing them. For example, water conservation programs have expenses associated with them, but the reduction in demand for additional water may also save money by reducing the costs of developing new water supplies, water treatment capacity and operations for municipal use, and wastewater treatment capacity and operations that would be incurred in the absence of a conservation program. Apportionment of costs between City planning and development functions and ESA compliance is extremely difficult. For tasks of this nature the Service has included in its cost estimate only the portion of costs allocatable to endangered species recovery, not the entire cost of the task.

Cost for some tasks in the recovery plan are not yet determinable, because they depend on the nature of the strategies selected for use in the regional Aquifer Management Plan or local management plans that are not yet developed. These tasks where expenses cannot yet be calculated are represented in the costs column with the designation NYD for "not yet determinable".

The terms "ongoing" and "continuous" appear in the implementation schedule. The term "continuous" is used to denote tasks that are expected to require constant attention throughout the recovery process, and therefore have an indefinite duration. The term "ongoing" is used in the recovery plan to identify tasks that have already been started, but are not yet complete.

Priorities in column one of the following implementation schedule are assigned using the following guidelines:

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the *foreseeable* future.

Priority 1• - An action that by itself will not prevent extinction, but which is needed to carry out a priority 1 task.

Priority 2 - An action necessary to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to meet the recovery objectives.

The following abbreviations used in the Implementation Schedule:

ADC - Animal Damage Control (USDA)
BR - U.S. Bureau of Reclamation
EAA - Edwards Aquifer Authority
EPA - U.S. Environmental Protection Agency
EUWD - Edwards Underground Water District
FWS - U.S. Fish and Wildlife Service
ES - Ecological Services
LE - Law Enforcement
PAO - Public Affairs Office
WM - Water Management
GBRA - Guadalupe-Blanco River Authority
GWD - Ground Water Districts
LCRA - Lower Colorado River Authority
NB - City of New Braunfels (including New Braunfels Utilities, in some cases)
NFWF - National Fish and Wildlife Foundation
NGO - Nongovernmental Organizations
SA - City of San Antonio
SMNFH&TC - San Marcos National Fish Hatchery & Technology Center
NRCS - Natural Resource Conservation Service
SM - City of San Marcos
SMRF - San Marcos River Foundation
SWTSU - Southwest Texas State University
TDA - Texas Department of Agriculture
TNC - Texas Nature Conservancy
TNRCC - Texas Natural Resource Conservation Commission
TPWD - Texas Parks and Wildlife Department
TSL - Texas State Legislature
USGS - U.S. Geological Survey

•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1	2.11	Assemble a working group to develop and promote a comprehensive short and long-term regional plan for aquifer management that considers all users	ongoing	ES	20.0	20.0	20.0	Total costs depend on number of cooperators, strategies selected, and timeframe for implementation.
				TNRCC				
				TPWD	5.0	5.0	5.0	
				SA, SM, NB, BR, USGS,EUWD, GBRA, GWD, UVALDE AND MEDINA COUNTIES, TSL,OTHERS	NYD in part	NYD in part	NYD in part	
1	2.34	Examine the potential effectiveness of legal actions such as requesting injunctions and prepare to initiate such action if a crisis appears imminent	as needed	EAA				Initiated only in absence of adequate state or local action to curtail groundwater use.
				GWD				
				SA				
				NB				
				SM				
				EUWD				
				ES	20.0	20.0	20.0	
				LE	10.0	10.0	10.0	
1	2.41	Develop and implement management plan(s) for the San Marcos system	ongoing	ES	20.0	20.0		
				SWTSU	5.0	5.0		
				TPWD	8.0	8.0		
				SM	10.0	10.0		
				SMRF				
				OTHER				
				LANDOWNERS	7.0	7.0		

•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
2	2.12	Provide regulatory protection	ongoing	EAA				Includes consultation work, enforcement activities, etc. Most are programatic after guidance development.
				ES	5.0	5.0	5.0	
				LE	2.5	2.5	2.5	
				TPWD	1.0	1.0	1.0	
				TNRCC	30.0	30.0		
				SM	2.0	2.0	2.0	
				NB	2.0	2.0	2.0	
2	4.2	Encourage public participation in conservation efforts	ongoing	ES	2.0	1.0	0.5	Uses support from task 4.1.
				EUWD	5.0	5.0	5.0	
				SWTSU	1.0	1.0	1.0	
				SM	1.0	1.0	1.0	
				NB	1.0	1.0	1.0	
				TPWD				
3	1.12	Identify diseases and parasites	3	ES	1.875	1.875	1.875	
				SMNFH&TC *	2.500	2.500	2.500	
				SWTSU				
				TPWD	.625	.625	.625	
				OTHERS				
3	2.9	Restore damaged habitats and enhance marginal habitats	ongoing	ES				Dependent on priority projects currently unidentified or scheduled.
				TPWD				
				SM				
				NB				
				OTHER NGO's				

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•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1	2.42	Develop and implement management plan(s) for the Comal River system	ongoing	NB	10.0	10.0		Landowners include Comal Co. Rec. District No. 1, Schlitterbahn, and others.
				GBRA	5.0	5.0		
				TNC	0.5	0.5	NYD	
				OTHER		20.0		
				LANDOWNERS	NYD			
				LCRA	4.5	4.5		
				NFWF	20.0			
				ES				
1	2.5	Implement measures necessary to protect water quality in the aquifer	contin-uous	ES	NYD	NYD	NYD	Dependent on conclusions of task 1.28.
				EPA				
				EUWD				
				TNRCC				
1	2.7	Establish and maintain captive stocks	ongoing	ES	12.5	5.0	5.0	Dependent on results of task 1.4 in part.
				Dallas Aquarium				
				SMNFH&TC *	NYD	NYD	NYD	
				SWTSU	12.5	10.0	10.0	
				TPWD-A.E.	8.0	2.0	2.0	
				Wood	5.0	3.0	3.0	
				OTHERS				
					NYD	NYD	NYD	
1	2.8	Reduce pollution loadings to San Marcos and Comal aquatic habitats and caves with Texas blind salamanders	contin-uous	ES	NYD	NYD	NYD	Costs dependent on conclusions of tasks 1.22, 1.23, 1.24, 1.25, 1.26, 1.27, & 1.28
				EPA				
				TNRCC				
				SM, NB				
				LANDOWNERS				

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PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1	2.11	Maintain and implement a contingency plan to bring species into captive refugia if an emergency exists	ongoing	ES	25.0	25.0	30.0	Year 3 reflects costs for an unpredict-able low flow period when task is implemented.
				SMNFH&TC *	15.5	15.5	40.0	
				SWTSU	23.0	23.0	10.0	
				TPWD	10.0	10.0	30.0	
				Dallas Aquarium				
				Uvalde NFH				
				Cincinnati Zoo	NYD	NYD	NYD	
1●	1.15	Identify habitat characteristics and requirements	ongoing	ES	70.0	150.0	150.0	Supports priority one sub-task 2.11 in part.
				TPWD	30.0	30.0	30.0	
1●	1.16	Conduct searches to locate San Marcos gambusia	3	ES	8.0	8.0	8.0	Supports priority one task 2.7.
				TPWD	2.0	2.0	2.0	
				SWTSU	1.0	1.0	1.0	
1●	1.21	Determine impacts from tourism enterprises and recreational use of springs and rivers etc.	3	ES	25.0	10.0	10.0	Supports priority one task 2.41
				SM	5.0	5.0	5.0	
				TPWD	3.0	3.0	3.0	
				SMRF				
				Lions Club				

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PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1●	1.25	Identify and determine effects of pollutants from point source discharges and other discharges on listed species and their habitats	5	ES	30.0	50.0	50.0	Supports priority one task 2.8. -some costs covered in EPA permits -includes stormwater, utility, and commercial discharge
				EPA				
				NB		10.0	10.0	
				SM		20.0	20.0	
				TNRCC				
				TPWD				
1●	1.26	Assess water quality in the San Marcos aquatic ecosystem and determine possible sources of negative impacts	2	ES		15.0		Supports priority one task 2.8. -contributes to management plan (2.41) -USGS has supported one year of study.
				EPA				
				EUWD	NYD	NYD		
				TPWD	5.0	5.0		
				TNRCC				
				USGS	24.0	5.0		
1●	1.27	Assess water quality in the Comal aquatic ecosystem and determine possible sources of negative impacts	2	ES		15.0		Supports priority one task 2.8. -USGS has supported one year of study -contributes to management plan (2.42).
				EPA	NYD	NYD		
				EUWD				
				TPWD		5.0		
				TNRCC				
				USGS	24.0	5.0		

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•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1●	1.28	Assess adequacy of existing aquifer water quality protection provisions	2	ES	1.0	1.0		Supports priority one task 2.5. -contributes to mgt. plan (sub-task 2.11).
				WM	5.0	5.0		
				EPA				
				EUWD	NYD	NYD		
				TPWD	5.0	5.0		
				TNRCC				
				OTHERS				
1●	1.4	Develop captive breeding and reintroduction techniques for all species	5	ES	58.0	58.0	58.0	Supports priority one task 2.7. -costs will decline if trials yield success earlier.
				SMNFH&TC *	25.0	25.0		
				SWTSU	5.0	5.0	5.0	
				TPWD	17.0	12.0	12.0	
				Dallas Aquarium	NYD			
1●	2.12 (sub-task)	Provide Service guidance and support for the regional aquifer management planning effort	ongoing	ES	6.25	6.25	6.25	Supports priority one sub-task 2.11.
1●	2.31	Continue to support proactive Federal agency conservation actions	ongoing	ES	.50	.50	.50	Supports priority one sub-task 2.11. From base costs in part.
				Other Fed. Agencies	NYD	NYD	NYD	

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•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1●	2.32	Continue to support private proactive conservation actions	ongoing	ES Other Fed. Agencies	5.0 NYD	5.0 NYD	5.0 NYD	Supports priority one task 2.11 -e.g. programs Partners for Wildlife.
1●	2.33	Aggressively pursue Federal agency compliance with obliga- tions for informal and formal consultations etc.	Ongoing	ES	.50	.50	.50	Supports priority one sub-task 2.11 from base costs in part.
1●	3.1	Monitor populations and habitats	ongoing	ES SMNFH&TC * TPWD	10.0 3.0 6.0	10.0 3.0 6.0	10.0 3.0 6.0	Supports priority one tasks 2.41, 2.42, 2.5, 2.8, and 2.11 in part.
1●	3.2	Monitor threats	ongoing	ES EPA EUWD EAA NB SMNFH&TC * SM TNRCC TPWD USGS OTHER NGO'S	15.0 5.0 17.0 5.0 5.0 25.0 15.0 20.0 15.0	5.0 5.0 5.0 5.0 10.0 5.0 4.0 5.0	5.0 5.0 5.0 5.0 10.0 5.0 4.0 5.0	Supports same priority one tasks noted for task 3.1 above. Part of basic mission for many agencies.

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•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
1●	4.1	Produce educational materials and inform a variety of audiences	3	ES	4.5	4.5	4.5	Supports priority one tasks 2.11, and subtasks 2.11, 2.41, and 2.42.
				EUD	4.0	4.0	4.0	
				EAA				
				TPWD	1.5	1.5	1.5	
				SM				
				NB				
				SA				
				OTHERS				
2	1.11	Determine food habits	3	ES	7.5	7.5	7.5	
				SMNFH&TC *	2.5	2.5	2.5	
				OTHERS				
2	1.13	Determine reproductive parameters	3	ES	7.5	7.5	7.5	Supports priority one task 2.7.
				SMFH&TC *	5.0	5.0	5.0	
				SWTSU				
				TPWD	2.5	2.5	2.5	
2	1.14	Determine survivorship patterns	3	ES	7.5	7.5	7.5	
				SWTSU				
				TPWD	2.5	2.5	2.5	
				OTHERS				

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•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
2	1.22	Compile information on the characteristics of the San Marcos watershed	2	ES	2.0	2.0		TPWD has compiled a great deal of useful information already.
				EPA				
				SCS				
				SM	1.0	1.0		
				TPWD	1.0	1.0		
				USGS	1.0	1.0		
2	1.23	Compile information on the characteristics of the Comal watershed	2	ES	2.0	2.0		
				EPA				
				NB	1.0	1.0		
				SCS				
				TPWD	1.0	1.0		
				USGS	1.0	1.0		
2	1.24	Compile data pertaining to pesticide and herbicide use in the San Marcos and Comal watersheds, etc.	2	ES	2.0	2.0		USGS is examining pesticides in water samples.
				EPA				
				SCS				
				TDA				
				TNRCC				
				TPWD	1.0	1.0		
				USGS				
2	1.29	Determine negative impacts by non-native species and develop control mechanisms	5	ES	70	70	70	
				TPWD	20	20	20	
				SMNFH&TC *	30	30	30	
				SWTSU				
				OTHERS				

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•SAN MARCOS/COMAL RECOVERY PLAN IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (years)	RESPONSIBLE PARTY	COST ESTIMATES ($ 000)			COMMENTS
					YR1	YR2	YR3	
2	1.3	Determine aquifer characteristics and recharge patterns and zones, etc.	3	WM EUWD TNRCC USGS	5.0	5.0	5.0	Contributes to management plan sub-task 2.11. - this task may involve other responsible parties.
2	2.2	Encourage Federal agencies to undertake or actively promote conservation activities under Section 7(a)(1) of the ESA	continu-ous	ES	0.50	0.50	0.50	funded by base budget in part.
2	2.6	Encourage management of spring, lake, river, and cave habitats by private individuals and others	ongoing	ES TPWD SM NB TNRCC LCRA SMRF OTHER NGO's	5.0 1.0 1.0 1.0 0.5	5.0 1.0 1.0 1.0 0.5	0.5	Costs reflect initial development costs. Activities would then be incorporated in basic program services.
2	2.10	Control and/or remove select non-native organisms, etc.	ongoing	ES ADC SM NB TPWD				Dependent on results of task 1.29.

l Technical Center has been identified for possible closure because of budget reductions.

APPENDIX
SUMMARY OF COMMENTS RECEIVED

FISH:

Dr. Tom Brandt
Dr. Clark Hubbs
Dr. Randy Moss
Dr. Bill Seawell

SALAMANDERS:

Casey Berkhouse
Joe Fries
Dr. Ed Maruska
Janet Nelson
Dr. Andy Price
David Schleser

INVERTEBRATES:

Dr. David Bowles
Dr. Cheryl Barr
Dr. Tom Arsuffi

TEXAS WILD-RICE:

Paula Power

HYDROLOGY:

Steve Cullinan
George Ozuna
Dr. George Veni

Comments were received from the individuals and agencies listed below:

City of New Braunfels, David Whatley
City of San Antonio and San Antonio Water System Board, Joe Aceves
Dr. Bob Edwards, San Marcos/Comal Recovery Team Leader, Department of Biology, UT Pan American, Edinburg Texas
Environmental Defense Fund, Peter Emerson
Dr. Clark Hubbs, Department of Zoology, the University of Texas at Austin
Kirk Patterson, San Antonio
Sierra Club and Clark Hubbs, attorney P.M Schenkkan
Society for Conservation Biology, University of Texas, Austin Student Chapter, L. Ramakrishnan
Texas Parks and Wildlife Department, Ms. Janet Nelson
Texas Parks and Wildlife Department, Ms. Jackie Poole
Texas Parks and Wildlife Department, Dr. Andy Price
U.S. Environmental Protection Agency, Anthony F. Maciorowski
George Veni, George Veni and Associates

All comments were considered when revising the draft plan. The Service appreciates the time that each of the commenters took to review the draft and to submit their comments.

The comments discussed below represent a composite of those received prior to the close of the public comment period. Comments of a similar nature are grouped together. Substantive comments regarding the approach, methodology, or financial need called for in the draft plan, or suggesting changes to the plan are addressed here. Comments received relating to the original listing decision or about the Endangered Species Act (ESA) in general that did not relate to the recovery of the species specifically covered in this recovery plan are not discussed here. Comments regarding simple editorial suggestions such as better wording or spelling and punctuation changes, were incorporated as appropriate without discussion here.

Comments received are retained as a part of the Administrative Record of recovery plan development in the Ecological Services Field Office, Austin, Texas.

Hatchery and Technical Center has been identified for possible closure because of budget reductions.

TECHNICAL ISSUES

Background Geography, Geology, and Hydrology

Comment: The proper technical name for the portion of the Edwards Aquifer discussed in the recovery plan is: San Antonio Segment of the Edwards (Balcones Fault Zone) Aquifer. In the first use in the document this exact name should be given, and noted that all subsequent references will use the abbreviated "Edwards Aquifer."

Service Response: To avoid confusion concerning the geological and hydrological area covered by the Recovery Plan, this suggestion has been incorporated in the plan.

Comment: A better map is needed for Figure 1 and Figure 3.

Service Response: The figures have been improved.

Comment: It would be helpful if the distribution of the species were displayed on maps.

and

Comment: The discussion of fountain darters should be expanded to identify the specific locations and preferred habitats in the Comal Springs ecosystem. The plan should state that the highest density is in the natural channel below the discharge from Landa Lake, and the flow regime there.

Service Response: This information is available in the Plan text and in cited references. Traditional dot-style distribution maps showing only sites where collections have been made and could be misleading if they led readers to discount the possibility of the occurrence of the species in other areas as well.

In a similar vein, detailed discussions of present localities of high densities of individuals may misrepresent natural fluctuations in the system, the importance of individuals that occur in other areas, or the importance of areas with potential habitat (or restorable habitat) for the future recovery of the species. In the case of the fountain darters, recent Service surveys have yielded data showing the occurrence of fountain darters throughout the Comal system down to the confluence with the Guadalupe River, with high densities in several areas. Service surveys in the San Marcos have shown fountain darters to be present from Spring Lake down to an area between the city wastewater treatment plant outfall and the confluence with the Blanco River. This recent information has also been added to the plan.

For recovery planning purposes consideration is given to historical accounts, past scientific records, current distributions as evaluated from recent sampling efforts, and potential (but uninhabited) habitat that is important for the recovery of the species. The general area of greatest importance for recovery of Texas wild-rice, and the San Marcos salamander is included in their critical habitat designations, which are described in detail under each species. For the fountain darter the habitat areas in both the San Marcos and Comal systems are very important. For the Texas blind salamander only limited information is available, and for the San Marcos gambusia there has been difficulty finding any remaining individuals, so the area needed for recovery for these species is unclear.

Comment: I disagree with the statement that the San Marcos River flows mostly over a firm gravel bottom. I would characterize it as a mud/silt bottom.

Service response: Crowe (1994) mapped the substrates of the Comal and San Marcos rivers and shows the majority of the substrate as gravel or gravel/sand composition (her Figure 38). However, the Service did not mean to imply that the substrate is not variable. As noted by Crowe, substrate is highly correlated with flow velocity, and where velocities are low, mud accumulates. The substrate can also be varied near the banks from bank erosion or reduction in flow velocities, or near stormwater drainage areas by siltation from runoff. Because of these factors and in the interest of clarity and understanding the text in this section has been expanded. The Service, Texas Parks and Wildlife Department, and other agencies are also currently studying river habitat, including substrates, and eventually more detailed information about substrate in the Comal and San Marcos rivers will become available.

Comment: It might be useful to summarize the information on the San Marcos and Comal systems (such as flow regime, discharge, runoff, listed species, candidate species, introduced species, algal cover, etc.) in tables or graphs so that the reader can more readily discern what environmental and biological features are common to both, and which set them apart.

Service Response: Recovery Plan guidance stresses that background material should be brief and concentrate on laying out the pertinent issues and tasks necessary to address them in a way that presents basic technical information needed but is also accessible to non-technical readers such as landowners, public officials, and local land managers. Hydrological information for the Edward Aquifer and the San Marcos and Comal Springs and rivers (such as time-series discharges, flow regimes, runoff data, etc.) is too voluminous to include in the plan in graphical or table form. This information is readily available in several of the cited references.

Comparative species lists may be helpful in demonstrating differences and similarities in the systems, and a table of listed and candidate species and major introduced species has been included in the plan, along with some summary statistics on springflows.

Comment: The draft text on page 8 gives discharge data only from 1973-1975. What is the significance of this time period? It seems it would be more helpful to include the maximum, minimum,and mean discharges for the entire period of record.

Service Response: The Service agrees and the text in this section has been revised.

Comment: You should note in the plan that the flows at San Marcos Springs have been below 200 cfs 25 times since 1957 with durations as long as 294 days. San Marcos Springs flows have been below 100 cfs 42 times since 1917, including one period of 454 days.

Service Response: The Service has reviewed data regarding flows in the river systems for the period of record (particularly periods of low flows). We know that there have been periods of low flow, some of relatively long duration, and this is noted in the plan. However, the number of times that flows have been below a particular point is not particularly useful in terms of interpreting biological impacts. Historical records (especially for the San Marcos) are somewhat incomplete, and the reported flows are corrected river discharges and not actual springflows. Biological interpretation is difficult because there is almost no information available about habitat conditions in the river (e.g., dry and wet spots) at the time, population information for the species of concern, and human activities such as diversions, discharges, number and distribution of wells, and pumping levels.

More important in terms of the survival and recovery of the species is the actual springflows needed today to maintain necessary habitats, which the Service has estimated and is working to refine. These needs can then be evaluated in terms of current sizeable and increasing aquifer withdrawals, increasing frequencies and duration of low flows, and the potential for the permanent loss of flow from the springs.

Comment: Many people are used to thinking in terms of the J-17 well reference for aquifer levels (a well located in Bexar County, near San Antonio). Table 1 should include an estimate of the J-17 levels that correspond to "take" and "jeopardy" numbers.

Service Response: While the Service acknowledges that many use the J-17 well as an index of aquifer levels, the Service does not believe that this should be the preferred or standard index for monitoring aquifer levels in terms of maintaining necessary springflows for the species of concern. The Service's take and jeopardy levels were evaluated in terms of springflows needed to maintain the species in their natural environment. While the correlation between J-17 and flows at Comal Springs is good, a good correlation between well J-17 and the San Marcos springflows has not been established. Further, local pumping centers (e.g., San Marcos municipal water wells) could affect springflows in a manner that would not be reflected in well J-17 levels. Similarly, local recharge events in Hays County may affect springflows, yet not significantly alter aquifer levels in Bexar County.

A more direct and accurate method of monitoring Comal and San Marcos springflows is desirable. Working cooperatively the USGS and the Edwards Underground Water District have established a stream gage just below Spring Lake that would measure San Marcos springflow plus runoff from Sessom and Sink creeks. Dry Comal and Blieders creeks in New Braunfels are also being gaged. These gages will give a much better understanding of springflows and flood events. Local wells in Comal and Hays counties that have been used in the past to monitor local aquifer levels and estimate springflows provide valuable information and should continue to be monitored as well.

Citations have been added to the text to assist those who wish to examine correlations between springflows and J-17 well levels.

Comment: Some references calculate that only 50-57% of the water recharging the Edwards Aquifer comes from the Nueces River basin, not 78%.

Service Response: The Service is aware that references vary in their calculations of the amount of recharge contributed by the basins west of Bexar County, and the accuracy of these estimates is unknown. To more clearly reflect the lower end of these estimates, we have changed the language to read "investigators have estimated that 50-78%" rather than "up to 78%."

Comment: The discussion of San Marcos Springs does not include their local recharge area. This should be included, as it is relevant to water quality protection discussed later in the recovery plan.

Service Response: This information has been added to the discussion.

Comment: The plan should state that the Edwards Aquifer is an underground river, factually and legally. It flows at rates several thousand times those of most aquifers, through caverns large enough that they have supported the evolution of unique fish, salamanders, and invertebrates.

Service Response: Because of the characteristics of the Edwards Aquifer (which include relatively rapid flow through underground caverns), there has been debate among hydrologists regarding whether it should be termed an aquifer or an underground river. This difference in terminology could have ramifications in terms of water-rights law in Texas, the right of the State to regulate the water, and which state agency would have regulatory authority. Recognizing the tremendous movement of water through the aquifer and its significance as a natural resource, the Texas Water Commission declared the Edwards Aquifer an underground river (TWC Rules, 17 Tex. Reg. 6601-6620) on September 25, 1992. In May of 1993, however, a Senate Bill (S.B. 1477) passed in the State legislature declaring that the Edwards Aquifer is a distinctive natural resource in the state, a unique aquifer, and not an underground stream. Information about the declaration of the Edwards Aquifer as an underground river, and the State Legislature's subsequent declaration, has been added to the text.

Water Quality

Comment: Hydrologist George Rice recently reviewed USGS and State data and found 54 wells in Bexar County have reported mercury and chlorinated solvents. Few had levels above that permitted in drinking water standards, however, 20 years ago there were virtually no reports of these contaminants. This suggests a steady degradation of the aquifer water supply, and if it continues contamination greater than drinking water standards will be common within 20 years.

Service Response: Rice's report examined contaminants in wells sampled from 1982 to 1992, and this information has been added to the plan. It should be noted that no early measurements are available for comparison, though the correlation between elevated contaminants and expanding urbanization (increasing potential sources of pollution) is suggestive of recent contamination. Rice also made no specific projections for the next 20 years.

Comment: In water quality discussions, motor vehicle accidents should be added as a potential major source of pollution to the spring system.

Service Response: The draft had noted the potential for tractor-trailer accidents to cause significant contamination; the more general impacts from motor vehicle and railroad accidents have been added to the plan.

Comment: The plan should specifically state that declining water levels in the Edwards due to excessive pumping not only threaten Comal and San Marcos springflows and dependent species, but also threaten to poison the Edwards as a human drinking water supply. The plan should provide a detailed description of the risk that the bad-water line will move if excessive pumping lowers aquifer levels below a critical point, including discussions and findings from the court proceeding in Judge Bunton's court together with any recent final published work that sheds additional light on the matter. The plan must note that Judge Bunton has found that even if the needs of the species were disregarded entirely this human water quality concern requires that pumping be limited to that necessary to maintain flows at the Comal at all times.

and

Comment: The draft discusses the possibility that the bad water line could move without any data to substantiate this. USGS review of wells at Comal and San Marcos Springs during the droughts of 1989 and 1990 found no evidence of change in water chemistry due to decreased springflow and lowered water levels at that time.

Service Response: The draft plan discusses the possibility that the bad water line could move in the threats section under water quality. The discussion covers what is known about this threat at present and directs the interested reader to additional information. Additional information has been included about the risk of movement of the bad-water line, and a discussion of the USGS data from 1989 and 1990 has been added. Information available at present is not definitive. As more information becomes available the Service will carefully evaluate it and ensure that new data are taken into account in implementing specific tasks under the plan.

In addition to concerns about the bad water line, the plan also discusses the concern that if aquifer levels fall, deterioration of water quality may occur due to the decreased dilution potential for any contaminants in the system. We have modified the text to emphasize how serious a potential change in water chemistry could be to the species, and the close link between preservation of the environments of endangered species and the health of the human environment.

Comment: Task 1.24 compiling information on pesticide and herbicide use in the Comal and San Marcos watersheds should also include data collection on use of these chemicals in surface watersheds that drain into the caves known to contain Texas blind salamanders.

Service Response: Language has been added to this task to clarify the need to collect this information as well.

Comment: Task 1.3 discusses determining aquifer characteristics and recharge patterns and zones that influence springflows. You also need to monitor the general water quality trends in the aquifer for potential impacts on spring quality.

Service Response: This is covered under task 1.28 (which calls for assessing water quality in the aquifer and providing for protection against both catastrophic and chronic water quality problems), under task 2.5 (which calls for implementing measures deemed necessary to protect the quality of water in the aquifer), and under task 3.2 (which calls for monitoring water quality).

Fish

Comment: In the fountain darter background section, under "Habitat," you need to add constant temperature to the list of requirements. You discuss it as critically important in passages before and after this one and it should be listed as a requirement.

Service Response: We agree temperatures should be addressed as a habitat requirement. Research has shown that temperatures vary in both systems, including the lakes. As noted in the text there is a typical gradient of slightly increasing temperature variability from the headwaters to the lower reaches. However, significant deviations from this temperature regime may be a real problem. To better reflect this, the language "Constant water temperatures within the natural and normal river gradients" has been added to the list of habitat requirements.

Comment: The loss of 46% of the alleles in the hatchery strains of *E. fonticola* suggests this species may be especially vulnerable to genetic drift. It would be helpful to give the number of fishes used to initiate the hatchery culture. At any rate, effective population size would be an important consideration in future hatchery breeding efforts.

Service Response: The Service agrees that this is an important concern and has funded studies to clarify the genetic variability in the species. Preliminary results indicate that fountain darters in the wild have considerable genetic variability. Provisions for adequately sampling genetic diversity and maintaining captive stocks is a task covered in the plan, as well as in the contingency plan revision currently underway. The text in the plan has been expanded to include a little more information about the previous history of captive breeding.

Comment: It is erroneously presumed in the plan that the population at the Comal must receive full protection under the ESA. It should be designated as "experimental non-essential" to minimize social and economic impacts of the plan, and to provide yourselves greater regulatory flexibility for this population.

Service Response: The Secretary of the Interior was given the authority by Congress to decide whether populations released prior to October 13, 1982, are experimental and whether the population is essential to the continued existence of the species in question.

The Service has thoroughly reviewed the situation of the fountain darters in the Comal system. Fish released by the Texas Parks and Wildlife Department following treatment with toxins for nonnative species control in the Comal River were wild individuals trapped and held for a very short time for this purpose. This operation, which did not eliminate the natural population of the Comal, was a management technique. It was not an experiment and did not constitute a reintroduction.

Comal Springs went dry in the drought of the 1950s, and this is generally believed to have resulted in the extirpation of the natural population because individuals were not found in subsequent repeated sampling. However, the question of whether the natural population was completely eliminated can not be definitively answered. Fountain darters from the San Marcos were introduced into the Comal system in 1975 and 1976 as a conservation measure, to restore the wild population, and to maintain the distribution of the species over its historical range. This stocking was successful in restoring fountain darters to the Comal, where they are now abundant and relatively widespread.

Having the species present in both systems affords greater protection against extinction than if the species were in a single river system. Preliminary genetic analysis has shown some genetic differences between the Comal and the San Marcos populations.

Because of the importance of having two populations in assuring the species doesn't go extinct and the possibility that the Comal population was never entirely extirpated, the Service has decided not to designate it as an experimental, nonessential population. The Service regards the Comal population and its habitat as significant and essential to the survival of the species over its historic range.

Comment: The recovery plan notes that the most important habitat requirement of the fountain darter is "adequate springflows," yet Dr. Bobby Whiteside and Dr. Randy Moss have testified in court that the fountain darter requires water of "a certain quality" but that the source does not have to be springflow.

Service Response: The testimony of Dr. Whiteside and Dr. Moss specifically pertained to water quality needs of the fountain darter, and not to its overall survival and habitat needs in the wild. While the fountain darter may physiologically be able to survive in waters other than those derived from the San Marcos or Comal Springs, this does not mean that the species overall habitat needs for long-term survival in the wild do not require springflow. The ESA requires not only the conservation of the listed species, but also the ecosystem upon which the species depends. The Service believes that one of the most important requirements in preserving the habitat that the fountain darter inhabits is to maintain springflows.

Comment: In the species account for *Gambusia georgei*, it would seem appropriate to discuss habitat changes in the habitat section, in particular the potential role of the elephant ears, even though it was already mentioned in the threats section.

Service Response: This seems appropriate in the context of habitat, and the text has been modified.

Comment: The Service should note in the plan that it knew about the imminent extinction of the San Marcos gambusia in 1980 (from your own status report), yet until December of 1989 did nothing except occasional searches for the species. The Service did nothing to save the species and now it is probably extinct. This highlights the importance of acting to save endangered species instead of merely monitoring their decline and extinction.

Service Response: The Service strives to implement effective recovery actions in addition to monitoring wherever possible. The assertion that little has been done to try to save this species is incorrect. The Service has been and remains actively involved in efforts to preserve the species. The text has been further expanded to include more detail and clarify the Service's concern and activities on behalf of this species.

In 1976, even before the species was listed, the Service contracted for a status survey to try to improve our understanding of the species, particularly its habitat needs, and promoted bringing individuals into captivity for breeding and study. Individuals taken during the 1976 study were held and bred at the University of Texas at Austin by Dr. Clark Hubbs in 1979, and fish from that captive population were used to establish a captive population at the Service's Dexter Fish Hatchery in 1980. In spite of maintaining populations at two localities, both captive populations later became contaminated with another *Gambusia* species, the fish hybridized, and the pure stocks were lost.

Many researchers have been involved and have devoted considerable effort in attempts to locate and conserve populations. Following publication of the status report and listing of the species in 1980, the Service contracted for examination of known localities, and to collect fish to establish captive stocks. As noted in the plan, in 1981, 1982, 1983, and 1984, Dr. Bob Edwards searched, quarterly in 1983 and 1984, to try to relocate populations and reestablish a culture of individuals for captive stocks, and this work was partially funded by the Service. Not enough pure San Marcos gambusia (and hybrids) were found to establish a culture, although Dr. Edwards attempted to do so with the few fish available. In the mid 1980s personnel from the Fish and Wildlife Service Fish Hatchery in San Marcos also searched unsuccessfully for the species in attempts to locate individuals to bring into captivity. In 1990 the Service organized three intensive searches conducted by Service biologists and volunteers, but no San Marcos gambusia were found.

Academic and other researchers, Texas Parks and Wildlife Department scientists, and the Service continue to search for the San Marcos gambusia during all collection and research with fishes that is done on the San Marcos River.

Currently, as noted as a task in the plan, funding is also being sought for a study that will attempt to restore what is believed to be optimum habitat in a portion of the river the species was known to inhabit, in an effort to attract and pool or concentrate any nearby individuals that may remain.

Comment: The late Kenneth Jurgens reported on the San Marcos fishes about 40 years ago, and his work might supplement discussions on page 33.

Service Response: This survey has been included in our background material in the plan.

Salamanders

Comment: The statement that *Eurycea nana* requires thermally constant environments seems open to criticism given that water temperatures vary with seasonal conditions.

Service Response: It is true that there are water temperature differences within the river, particularly between the headwaters and downstream areas. There are also local areas more isolated from the main channel where temperatures fluctuate, although within the upper river as a whole, in any given position the temperature is remarkably stable. The salamanders are distributed in areas close to spring openings, where water temperatures are very stable. One of the factors most strongly correlated with their microgeographic distribution is water temperature, and for the salamanders this appears to be essentially constant in the wild.

Comment: I disagree with and would delete the statement that small mats of *Lyngbya sp.* occur in the immediate vicinity of some of the larger and deeper springs in the lake and could be the source of specimens collected there. The algal mats occur mostly around the hotel area, not in deeper areas.

Service Response: The reference to algal mats near deeper springs has been deleted.

Comment: It should be made very clear in this document, as has been clearly demonstrated by Chippindale et al., that the population of salamanders at Comal Springs is not conspecific with *Eurycea nana*. The statement on p. 45 that Chippindale et al. found the two populations to be distinct despite morphological similarities is misleading because the report shows clear morphometric differences. The contingency plan in the appendix needs to make this distinction clear as well, and needs to deal with the implications of these differences in providing for captive refugia of the taxa as well. Because these are different species, they should not be kept together in the same refugium to avoid any possible contamination between them.

Service response: The text has been clarified to avoid misunderstanding of the differences between these taxa. The 1990 Contingency Plan that was included as an appendix in the draft recovery plan is currently being revised and will provide for the establishment and maintenance of separate, genetically representative captive populations of each taxa.

Comment: Using the terms burrowing or burying as you have on page 50 may be misleading as the salamanders are undoubtedly incapable of actually moving much substrate around, and instead insinuate themselves into interstitial spaces between particles of the substrate, or into natural channels, grooves, crevices, fissures, etc. This could have great implications in interpretation of their ability to survive actions like physical modifications to springs and spring runs.

Service Response: The Service agrees and has modified the text to make this clear.

Comment: The Blanco River gravel quarry site is the type locality for another species of *Typhlomolge*, but not a collection locality for *Typhlomolge rathbuni*, as far as I have been able to find.

Service Response: You are correct in that the "species" found at the Blanco River quarry site has been described as *Typhlomolge robusta.* The description is based on very limited data, and some researchers feel that the salamander located there may actually be *Typhlomolge rathbuni.* Because the site is no longer accessible and no additional specimens have been collected for examination it has not been possible to resolve the taxonomic questions about salamanders from this locality. Because of this taxonomic uncertainty the reference to the Blanco River quarry site as a location for *T. rathbuni* has been deleted in the final plan.

Comment: Without quantification, the phrase in the discussion of setting up captive refugia that preserve "...genetic integrity of ...species..." in paragraph 2 on page 68 and on p.78 paragraph 3 is not useful.

Service response: The phrase about maintaining genetic integrity is important to include because it makes it clear that the purpose of captive stocks is to protect and maintain a representative population of individuals from the wild, to serve restoration and possible reintroduction efforts if needed. This is a very different situation than maintaining a captive group of individuals simply for display or education. It is qualitative because we lack information needed to give numbers of individuals from exact localities (or similar information) supported by reports of the levels of genetic variability found in the wild. Nevertheless, the language provides important guidance about the parameters under which captive propagation programs will need to be set up and managed. As more detailed information becomes available it is expected that the contingency plan will be revised to provide more exact guidance.

Texas Wild-rice

Comment: In the species account for *Zizania texana* it would be good to reiterate the various factors, such as recreation, introduced species (like hydrilla and nutria), etc. that are likely impacting the populations of this species.

Service Response: The Service makes an effort to avoid repetition in recovery plans, to make them concise and readable. None of the species accounts have a general discussion of known and potential threat, as these are covered in B. Threats to the Species and their Ecosystems. However, in the case of hydrilla, it is germane to discuss known changes in habitat, and the text has been modified to reflect this.

Comment: In the habitat section on wild-rice the statement is made that some tree species shade the river "possibly to the exclusion of Texas wild-rice." Do you mean to imply that native trees are a threat to wild-rice?

Service response: The passage refers not to the trees in particular but to the dense shade in some areas, which some think may influence the ability of Texas wild-rice to grow there. The text has been clarified.

Comment: Critics will be quick to point out that apomixis (selfing) is not generally considered a "reproductive anomaly."

Service Response: The reference was not in the context of the plant kingdom in general, but in the context of the genus and its known reproductive strategy. However, to avoid misunderstanding, the word "other" has been changed to "any."

Comment: In examining areal coverage of Texas wild-rice the table includes data up to 1993, but the text included data only up to 1989. 1994 data are available and the text and graphics should use the most current information available.

Service response: Text and tables have been updated to reflect the most recent data available.

Comment: In considering the recovery criteria outlined for Texas wild-rice, it seems that documenting flowering alone will not ensure that the species is completing its natural life cycle in terms of sexual reproduction. This would also require evidence of fruiting, in situ seed germination, and establishment of new seedlings. This may take more than 5 years.

Service response: Although it is unknown to what degree and under what conditions healthy populations of wild-rice recruit new plants from seeds, it is undoubtedly an important part of the life cycle at some point in terms of maintaining the species as a whole. The text has been expanded to include more complete reproductive criteria, and a discussion of its basis.

Comment: The requirement that flowering be occurring in at least three of the identified segments in your delisting criteria is not enough. This occurs sometimes now, and we know that the species is not reproducing sexually in any viable manner. I recommend that you consider requiring that at least 5% of the stands within the critical habitat area should be successfully sexually reproductive each year for a 5 year period (and this may be an underestimate).

Service response: The Service agrees, and the recovery criteria have been modified to reflect these recommended changes.

Comment: Section 2.9 (habitat restoration) of the step-down outline emphasizes the segment of the San Marcos River below Rio Vista dam. This may be fine for other species, but for Texas wild-rice, the section of the river from Spring Lake to the Rio Vista Dam provides more than three times the amount of potential habitat than does the remainder of the river.

Service response: The text has been modified to clarify the relative degree of potential habitat available above and below Rio Vista Dam and in the lower reaches of the critical habitat area.

Recovery Criteria

Comment: In your recovery criteria sections for each species when discussing target criteria the statement "all measures identified in this plan to remove or minimize 'local' threats have been successfully implemented." This item is too vague. You should give a list of the "local" threats that need to be removed or minimized. This is needed to give the reader a clear picture of the items of concern.

Service Response: These local threats are discussed in the Recovery Strategy section. To improve clarity, language including example activities has been added to the criteria sections as well.

Comment: The target density estimates for the San Marcos salamander should probably be provided in the form of ranges to be observed for a minimum of two or three consecutive years rather than as single numbers at a single point in time, more like the strategy for wild-rice.

Service Response: The guidance given for the San Marcos salamander is not criteria for considering downlisting, as they are for Texas wild-rice. The interim objective for the salamander for the period of this recovery plan is the continued existence of healthy, self-sustaining populations of these salamanders in their native habitat. To provide measurable factors to determine the success of the efforts outlined in the plan to prevent decline, guidance is given for annual monitoring, with figures given representing our best knowledge of healthy populations. These figures are to be used as a base reference point against which to evaluate the relative health of the populations. Higher levels are desirable and not precluded. For monitoring and evaluation purposes, annual monitoring is considered essential, at a minimum.

Comment: The executive summary does not include recovery criteria for the San Marcos gambusia, San Marcos salamander, and Texas Blind salamander. Since the plan does not provide criteria for downlisting or delisting, it should specifically state here that the potential for recovery is limited.

Service Response: It is stated in the plan that the potential for full recovery of these species is low. A sentence has been added to the executive summary to reflect this. However, it should not be concluded that significant progress toward increasing the chances of long-term recovery cannot be made for these species. In this final plan, downlisting criteria have been given for the Texas blind salamander. The San Marcos salamander is listed as threatened, and therefore no downlisting criteria are needed. The plan states that the San Marcos gambusia has not been found in over 10 years and may be extinct. Where specific downlisting and delisting criteria could not be formulated for a species, criteria for measuring progress is given in the plan. These criteria are too lengthy and complex to be included in the executive summary.

Comment: Your plan suggests that delisting is unattainable in the foreseeable future for all five species, because of potential catastrophic events. This means you have not met your statutory requirements. You must find a way to protect the species and their critical habitat in any and all events. It is your job to delist, and the plan is supposed to describe how it will be done. If none of the actions you propose are sufficient to delist they should not be required at all.

Service Response: Actions outlined in recovery plans are intended to provide guidance and coordination for recovery efforts. While it is the ultimate objective of the recovery process to provide for listed species comprehensively enough that they can be delisted, this is not always possible within the projected life of a particular recovery plan. When this is the case, Service recovery plan guidance states: "If the prospect of reclassification is uncertain, a measurable interim objective may be used."

Recovery plans are evaluated for the need to revise every 5 years, and plans that don't need significant revision may be used for longer than five years. For the San Marcos/Comal plan it is estimated that another revision will be needed within 5-10 years. Because delisting is not projected to be feasible within the reasonable life of this recovery plan, interim measurable objectives for increasing protection for the species, increasing population stability, and increasing the probability of survival, are given in the plan. For three of the species (Texas wild-rice, fountain darters, and Texas blind salamanders) it is believed that recovery actions should be attainable that would allow downlisting from endangered status to threatened status.

In selecting criteria for judging recovery progress, several of the elements included are essential for the prevention of extinction of the species, and the Service feels that these are essential criteria for measuring progress made in stabilizing the species.

Comment: Your recovery guidance states that "concise and measurable recovery criteria are essential, they represent the central pillar of recovery." Therefore, the plan must state the specific requirements of a state or regional plan that would be adequate to justify issuing an incidental take permit.

Service Response: Recovery criteria and criteria for issuing permits are not the same thing. Recovery criteria deal with the species as a whole, over its entire range, and cite measurable conditions that are believed to be necessary to demonstrate increased stability, or complete recovery of a species, before downlisting or delisting can be considered. Incidental take permits are issued in response to requests that come in from an applicant, not as part of a downlisting or delisting evaluation. Take permit applications may be submitted for a variety of specific activities and varying geographic areas. Therefore, specific requirements vary and depend on the area to be included, the planned activities of the applicants, and the alternatives presented to avoid impacts to the species. The Service works with permit applicants so that conservation actions in habitat conservation plans are consistent with recovery objectives.

While it is not feasible to include specific criteria for an incidental take permit in the recovery plan, the Service recognizes the need to develop better guidance and support for incidental take permit applicants. Task 2.12 has been added to the plan to address that need.

Contingency Plan and Captive Populations

Comment: Many of the proposed contingency plan activities, such as genetic studies, should begin immediately and not wait for water levels to drop into the critical zone.

Service Response: The contingency plan attached to the draft recovery plan was developed in 1990 and is currently being revised. The Service recognizes the need for many of these studies to be done in order to provide information needed to guide collection and captive breeding programs. Genetic studies of the fountain darter are underway, proposals have been developed for other identified information needs, and several of them have been recently funded.

Comment: When downlisting is felt to be possible, the year 2025 is given as the estimated year for downlisting. There should be some discussion of the basis for that date.

Service Response: This is simply the Service's estimate of a reasonable time period needed to achieve the necessary recovery tasks outlined if continuous progress is made. Language has been added to the plan to clarify this.

Comment: Task 2.10 calling for bringing species into captive refugia in an emergency appears to exclude the Texas blind salamander.

Service Response: It is true that the original contingency plan did not include provisions for the Texas blind salamander. The contingency plan is currently being revised and will have provisions for the Texas blind salamander. However, because the Texas blind salamander is subterranean, in the event of very low flows, it may be very difficult to get any additional individuals to bring into captive populations. Problems such as this are one reason the plan also has task 2.7, which calls for setting up genetically representative captive stocks at appropriate facilities for all listed species as soon as possible. The contingency plan cooperators have recognized this and the new plan will recommend captive populations for the Texas blind salamander be maintained at all times, not just during low flows. Their recommendations are very similar to the sort of actions intended under Task 2.7. Because of this potential overlap the text for task 2.11 (which was task 2.10 in the draft) has been modified to reflect this broader scope, more inclusive of both tasks 2.7 and 2.11.

Comment: If we face a major aquifer emergency, shouldn't emergency conservation measures for the candidate species of the Comal be considered by the Service?

Service Response: In revising the contingency plan, the Service and its cooperators have made the decision to include the Comal salamander in captive refugia as well as the listed species. Contingency plan cooperators are examining the potential to take action on behalf of the riffle beetle and other invertebrates to see if it is feasible to establish some sort of captive stocks. There is so little information on the life cycle of the invertebrate species and how to maintain them in captivity (much less how to reintroduce them later) that it may be impossible to do so at the present time. Further studies are needed.

Comment: In the plan in discussing take and jeopardy numbers you state that flows should be maintained above jeopardy levels or adverse modification of the critical habitat, yet the recovery plan itself fails to ensure that there will always be flows in the critical habitat.

and

Comment: In the draft plan, you state that captive populations cannot fulfill recovery objectives or fully meet the intent for conservation of the species under the ESA. But in fact the recovery plan as a whole fails to do these things, and would depend on captive populations to maintain the species in a drought of record. The recovery plan must come up with a strategy that does not require captive populations and can protect the species in the wild in both ordinary dry times and in droughts of record.

and

Comment: Captive populations are an inappropriate conservation strategy.

Service response: Recovery plans by themselves are guidance documents and cannot assure the survival of listed species or protection of habitat. To assure survival the plans must be implemented in a timely manner. The Service believes that the implementation of the tasks outlined in this plan will be sufficient not only to assure necessary springflows for the species and their habitat, but also to deal with other threats, and the restoration needed to stabilize listed species and prevent their extinction.

However, the Service acknowledges that there is uncertainty in implementation of recovery plans. Many elements of recovery plan implementation are not under the Service's control. There are fiscal, logistical, and regulatory limitations. Implementation of recovery tasks by parties outside the Service is not required (with the exception of some Federal agency obligations). Implementation of tasks identified as Service responsibilities are dependent on adequate funding. Some tasks will require changes in public attitudes and behaviors. For other tasks the necessary technical expertise has not yet been developed.

In addition, it is not realistic to propose that the Service can achieve recovery alone. Progress toward recovery takes the cooperation of numerous other parties, particularly in complex, wide-ranging situations such as this one. The Recovery Plan includes many tasks that clearly state they must be cooperative and will require many partners.

While the Service cannot mandate recovery plan implementation, it can and does conscientiously and energetically promote implementation and undertakes as many tasks as possible. Significant progress has been made for these species, as outlined under conservation measures throughout the plan.

The Service does have legal powers it can use to help prevent take, jeopardy, and adverse modification of critical habitat. Tasks directing that regulatory protection should be provided were included in the draft in task 2.11 (now task 2.12). However, an additional task (2.3) has been added to the plan to clarify Federal options and the approach that would be taken if sufficient progress toward recovery is not made.

The Service believes that captive populations are a part of a valid conservation strategy, when used in the context of planning for restoration in the wild. Even if springflows were assured the Service would still recommend that genetically representative captive populations be established and maintained. Captive populations are needed for some species to provide material for restoration work called for in the Recovery Plan. In addition, if some unavoidable catastrophic event lowered wild populations to the point they are were longer viable in the wild or they were totally eliminated, captive stocks would allow us to prevent the total loss of the species and attempt restoration.

Habitat Protection and Management

Comment: Task 2.5 encourages management of spring and river habitat, but does not include cave habitat.

Service Response: Language has been added to the plan to clarify the need to work with landowners to protect cave habitat and recharge features.

Nonnative Species

Comment: The recovery plan should explain what would constitute "significant control of certain nonnative species" that would allow springflow determinations to be modified.

Service Response: The Service has added a sentence to this footnote to further clarify what is meant by "significant control."

Comment: The plan hypothesizes that decreased flows may exacerbate the problem imposed by nonnative species, including the giant ramshorn snail, without any data to support this hypothesis.

Service Response: The Recovery Plan text details several independent observations over time (by Horne et al. 1992, Arsuffi pers. comm., and Linam et al. 1993) that support the concern that the ramshorn snail may be a significant threat, especially during low flows. This information is based on observations of the snails, their relative abundance, and their impacts on vegetation during low flows. Additional research is needed to better understand the snails and their relationship to essential habitat for the listed species. Conducting this research is included as a task in the recovery plan. Dr. Arsuffi of Southwest Texas State University has undertaken some quantitative studies. The text language has been clarified and additional citations have been added to this section.

Comment: Appendix 1, the contingency plan, discusses activities to occur when springflows cease. This would provide an opportunity to work in the dry channel to remove exotic species that stress or threaten the native species. Some chemical treatments may be possible to eradicate nonnatives, and still have time to break down or wash away before natives are returned to the system. Some discussion of eradication treatment for nonnatives should be included in the plan.

Service Response: The Contingency Plan included in the original recovery plan is being revised, and cooperators have discussed the potential for exotic species control. There was concern that low flows, while they might call for intervention on the part of species of concern, might not actually present the best time for control of nnonnativespecies. The persistence of individuals of listed species during low flows will depend on the extent and duration of drying. As springflows fall the river systems are not expected to dry out uniformly. Most remaining organisms would be extremely stressed, and actions taken with chemical or other means to treat nonnative species would likely also be destructive of surviving native organisms, listed and otherwise. This would not be a good approach if the crisis was short duration and survivable, even by low numbers of native individuals. Survivors would be pivotal in the ability of the natural system to restore itself quickly.

Further, we do not yet know how best to control many of these species, especially under low flow conditions, and it is difficult to develop guidance in advance. Including specific nonnative species control projects in the Contingency Plan could be detrimental if evaluation and planning are not adequate.

Water Quantity

Comment: The plan should emphasize the importance of human activity, especially overpumping, as the cause of the principal threat to the Comal and San Marcos, and the historically increasing nature of that threat. It should state specifically that the Comal would not have gone dry in the drought of record except for human withdrawals, and the San Marcos would not reach jeopardy levels except for human pumping.

and

Comment: The plan should note that projections show that the Comal Springs will go dry on their own in a drought of record, even without any pumping. Pumping restrictions will not prevent the springs from going dry in a drought of record.

and

Comment: You are incorrect in assuming that pumping limits will provide a recovery plan. You have ignored computer simulations that show that the aquifer will go below 100 cfs at San Marcos in many droughts, even in the absence of any pumping in the region.

Service Response: The background text section on water quantity stated that loss of springflow is tied inseparably to water usage from the Edwards Aquifer, noted the increase in withdrawal from the San Antonio area from 1934 to the present, and discussed projections for increasing pumpage in the future, with a permanent loss of flow at Comal and San Marcos Springs as a result.

Projections about when the Comal would go dry in a drought of record, with or without pumping, vary from source to source, depending on assumptions and models used.

In today's situation, however, pumping is undoubtedly a factor in whether and when the springs go dry and for how long. Groundwater withdrawals are a primary concern. Pumping levels threaten springflows during mildly dry years, at least intermittently, and all future projections show that without intervention the springs eventually are likely to go dry. Both intermittent and permanent loss of springflow are unacceptable for the preservation of the endangered species' ecosystem and their survival and recovery.

Comment: The plan should note that during years of at least mild drought, springflows drop very rapidly. This is why an enforceable emergency withdrawal reduction plan is needed that triggers well before springs reach a "take" level.

Service Response: The Service has added a comment about the potential for rapid declines in flows from Comal Springs in the background section. Because of the logistics of implementing reduction measures, in situations where flows are dropping rapidly it is possible that emergency reduction measures will need to have implementation triggers at levels before "take" is reached, in order to prevent jeopardy. The need to develop these operational scenarios and prepare to implement them is discussed in the final plan under tasks 2.11 and 2.34.

The purpose of a recovery plan, however, is not to prescribe measures that will prevent any possible "take" of a listed species. The recovery plan sets forth the long-term measures that are most likely to enable the Service to downlist or delist a species. Some degree of "take" under section 9 of the ESA may be permissible through issuance of an incidental take statement under a section 7 consultation or a section 10 incidental take permit, in conjunction with Service approval of a habitat conservation plan.

Comment: Loss of springflows is not a "primary threat," it is the "most serious" threat to these species.

Service Response: The Service prefers to use the term primary. Loss of springflows is not the only threat that could cause the extinction of these species. The decline of the San Marcos gambusia is thought most likely to have been caused by habitat alteration and loss and/or the impacts of exotic species. A catastrophic event such as an accidental spill of a toxic chemical from a railway bridge or roadway crossing could also be serious. The recovery plan is responsible for identifying and attempting to address all such potentially serious threats.

Comment: The plan should provide at least three projections of San Antonio's increased demands, by the San Antonio Water System, by the Texas Water Development Board, and by Research and Planning Consultants, Inc.

and

Comment: The Texas Water Development Board's model is not the only, or even most reliable, predictor of the impacts of pumping on Comal springflows. Other models and projections include: Thornhill (1992), TBEE Educational Consultants (1994), and Center for Research in Water Resources (1993). All show more drastic impacts than TWDB, with Comal Springs drying up or falling below "take" and "jeopardy" levels in milder droughts and for longer periods.

Service Response: More citations for the interested reader to explore background information have been included in the plan, including reference to most of these reports. However, it is not the purpose of the background section to provide a detailed and voluminous literature review, data display, and evaluation of all previous work. This would result in a burdensome and unwieldy plan. Guidance directs that plans briefly and concisely state the problems, issues, and tasks needed to be resolved.

That the city of San Antonio's water demand will increase significantly as it grows is not debated. San Antonio is not the only user of aquifer waters in the area, and increases in demand can be projected for other areas as well. That both springs are in danger of drying up intermittently, and progressively until they cease flowing altogether is also not debated. Better recharge and discharge data sets are needed, and more work is needed to gather additional information and refine models before accurate and more consistent interpretations can be expected. The essential point out of all of these investigations and projections is discussed in the "threats" section under water quantity. The plan states that even with a low (and unlikely) rate of growth for this region overall, demands on the Edwards Balcones Fault Zone aquifer will far exceed the recharge over the long-term. Clearly a new approach to meeting water demands in the area will be needed to avoid overuse of the aquifer and loss of its biological resources and integrity, let alone the economies that are presently dependent upon it.

Comment: The plan should state, as Judge Bunton has found, that to provide for flow at the Comal Springs, pumping must be reduced in a repeat of the drought of record to a level of only 200,000 acre-feet/year.

and

Comment: Some people feel that under S.B. 1477 the new Edwards Aquifer Authority cannot reduce pumping below 400,000 acre-feet/year. Therefore the plan needs to state that Judge Bunton found that pumping even 350,000 acre-feet/year in a drought of record will dry up the Comal Springs for years.

and

Comment: It is obvious that pumping will have to be reduced in average years to less than 400,000 acre-feet/year and roughly 200,000 acre-feet/year in serious drought years.

Service Response: For the recovery of the species the first priority has been to identify the levels of springflow needed for the continued subsistence and recovery of the listed species in their ecosystems. The Service has used the best available information to evaluate and provide an estimate of what these springflows are, and has been candid that these numbers could change as more detailed information becomes available. The plan includes these estimated springflow levels needed, and the Service is conducting additional studies to refine these estimates.

It is beyond the scope of this plan to definitively determine the limits of groundwater use or pumping needed to protect springflows and subterranean habitat. There has been considerable diversity of opinion on levels of groundwater use that would preserve needed springflows under various conditions. The Service recognizes the need to improve guidance on the likely levels of reduction in groundwater use needed to provide necessary springflows. Additional analysis and assistance are needed. Task 2.11 has been added to the plan and is designed to provide additional technical guidance by convening an interagency team of biologists, geologists, hydrologists, economists, and water resource planners. This group will examine baseline information and current models, and build upon other efforts to date (such as proposed emergency reduction plans) to develop better guidance on aquifer levels needed (under varying conditions) to support the survival and recovery of the species.

Relating springflow levels to exact levels of groundwater use limits needed to protect against low aquifer levels is dependent on a number of factors. Different modeling efforts have shown different results depending on the assumptions and mathematical relationships used to develop them. Determinations of needed limits on groundwater use must be based on an evaluation of factors including proposed amounts and times of use, projected future withdrawal needs, availability of alternative water supplies, and other concerns of conservation agencies and of the community. Undoubtedly, models may be refined, and adequate plans regulating groundwater use may evolve in response to our experience and continued monitoring of the aquifer. Over time we expect to gain a better understanding of the response of the springs to recharge, pumping levels, local weather patterns, and changes in water use profiles. Stating a particular target level for pumping in the plan could be misleading, and would not provide for the flexibility needed to address the numerous variables involved.

It is clear, however, that an enforceable state/regional/local plan or plans to reduce pumping would be needed to prevent unacceptably low springflows. Reduction in current use levels would be needed to ensure that aquifer levels do not approach unacceptable minimum levels in dry periods or periods of intense demand. In a repeat of a drought of record the reduction in pumping that would be needed to sustain springflow would be even more severe, and wording has been added to the text to be sure that this is clearly understood. Task 2.1 states that to assure adequate springflows and aquifer levels a mechanism for controlling groundwater withdrawal is needed, as well as the development and implementation of an Aquifer Management Plan that would achieve necessary groundwater use reductions.

Task 2.1 has two tasks (2.11 and 2.12) which have been added to the plan. Task 2.11 calls for a representative working group including users, regulatory agencies and biologists and technical advisors to development and implement this comprehensive Aquifer Management Plan. It is expected that the interagency team examining needed aquifer levels and providing technical guidance (task 2.12) will be working closely with the working group developing the comprehensive Aquifer Management Plan.

Comment: It is obvious that to protect the species and springflows a regulatory authority with jurisdiction over all pumping will be required.

Service Response: The Service agrees that there needs to be a State mechanism for regulating groundwater withdrawals, as was stated in the draft plan in the recovery strategy section and under task 2.1. The State legislature passed legislation in 1993 creating the Edwards Aquifer Authority, with regulatory powers. However, the legislation was unimplementable due to legal challenges based on Voting Rights Act concerns about adequate representation for the regulated area. The Service is hopeful the Edwards Aquifer Authority will soon be operating. In 1995 the legislature addressed these problems with an amendment to the legislation, but implementation has again been challenged in the courts, this time by the Medina and Uvalde County Underground Water Districts. Recently a State court judge ruled that the legislation was unconstitutional under Texas law, an appeal is expected, and litigation may continue. If no State plan can be implemented under the 1993 legislation, then the Service will have to examine other means of protecting the species. Information updating legislative and court action in 1995 has been added to the text.

Comment: An emergency reduction plan must be in place, enforceable, and ready to reduce pumping quickly in crisis situations. The Service can and should provide an emergency withdrawal reduction plan that defines specific trigger levels for emergency pumping reductions. The plan should include cutting out all outdoor watering (agricultural and municipal) and this should happen at trigger levels well above jeopardy.

and

Comment: The plan should describe specific institutional arrangements by which San Antonio military bases can be assured of water that is not dependent on the Edwards.

and

Comment: Alternative water supplies must be developed to enable users of Edwards water to reduce their dependance on the aquifer. The only sources of water that are large enough, cost-effective, and environmentally acceptable are interbasin transfers.

and

Comment: The plan should specifically address the projected potential and limits of agricultural, municipal, and industrial conservation and wastewater re-use. This should be discussed in detail relating studies, projections, and potential achievements and limits. They have the potential to contribute significantly to reducing water demand in a cost effective way. However, they cannot provide in "savings" the amount of water projected to be needed in the area without the need for pumping controls or alternative water supplies."

and

Comment: The draft plan focuses solely on controlling groundwater pumping without any consideration for the existence of other alternative techniques that might contribute to conservation of the species, with more minimal social and economic impacts.

Service Response: The important point regarding the development of an Aquifer Management Plan is that it should use a multifaceted approach. The Aquifer Management Plan would derive greater reliability and minimize potential adverse impacts through significant diversification. The recovery plan states that the plan may include conservation, water reuse such as wastewater use, constant monitoring and regulation of aquifer withdrawals, groundwater use emergency reduction plans, limited use or retirement of water rights through a marketing system, recharge enhancement, and development of alternative water sources. The text under task 2.1 has been modified to emphasize our recommendation of a multifaceted approach.

However, the Service does not believe it is appropriate or within its statutory duties to dictate exactly how this objective is met. The appropriate Service role is to provide technical support and biological evaluations to help evaluate the suitability and feasibility of locally and regionally developed plans in terms of whether they are likely to be able to protect the species of concern.

Current Service policy provides for the involvement of stakeholders in planning the implementation details of specific recovery actions in order to minimize social and economic burdens to local communities whenever possible. Emergency groundwater use reduction plans should be developed by those who have the authority to impose and enforce emergency reductions in groundwater withdrawal, and by those from the community to be regulated. As noted previously, considerable progress has been made in local and regional planning since the draft recovery plan was prepared.

The Department of Defense has indicated an interest in making arrangements to obtain water from sources that do not depend on the aquifer. It is appropriate for specific details of such arrangements to be developed by the appropriate Department of Defense authorities, not the Recovery Plan.

The plan acknowledges under task 2.1 that development of alternative sources of water is an appropriate and potentially promising part of an approach to aquifer management. The task also notes the appropriateness of strategies for water conservation and wastewater reuse. Conservation strategies and wastewater reuse should be pursued aggressively to derive the maximum savings possible. These approaches can contribute significantly to reducing demand on the aquifer. The Service acknowledges, however, that conservation alone is not likely to be sufficient to meet projected water demands for the area through savings, hence the recommendation that the plan include other strategies as well.

Current assessments regarding the potential contributions and limits of various approaches might be modified following additional review, evaluation, and fine-tuning. Rather than include them in the present Recovery Plan, a review of these issues is included as part of the deliberations of the working group called for in new task 2.11, and the evaluations of the technical support team included in new task 2.12. Decisions regarding the appropriate contribution to groundwater use reduction to be realized from these techniques is also best left to these groups during the development of the comprehensive Aquifer Management Plan.

Artificial Augmentation

Comment: In discussions of supplementing the region's water supply, recharge enhancement/dams is a major option which is unmentioned except for cautions that possible impacts on sensitive cave species must be considered. Recharge enhancement should be included in the options discussed.

and

Comment: The plan should discuss the Service's position on recent proposals for streamflow augmentation. It is not addressed. Some interests believe that augmentation can allow pumping to continue unregulated.

and

Comment: Your river management plans should include provisions for local recharge and augmentation.

and

Comment: Your plan should call for the development of injection, local recharge, augmentation directly into streambeds, and recirculation of springflow. The recovery plan needs to include a whole chapter on these various strategies and their relative cost vs. shutting down the aquifer and going to other sources of water.

and

Comment: Studies for the Edwards Underground Water Board have shown that augmentation techniques in at least five different configurations are feasible for keeping water in the critical habitat, even during a drought of record. Your plan, to be fair, must include these techniques.

Service response: The Service wrote to the Texas Water Development Board (Sept. 1, 1994 and January 23, 1995), commenting on the McKinney and Sharp draft report "Springflow augmentation of the Comal Springs and San Marcos Springs, Texas: Phase 1--Feasibility Study (Draft)." We stated that augmentation alternatives described involving injection wells, infiltration galleries, aquifer baffles, and direct addition to spring fed lakes are not feasible in terms of providing adequate protection for listed species dependent upon the Edwards Aquifer, with additional comments on our reasons for concern. These augmentation approaches are unlikely to preserve the biological integrity of the ecosystems of concern, and do not address the underlying problem of excessive demand on the aquifer. Other more feasible approaches involve actions directly addressing this problem, therefore providing a long-term solution to these problems.

As stated above, the Service believes that the most effective regional Aquifer Management Plan will be one using a multifaceted approach to reduce groundwater demands on the aquifer. While regional and local recharge enhancement opportunities may have some potential benefit, they must be carefully evaluated. The Service does not believe that recharge alternatives can be adequately evaluated until data are developed and analyzed that address potential impacts to the Texas blind salamander and water quality issues (such as the potential for contamination, and likelihood that recharge enhancement waters will equilibrate to normal aquifer conditions without harm to the species). A careful evaluation is needed of the realistic potential for recharge enhancement to provide any significant water to the aquifer during drought periods. Impacts to fish and wildlife at the point of recharge, from decreased flows in rivers and streams downstream of recharge, and other impacts to drainages that will be deprived of waters normally accruing to them (due to diversion to recharge) must be carefully evaluated as well.

The text under task 2.1 has been expanded to clarify the Service's position on these augmentation approaches.

Miscellaneous Technical Comments

Comment: As a tool to aid the recovery of these species, preliminary population viability analyses (PVAs) for the Texas wild-rice, fountain darter, and salamanders should be done. By using estimates of biological parameters and environmental variability one can explore by computer simulation the consequences of unexpected events on the probabilities of extinction. These estimates can be very helpful in guiding management decisions.

Service Response: The Service agrees that PVA can be a valuable analytical tool and has explored the use of PVA techniques for several species. It is most useful with comprehensive and reliable baseline data to support it, and a model configuration that is a good fit to the actual biology of the species and its habitat. We have found some models limited in their ability to handle large brood sizes or other life history parameters for the species involved. Task 1.15 (determining survivorship patterns), would logically include these sorts of investigations.

Comment: Although the Recovery Plan will specifically address only currently listed species, candidate species from the Comal Springs need protection too--and some of them may end up being listed in the future. By protecting the habitat of the fountain darter will we be protecting the site specific habitats of the Comal Springs salamander and the riffle beetle?

Service Response: Generally it appears that this would be the case. If the decision is made to proceed with listing these species, no major changes in the recovery plan would be needed to provide protection for them as well, as the threats faced are similar. However, springflow levels where take and jeopardy would occur for these species may differ from those given for the fountain darter at Comal, particularly because these species are located primarily in the spring runs of the Comal.

INFORMATION AND PUBLIC EDUCATION

Comment: While it should not be the primary emphasis of the recovery plan, the connection between species protection and people protection should be emphasized. Keeping the aquifer clean and springs flowing for these species is also good for people drinking the water and for local economies dependent on the river systems. Many people who do not appreciate a particular organism's worth or intrinsic right to protection can appreciate this more immediate connection to the need for protection of natural resources.

Service Response: Task 4.0 covering public information and education efforts included the need to show the human benefits of protecting the ecosystems upon which these species depend. This text has been expanded to clarify the importance of this aspect.

POLICY AND IMPLEMENTATION ISSUES

Comment: The Draft Plan fails to minimize the social and economic impacts of implementation as directed in the FWS policy statement of July 1, 1994.

Service Response: The Service considers the minimization of potential social and economic impacts of recovery to be important to the success of recovery efforts on behalf of listed species and their ecosystems. The Service recognizes that in planning for recovery for these species, the greatest potential impacts are in the area of controlling groundwater withdrawals from the Edwards Aquifer, and in addressing other human impacts in the ecosystems that may cause habitat alteration or destruction.

Recovery plan tasks to achieve these objectives have been designed to be cooperatively developed and implemented in order to take advantage of the input of concerned parties for both design and implementation. The recovery plan makes it very clear that public involvement in the details of recovery planning and implementation are necessary and welcome under task 2 and its various tasks. The draft plan also included a specific objective (4.2) for encouraging public participation in conservation efforts. This is done in part to facilitate consideration of social and economic impacts and help minimize them.

Implementation of all recovery plan tasks may not involve significant economic or social impacts or require public participation and planning. However, in many cases there may be several avenues that could be pursued to achieve a particular task, and several involved parties or cooperators. When appropriate for the implementation of a particular task, the Service may convene affected parties to examine options available, evaluate concerns and ideas offered, and be certain that implementation supports timely achievement of the task while minimizing social and economic costs as much as possible.

In order to clarify our intention to minimize social and economic costs while still achieving the timely implementation of recovery tasks, we have added language explicitly stating these goals to tasks 2.0 and 4.0 and appropriate tasks.

Comment: The key to efficient aquifer management, including spring-fed ecosystem maintenance, is transferable, prioritized pumping rights.

and

Comment: The plan must specifically address the potential and limits of water rights marketing, and discuss the impediment faced today because property rights to Edwards water are not currently defined. You should educate about the concepts, facts, and the law. There is remarkable consensus among stakeholders about the potential usefulness of a marketing approach.

Service Response: The Service feels that there are many ways to achieve limitations on the amount of water pumped from the Edwards aquifer in order to protect the species that depend upon it. Transferable pumping rights is one water marketing system that could be employed, and such water rights marketing systems are included as an option in the plan.

Comment: You need to hold a public hearing as soon as possible to collect the ideas and comments of the people on your proposed recovery plan.

Service Response: The draft recovery plan and notices of its availability for public comment were widely circulated, with a 90-day public comment period. A notice of availability appeared in the *Federal Register*, and in addition over 850 letters were sent notifying potentially interested parties of the availability of the plan for public comment. Over 160 copies of the plan were mailed out. Issues surrounding the needs for the conservation and recovery of the listed species in the Comal and San Marcos systems have had wide media exposure in the area and statewide, and have had a great deal of scrutiny by agencies, organizations, local and state governments, and interested individuals. The Service feels that notifications and draft plans sent out for review and comment have been sufficient to allow consideration and comment of the people. Only 13 letters of comment were received. A costly public hearing would not be likely to result in any wider consideration of the draft plan than has already been achieved, nor is a public hearing believed to be more effective at soliciting comments than methods already used. The Service prefers to direct its limited funds toward support of on-the-ground recovery actions.

Comment: Recovery Plans are subject to requirements of the National Environmental Policy Act. You have failed to consider the environmental impact of alternatives under NEPA. A full environmental impact statement will be required before any Recovery Plan is put into place.

Service Response: The Service determined in 1986 that, consistent with the Council of Environmental Quality regulations implementing NEPA, recovery plans are categorically excluded from NEPA requirements for Environmental Assessments or Environmental Impact Statements during the development and approval process. This exclusion is based on the fact that recovery plans are broad planning documents that list all tasks the Service believes may contribute to the recovery of species and set general policies and priorities for management and treatment of species. Recovery plans cover tasks that may involve actions by the Service, other Federal agencies, State and local governments, the private sector, or a combination of these. However, recovery plans do not impose any obligation on any agency, entity or person to implement the tasks listed in the plan.

While a recovery plan does not require NEPA analysis for development and approval, actual implementation of actions outlined in the plan may. NEPA analysis (and the preparation of any needed Environmental Assessment or Environmental Impact Statements that may be required) is expected to be done by any Federal agency as they prepare to actually implement particular recovery actions, if appropriate.

Comment: Under ordinary circumstances recovery plans may not be subject to NEPA analysis requirements, because recovery plans are broad planning documents without specific implementation obligations or proposals. However, in this case, as Judge Bunton has ordered the preparation and implementation of the plan, it appears that recovery plan development and implementation are now a nondiscretionary duty. Under these circumstances it seems FWS must comply with NEPA.

Service response: NEPA requirements only apply to discretionary actions of Federal agencies, not to nondiscretionary actions, such as specific court-ordered recovery tasks. The court's order was directed specifically at (1) the need for the Service to announce the threshold "take" and "jeopardy" springflow and aquifer water levels, and (2) the need to update the plan to consider Comal Springs and aquifer-dependent species, which the revised plan now does. The plan itself remains a broad planning document, without specific legally enforceable duties upon other agencies or persons. Discretionary implementation of specific recovery actions called for in the plan would still be expected to go through compliance with the NEPA process.

Comment: You have outlined a vast number of studies that the people will pay for that have no obvious connection to protecting species in droughts. Some explanation of the relevancy of each proposed study should be included in the plan.

Service Response: Drought is not the only issue that must be addressed to assure the conservation and recovery of the species. Part 1, B. Threats to the Species and Their Ecosystems, devotes several pages to a detailed discussion of other problems that must be examined and addressed. Part 1, E. Recovery Strategy, discusses the need to investigate regional and local threats and additional research needed regarding the biology of the individual species. Lastly, Part II, C. Narrative Outline for Recovery Actions, includes in the text for each task a discussion of the role of each task in furthering conservation and recovery.

Comment: You mention state legislative action on S.B. 1477 in the draft plan but fail to note that the bill was declared void by the Justice Department, and that according to some models does not come close to protecting the species from jeopardy anyway.

Service response: Since the draft plan was circulated for review and comment the State Legislature has convened and passed legislation in

1995 (H.B. 3189) amending S.B. 1477 (passed in 1993 to create the Edwards Aquifer Authority) that resolved the Justice Departments concerns previously preventing implementation due to concerns about representation under the Voting Rights Act. Implementation of the legislation has been prevented by new legal challenges brought by the Medina County Underground Water District and others. Recently a State court judge ruled that the legislation was unconstitutional. However, it is expected that the state will appeal, and the case likely will be decided by the Texas Supreme Court.

The Service believes that this legislation is a significant action toward implementation of regulated groundwater withdrawal from the Edwards Aquifer and share the state's view that this law should be implemented. The Service is hopeful that concerns will be resolved quickly so that it may be implemented. Regulating groundwater use in turn is an important part of a comprehensive plan to maintain adequate water supplies in the ecosystems of the Comal and San Marcos Springs for the survival and recovery of the listed species.

COMPLIANCE WITH JUDGE BUNTON'S ORDER

Comment: Judge Bunton ordered that the draft plan "...shall include such combinations of pumping restriction, Federal agency ESA Section 7 cutoff of permits or funds or other actions, and other affirmative measures as appear necessary and appropriate to protect the aquifer and the species dependent on the aquifer, even if a repeat of the drought of record begins now, and assuming the continued indefinite absence of an adequate state or regional plan." Yet the draft plan does not state the specific pumping restrictions needed to avoid causing take or jeopardy to the species, does not examine specific water supply alternatives, or identify specific Federal agency section 7 cutoffs.

Service Response: Judge Bunton's order did not require that the Service dictate specific detailed controls for water conservation, development, and apportionment for the San Antonio segment of the Edwards Aquifer in this Recovery Plan. He recognized that the Service should include those measures that it deemed to be "necessary and appropriate" for inclusion in a recovery plan. The Service provided what was requested, and clearly states in task 2.1 that an enforceable plan should be developed to manage the water in the Edwards Aquifer (using a variety of biologically supportable approaches) to preserve water supplies for the springs (even in a drought of record). This task also clearly expresses and includes the obligations mandated by the Act for Federal agencies.

It is undesirable for the Recovery Plan to attempt to determine and dictate the specific components or requirements for any State or regional regulatory plan to meet this objective. Doing so would not provide for the kind of considered, comprehensive planning, continuous evolution, and fine-tuning that will be involved. Current Service policy states that the Service intends to minimize social and economic impacts as much as possible while providing for the timely recovery of listed species, by using the information and input from affected interests to develop alternatives for recovery implementation, as well as by seeking their participation in recovery implementation. This recovery plan is consistent with that policy.

Regulation and management of the water in the Edwards Aquifer involves many State, regional, and local agencies with responsibilities and authorities regarding water use, both rural and urban. As noted in the Recovery Plan, State and local entities should be the primary parties developing the Aquifer Management Plan. Any plan setting restrictions should be flexible, use continuously updated or adjusted projections of water supplies and use, and be able to stimulate and implement programs and projects that are successful in reducing water consumption or developing alternative supplies. It is clear that the design and implementation of an effective plan should involve the participation of local, State, Federal and private entities in a cooperative, regional approach, consistently monitored and enforceable.

Since the draft was made available for public comment the Service has sought the participation of other entities and has been working cooperatively to advance the planning and implementation process. The Service is working in cooperation with the city of New Braunfels and others to develop a local spring and river management plan. Judge Bunton appointed a court monitor who has been examining emergency use reduction plans and a regional conservation strategy that may result in a regional HCP and incidental take permit(s). At Judge Bunton's order a committee of lawyers has also drafted an alternative emergency reduction plan for municipal and industrial water use that is being considered by the city of San Antonio and other municipalities. The State legislature passed legislation in 1995 (H.B. 3189) amending S.B. 1477 (passed in 1993 to create the Edwards Aquifer Authority) that now has resolved problems previously preventing implementation and enforcement of water use regulation due to concerns regarding the Voting Rights Act. Hopefully new legal challenges from the Medina and Uvalde County Underground Water Districts can also be resolved. The text of the revised plan has been modified to reflect these efforts.

The Service should continue to have an active role in planning for aquifer management, and the Recovery Plan does provide guidance for the planning process. It includes the Service's determination, based on best available information, of the springflows needed to prevent take and jeopardy. Task 2.1 also gives guidance on what kind of restrictive and affirmative measures are felt to be useful (and biologically supportable) to protect the aquifer and its sensitive species. The list includes conservation, reuse, limits on withdrawal, implementation of groundwater use reduction plans in trigger situations such as drought, changes in delivery systems or management practices, development of alternative sources, and creation of a water rights marketing system. New tasks have been added under task 2.1 to clarify the Service approach and objectives. The Service has recognized a need for additional technical guidance and provides in task 2.11 for an interagency team to be convened to assist in determining aquifer levels and pumping reduction levels needed to maintain springflows under various scenarios.

Tasks 2.1 and 2.12 also make it clear that Federal agencies should take actions within their authorities to conserve the species and their ecosystems, and reminds them of their section 7 obligations to consult under the Act. A new task (2.2) encourages proactive programs to assist species survival. Another new task (2.3) outlines the Federal agency approach if no adequate and enforceable Aquifer Management Plan is developed and notes that agencies may decide to withhold permits or funds for actions that are likely to jeopardize the species. The point at which permits or funds may have to be withheld has to be determined by these Federal agencies through the interagency Section 7 process. The Service does not have the authority to initiate or compel a consultation. Each Federal action agency is responsible for reviewing their activities and initiating formal section 7 consultation if appropriate.

Again, the focus of the recovery plan is not on particular projects or programs, but on a prescription for long-term improvement in the status of the species and the prospects for eventual downlisting and delisting.

The Service has notified all Federal agencies known to impact water use of the Edwards Aquifer about their Federal consultation responsibilities and the potential implications for their activities in the area. There are continuing discussions regarding the best method of fulfilling their obligations and protecting the species of concern.

FEDERAL AGENCY OBLIGATIONS

Comment: The 1984 San Marcos Recovery Plan called for vigorous pursuit of a systematic procedure of consultation, even though a commenter on that plan complained that this appeared to constitute indirect Federal control on pumping. The current draft appears to abandon this commitment.

and

Comment: If the Service is convening an interagency task force to prepare an overall Section 7 Recovery Action Plan, this should be described and the identification of the agencies asked to participate, responsible officials and contacts at each agency, and schedule for meetings should be included.

Service Response: The Service has not abandoned its commitment to vigorously encouraging Federal agencies to consult with the Service regarding their impacts to the Edwards Aquifer and its listed species. See the response to the comment above for a discussion of Service efforts and responsibilities regarding section 7 consultations. The Service continues to work with cooperative Federal agencies in the consultation process.

The Service believes however, that the rapid completion of a review of section 7 obligations with *every* known agency whose actions may affect groundwater withdrawals may only be critically important in the absence of the development and implementation of an adequate State and local plan for aquifer management. The need for rapid completion of section 7 consultations with all such agencies would become paramount only if the ongoing efforts to develop a comprehensive plan at the state, regional, and local levels were abandoned or inadequate.

Comment: You do not explain why Federal agencies should not be considering any means at their disposal to maintain water in the critical habitat.

Service Response: The plan notes in the discussion under task 2.2 that under section 7(a)(1) of the ESA all Federal agencies are to "utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered and threatened species...," and points out other agencies whose missions and/or administration of existing legislation may complement the efforts to preserve listed species. The Service will continue to encourage other Federal agencies to take proactive measures. The Service welcomes other Federal agency's efforts to assist in assuring water in these ecosystems and has encouraged them to examine their abilities and obligations to do so.

In addition, the plan makes it clear that Federal agencies have obligations to consult for actions that may affect the listed species of the Edwards Aquifer and its major spring systems, under section 7(a)(2) of the Act, which is discussed above.

In the absence of the development and implementation of an adequate Aquifer Management Plan, Federal agencies should do what they can to assure that springflows are protected. A new task in the plan (task 2.3) makes it clear that the Service should continue to encourage agencies to undertake voluntary measures to assist species survival and to comply with their nondiscretionary obligations for consultation under section 7(a)(2) of the ESA, and that the Service itself should continue to do everything it can to be sure that springflows are protected.

Comment: The draft does not address the obligations or activities of the Environmental Protection Agency (EPA) to take actions to protect the human water supply, under the ESA, CERCLA, Clean Water Act, and Safe Drinking Water Act. The plan should also describe EPA's current progress, if any, to assess and prevent the threat of the potential movement of the badwater line. If nothing is being done by EPA the plan should give their explanation for failing to do so.

and

Comment: The Draft plan states that EPA may have statutory authority under Clean Water Act, Safe Drinking Water Act, and CERCLA that should be used to assist in the protection of the listed species and their ecosystems. No legal or factual basis is given for this contention.

Service Response: The draft plan discusses under task 2.2 that according to Section 7(a)(1) of the Act Federal agencies should use their "authorities" to further the purposes of the Endangered Species Act by carrying out programs for the conservation of listed species, and should do so in consultation with or with the assistance of the Secretary (in this case, Interior). There are also obligations under section 7 to enter into consultation with the Service for actions they fund, permit, or carry out that may affect listed species.

Task 2.2 includes a reference to authorities given to other Federal agencies under other environmental legislation including the Clean

Water Act, Safe Drinking Water Act, and CERCLA. The Service feels that there are complementary functions in conserving habitat for listed species and in protecting human health. Situations such as this, where there are obvious authorities granted to an agency that may also benefit endangered species, should be considered by those agencies in setting up their programs to further the conservation of listed species, and should be taken into account in decisions regarding such areas as discretionary actions, granting variances or exclusions, setting permit requirements, making requests for consultation with the Service under section 7, etc. The idea is that by working cooperatively agencies can minimize harm and maximize potential benefits in the course of discharging their ordinary duties under both their enabling legislation and the ESA. Wording has been added to section 2.2 to clarify this.

Comment: The draft plan does not address the Service's own obligations to list subterranean Edwards Aquifer dwelling species, to designate Critical Habitat and to propose and seek funding for habitat acquisitions.

Service Response: The recovery planning process is intended to provide guidance for the conservation and eventual recovery of Federally listed species. Evaluations of the need to list species and designate Critical Habitat are separate activities conducted under section 4 of the ESA.

Habitat acquisition is not mandatory or beneficial for all listed species. Recovery plans may recommend habitat acquisition as a recovery tool, but many recovery plans do not include habitat acquisition as a strategy if it is not needed to recover the species. At this time the Service does not believe habitat acquisition is necessary in achieving the tasks needed to protect the species of concern in this plan.

It is Service policy to take a functional ecosystem approach to species and habitat protection. Therefore in recovery planning, wherever possible, correlated needs of (and benefits to) candidate species in the same ecosystem are pointed out and included.

Comment: The Service should address the fact that the measures in this plan may be adequate to protect Comal and San Marcos Springs and spring-dependent species, but are not likely to be adequate to protect the entire Edwards Aquifer itself and the underground, Edwards dependent candidate species, some of which are known from only distinct portions of the aquifer.

Service Response: This recovery plan has as its primary objective to provide for the listed species of the San Antonio region of the Edwards Aquifer, which includes the Texas blind salamander. Conservation measures already underway are described in the background material for this species. Specific needs for the Texas blind salamander are included under many tasks. Many of the tasks outlined to protect water quality for the listed species (including the Texas blind salamander) will benefit other aquifer-dependent species as well.

Comment: The ESA authorizes and requires the Secretary to conserve listed species by utilizing his authority to acquire, including by purchase, "lands, waters, or interests therein." Any adequate plan must address the potential for use of this tool, for example in the purchase of irrigation rights.

Service Response: The ESA does not require the Secretary to acquire property or water rights to protect endangered species, although Section 5 of the ESA authorizes the Service to do so, as appropriate. Neither the Service nor the Recovery Team identified land acquisition or water rights acquisition as a feasible or high priority recovery strategy for the conservation of these listed species. If water users and property owners work cooperatively to find a solution to water supply problems and other threats, acquisition of property should not be necessary. Currently, water rights in the Edwards Aquifer region operate under principles of the "right of capture," not under a system of transferable, salable water rights. If this system changes to a market-based system with salable water rights, the effectiveness and desirability of purchasing water rights for the purposes of protecting listed species or their habitat would be reevaluated.

Comment: In the recovery plan section where springflow and aquifer level determinations made by the FWS under court order are mentioned as being given to provide guidance to Federal agencies and pumpers to assist them in taking appropriate actions to avoid take or jeopardy, it should also be noted that the U.S. Court of Appeals for the Fifth Circuit has held that these determinations have no legal consequence and in no way are a prerequisite to ESA-enforcement litigation. The plan should restate the caution that these determinations were made in a very narrow context with limited data and should not be considered as the definitive flow requirements for the species/ecosystems.

Service Response: Language has been added to this section to clarify the preliminary nature of these estimates. The Service is currently conducting additional detailed studies to collect additional data needed on flow conditions in the Comal and San Marcos. These studies should help refine these numbers. As more definitive information becomes available, the Service has a duty to notify the court and State, regional, and local water authorities and other pumpers of any changes to the springflow numbers.

Comment: In discussing recovery criteria and interim goals where criteria cannot be determined, the draft plan noted that flows that would "jeopardize" any of the listed species or "adversely modify" critical habitat should not be considered adequate. It seems inappropriate to use these terms as true "jeopardy" arises only in the context of a formal section 7 consultation in a biological opinion with detailed consideration of reasonable and prudent alternatives for a particular situation.

Service Response: It is true that the terms jeopardy and adverse modification have specific meanings in terms of a formal section 7 consultation. However, the discussion here is a general one about goals for maintenance and recovery of the species. It is useful to discuss adequate flows during the recovery process, and the concept of a lower limit where low flows are severe enough that the extinction of the species in the wild seems imminent, or that habitat necessary for the survival and recovery of the species would be adversely modified. In this context these terms would refer to such declines without any consultation being done or alternatives that would prevent the threat of extinction in place.

Comment: The Recovery Team is composed solely of biologists. To comply with the policies on recovery planning and implementation published in July, the Service should widen the representation on the team. It should include a surface water and groundwater hydrologist and an economist.

Service Response: This is a recovery team that has been in existence for many years. A number of agency representatives also serve as consultants to the team. The Service is reviewing the need to revise or expand the team in light of new guidance published in July 1994, and will do so if it appears appropriate and necessary.

It should also be noted, as discussed above under a comment concerning the minimization of social and economic impacts, that the implementation of several tasks in the recovery plan call for a team approach to implementation, which will also provide for the involvement of all affected interests as outlined in the July 1, 1994, policies.

IMPLEMENTATION SCHEDULE, PRIORITIES, AND COST ESTIMATES

Comment: The plan should give the origin of all the cost estimates you give for each and every task. Support for each cost estimate must be included in the plan.

Service response: Cost estimates given in recovery plan implementation schedules are given for the first three years only, and are merely rough estimates, given for general guidance in long-term planning. Because the details of how specific recovery tasks will be achieved, and by whom, are unknown, a detailed and accurate assessment of costs are not possible. Where agencies and municipalities have estimated the costs they expect to incur in their planned activities for preservation of endangered species that exceed their usual responsibilities and activities, they have been included.

Comment: The implementation schedule should include a specific time schedule for section 7 (Federal agency) consultations.

Service Response: As noted above, the Service does not have the authority to initiate section 7 consultations and is not in a position to predict schedules of when various agency consultations may occur. The need for a section 7 consultation may arise at any time, for any number of specific projects or activities which cannot be comprehensively predicted in advance.

Comment: The implementation schedule appears to use the term "ongoing" to avoid setting timetables/deadlines for actions that require them and are long overdue, such as developing an aquifer management plan. This is an evasion to represent these tasks as having an indefinite duration, instead of imposing deadlines for completion after which enforcement actions may be used.

Service Response: Recovery plan tasks, including estimates of task durations, are not mandatory enforceable actions, as discussed earlier in previous comments. Information arrangements and terminology in Recovery Plan implementation schedules are nearly standardized from plan to plan. Task duration in recovery plan implementation schedules represents a simple estimate of how long it might reasonably take to complete a task. It is not intended to imply any sort of deadline or point of imposition of regulatory enforcement. It also does not specify exactly when the task will be initiated.

The term "continuous" is used to denote tasks that it is expected will require constant attention throughout the recovery process, and therefore have an indefinite duration. The term "ongoing" is used in the recovery plan to identify tasks that have already been started, but are not yet complete. This means tasks identified as ongoing, far from being neglected, are tasks that have been initiated. While in our standard use the term "ongoing" does not include an estimate of time remaining to completion, this does not mean that they are considered to be of an indefinite duration or that the Service is avoiding timely action. We have added language to the first few pages of the implementation schedule, where priority numbers and abbreviations are defined, to clarify the meaning of the use of the terms "continuous" and "ongoing."

Comment: The city of San Antonio estimates its costs for implementation of alternative water supplies to vary between 45 million and 127 million dollars a year, depending on the scenario used for alternatives. In addition an estimated cost of 15-20 million dollars per year will be incurred for reductions in use through the development of conservation, reuse, water market and demand management initiatives. We feel the implementation schedule should reflect these costs as well as total costs for all other Federal, State, and local governments and private parties.

Service Response: The Service has done its best to estimate the potential recovery costs. However, costs fluctuate widely when one considers differences in approaches selected, and even the widely variable alternatives available within a scenario such as interbasin transfers of water.

Further, given the obvious limits of Edwards Aquifer water in dry years, many communities are undertaking the development of alternative water supplies to meet future needs based on projected growth and needs for economic development, in addition to concerns about violations of the ESA. ESA concerns in many cases are merely accelerating the development of alternative water sources and are not the total basis for projections of additional water supplies needed. In addition, implementation costs of some tasks or task elements may actually be largely offset (or even cost-saving) for the entities implementing them. For example, water conservation programs have expenses associated with them, but the reduction in demand for additional water saves money by reducing the costs of developing new water supplies, water treatment capacity and operations, and wastewater treatment capacity and operations that would be incurred in the absence of a conservation program. Therefore the true cost of a conservation program would be the difference between water related costs without a conservation program and with the program, not the full cost of the program. Apportionment of such costs between City planning and development functions and ESA compliance is extremely difficult.

Since the comprehensive Aquifer Management Plan is not completed, and the mix and apportionment of water use for approaches to be used has not been solidified, cost estimates are a sketchy estimate at best and should not be regarded as definitive. Until the plan is completed and analyzed for a reasonable representation of the costs attributable to recovery needs for the listed species, such unquantifiable costs have been designated as "not yet determinable." They have also not been included in the total cost of recovery. However, as more definite plans emerge and better cost estimates become available, they can be used to revise and update the plan, if necessary.