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Marine Matters

Pacific Salmon Recovery Planning and the Salmonid Watershed Analysis Model (SWAM): A Broad-Scale Tool for Assisting in the Development of Habitat Recovery Plans

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Abstract

Pacific salmon in the lower 48 states, once numbering in the millions, are now counted by the thousands, the hundreds, and the tens (NRC, 1996). In the early 1990s, the National Marine Fisheries Service (also referred to as NOAA Fisheries), part of the National Oceanographic and Atmospheric Administration, was petitioned to list several salmon populations as endangered or threatened under the U.S. Endangered Species Act (ESA). As a result, status assessments were conducted for all anadromous Pacific salmon populations that migrate between the Pacific Ocean and their natal streams in Washington, Oregon, Idaho, and California. From these status assessments, NOAA Fisheries scientists identified 52 evolutionarily significant units (ESUs), the smallest population unit that can receive federal protection under the ESA. Of these 52 ESUs, 26 have been listed as endangered or threatened. Furthermore, it is estimated that scores of historic populations have become extinct. In this article, we provide a brief overview of salmonid life-history patterns and the importance of salmonids to the culture and ecology of the Pacific Northwest. We describe the recovery planning framework for salmonids, with an emphasis on the habitat components of recovery planning, and we present in detail one new tool, the Salmonid Watershed Analysis Model (SWAM), that has been applied as an early step in developing habitat recovery plans for many of the basins in which listed salmonids live.

Resumen
El salmón del Pacífico que anteriormente existía por millones en 48 estados de los Estados Unidos (ésto es, sin incluir Alaska y Hawaii), se cuenta ahora sólo por millares, centenares y decenas. A principios de los años noventa, el "National Marine Fisheries Service" (Servicio Nacional de Pesca Marina, NMFS), el cual es parte de la "National Oceanographic and Atmospheric Administration" (Administración Nacional Oceanográfica y Atmosférica, NOAA), recibió la petición de listar bajo el "Endangered Species Act" (Acta de Especies en Peligro de Extinción, ESA) de los Estados Unidos, como poblaciones en peligro de extinción o amenazadas a varias poblaciones de salmón . Como resultado de la petición, se llevó a cabo una valuación del estatus para todas las poblaciones de especies anadrómicas que migran entre el océano Pacífico y los ríos y arroyos natales en Washington, Oregón, Idaho y California. Con estas evaluaciones del estatus de poblaciones, los científicos de NMFS (también llamado "NOAA Fisheries") identificaron 52 "evolutionarily significant units" (unidades significativas en términos de su evolución, UES). UES es la más pequeña unidad poblacional que puede recibir protección federal bajo el ESA. De estas 52 UES, 26 han sido listadas como unidades en peligro de extinción o amenazadas. Además, se estima que veintenas de poblaciones históricas se han extinguido. En este artículo, damos un breve resumen de los patrones del ciclo de vida de los salmónidos y la importancia de éstos para la cultura y ecología del Noroeste Pacífico. Describimos el modelo de plan de recuperación, y presentamos en detalle una nueva herramienta llamada "Salmonid Watershed Analysis Model" (Modelo de Análisis de Cuencas de Salmónidos, SWAM), la cual ha sido aplicada como una etapa previa al desarrollo de planes de recuperación de habitat para muchas de las cuencas en las cuales viven los salmónidos listados.

Résumé
Les saumons de Pacifique, dans les Etats-Unis contigus, à une temps comptent dans les millions, comptent actuellement par milliers, les centaines, et les dizaines. Au début des années 90's, le "National Marine Fisheries Service" (le NOAA Fisheries), une partie de "National Oceanographic and Atmospheric Administration", a pétitionné de faire la liste de plusieurs populations de saumons comme des espèces en voie de disparition ou menaces sur le "US Endangered Species Act" (ESA). En conséquence, les évaluations de statu pour toutes les populations des saumons Pacifiques et « anadromous » qui migrent entre le Pacifique et leurs ruisseaux dans le Washington, l'Oregon, l'Idaho, et en Californie. De ces évaluations de statu, NOAA Fisheries a identifié 52 des unités importantes dans le monde d'évolution (ESU), l'unité de population la plus petite qui peut recevoir la protection fédérale sous le ESA. 26 de ces 52 ESU ont énuméré comme des espèces en voie de disparition ou des espèces menacées. De plus, il évaluait que des tas des populations historiques sont devenues disparu. Dans cet article, nous présentons une vue d'ensemble des modes de vie historique et l'importance des saumons a la culture et l'écologie du Nord-Ouest Pacifique. Nous décrivons la structure de la planification de rétablissement pour les saumons, avec emphase sur les composants de l'habitat de la planification de rétablissement, et nous présentons en détail un nouvel outil, le "Salmonid Watershed Analysis Model" (SWAM), qui a été appliqué comme une mesure tôt dans le développement des planifications de rétablissement de l'habitat pour plusieurs des bassins en lesquels les salmonids énumérés habitent.

Salmon and their Importance to the Pacific Northwest

There are seven species of salmonids living in the Pacific Northwest – coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*), chum (*O. keta*), sockeye (*O. nerka*) and pink (*O. gorbuscha*), as well as anadromous steelhead (*O. mykiss*) and cutthroat (*O. clarki*) trout. Each species is made up of one or more evolutionarily significant units (ESUs), which are composed of one or more populations (Figure 1). In most cases, populations correspond roughly to traditional distinctions between stocks used by fisheries management agencies. By definition, independent populations must be reproductively isolated; therefore, salmonid population boundaries are normally delineated using spawning location. The geographic range of a population's spawning area depends on local geography, stream morphology, and, perhaps most importantly, population life history characteristics.

Figure 1. Map of total area occupied by ESA listed anadromous salmonids. Map compiled from various maps of ESA listed anadromous salmonid species (NMFS 2002). These source maps depict major river basins within the current known range of the species or ESU. The various species do not necessarily inhabit all drainages or river reaches depicted. Data for analysis and display were compiled from the best available sources and are for general reference only.

Salmonids have unique life-history patterns that make them at once vulnerable to ecosystem alterations yet highly adaptable to a wide variety of habitat conditions. Salmon build nests in gravel of freshwater streams, lakes, and rivers. The young emerge as fry and, in species such as chum or pink salmon, migrate almost immediately to the near-shore or ocean environment. Other species, such as sockeye salmon, coho salmon, and steelhead, may rear for a year or more in freshwater, often migrating between freshwater habitats before the final migration to the sea. Chinook salmon exhibit a variety of emigration strategies, displaying a range of migrant ages from fry to two-year olds, depending on the population and on local conditions. Most salmonids feed and grow in the ocean, though a few species (e.g., sockeye salmon and steelhead) have life-history variants that remain in freshwater and never migrate (e.g., kokanee and rainbow trout respectively). All species return to their natal streams to deposit eggs; most species are semelparous, spawning once before dying, though some steelhead and most cutthroat trout are iteroparous, maintaining the ability to migrate back to sea after spawning and to return to spawn again. The variability in life-history patterns within and among species and populations enables salmon to utilize multiple habitat types within a watershed; thus, the requirements of individual populations can be important to effective management. For example, those species and populations with an extended freshwater residence seem to be most susceptible to habitat degradation (NRC, 1996). The wide variety of life-history trajectories makes management of multiple listed stocks within a single watershed both critical and challenging.

Salmon are at the cultural, economic and recreational center of many Pacific Northwest communities. For centuries, local tribal communities have relied on salmon for subsistence. Today, many of those tribes continue to rely on salmon as a primary source of revenue. As an economic resource, salmon are an important regional industry. There were estimated to be over 8,000 full-time work years involved in the West Coast salmon industry in the early 1990s (NRC, 1996). However, the economic value of salmon fishing has been declining with salmon population declines. The value of West Coast commercial landings at first sale was estimated at $98 million in 1979 and dropped as low as $6.6 million by 1994 (NRC 1996). Recreational fishing, along with its related industries, provides further economic resources to the region; these industries have also been affected by salmon population declines (NRC 1996). In addition to their cultural and economic benefits, salmon help maintain a healthy ecosystem. Adult salmon returning from the ocean to spawn bring with them nutrients that contribute to the growth of aquatic and terrestrial plants and animals and to the next generation of salmon (Bilby et al. 1996, Bilby et al. 1998, Helfield and Naiman 2001).

The Pacific Northwest has been dramatically altered by humans; its watersheds have been extensively diked, channelized, dammed, logged, mined, farmed and urbanized (Beechie et al. 1994, Sedell and Luchessa 1982). There are multiple hydro-electric dams on major rivers. The Pacific Northwest depends on hydropower for approximately 90% of its electrical energy (NRC 1996). These alterations, in combination with a long history of commercial fishing exploitation, have been identified as chief causes for the decline of salmon populations in the region (NRC 1996).

Recovery Planning

One of the main purposes of the Endangered Species Act (ESA) of 1973 is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." For ESA-listed salmon in the Western United States, this requirement is no small task; salmon habitat is ubiquitous and the actions required to protect or restore the ecosystems on which salmon depend are in conflict with nearly every land use in the region.

Over the past decade, many scientists have pointed out that the approach for managing salmon and other species listed as threatened or endangered has focused on individual species and habitat characteristics, rather than on whole ecosystems (e.g., Doppelt et al. 1993, Frissell et al. 1997). It has also been recognized by scientists and managers alike that restoration plans that carefully consider the watershed or ecosystem context are most likely to be successful at restoring individual or multiple species and preventing the demise of others (Nehlsen et al. 1991, Doppelt et al. 1993, FEMAT 1993, Lichatowich et al. 1995, Reeves et al. 1995, Beechie et al. 1996, Moore 1997). These conclusions suggest that habitat recovery planning will require assessments of disruptions to ecosystem functions and biological integrity, which have reduced the productive capacity of Pacific Northwest river systems and are partly responsible for the declines in salmon abundance. With this approach, restoring specific salmon populations (or any other single organism) is subordinate to the goal of restoring the ecosystem that supports multiple salmon species. In addition, information on habitat changes or conditions that limit specific salmon populations can be useful for identifying actions that may have the greatest effect on salmon recovery (e.g., Reeves et al. 1991), or for helping to set population and ESU recovery goals. As long as all restoration actions are consistent with the overriding goal of restoring ecosystem processes and functions, habitats will eventually be restored for multiple species, but the sequence of actions may favor one species over the others (Beechie et al. In Prep).

NOAA Fisheries is tasked with recovery planning for Pacific salmon, including habitat recovery planning, for species listed under the ESA that spend all or part of their life in the marine environment; therefore anadromous salmonids are under the jurisdiction of NOAA Fisheries. Non-anadromous species in the same watershed, and often in the same stream, are under the jurisdiction of the United States Fish and Wildlife Service (USFWS). Recovery planning over such a wide and diverse geographic area and for multiple species, each with differing habitat requirements and multiple life-history stages, is a challenge. NOAA Fisheries has divided the region into nine recovery domains and appointed a Technical Recovery Team (TRT) for each domain. These TRTs are tasked with developing the technical aspects of a recovery plan for each ESU within the recovery domain.

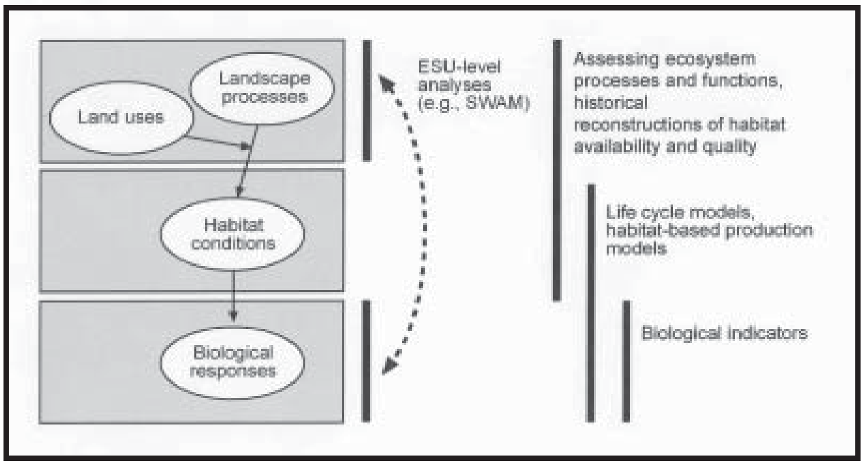


Figure 2. Schematic diagram of linkages among landscape processes, land use, in-stream habitat, and biological responses. For ESU-wide analyses of land use effects on salmon populations, landscape and land use factors can be correlated with indicators of population performance (e.g., SWAM) (Modified from Beechie et al. In Prep.).

The ESA provides limited guidance concerning the content of recovery plans for individual species. Three documents produced by NOAA Fisheries provide additional guidance on recovery planning needs and related scientific concepts. Scientific guidance on setting population recovery goals (McElhany et al. 2000) is based on the concept of viable salmonid populations (VSPs). McElhany et al. (2000) identify four types of goals that must be met in order for a population to be considered viable: abundance; productivity; spatial structure; and diversity. The TRT Guidance Document (NMFS 2000) written by NOAA Fisheries provides detailed information on recovery planning needs. With respect to habitat, this document indicates that an important step in recovery planning is to characterize habitat/fish productivity relationships. This includes assessing the spatial distribution of fish abundance for each population in the ESU, associating fish abundance with habitat characteristics, and identifying human factors that have the greatest impact on key freshwater and marine habitat. However, it does not specify appropriate spatial scales or resolution of data analyses. Lastly, the Watershed Program within the Northwest Fisheries Science Center, in coordination with the TRTs, has nearly completed a NOAA Fisheries Technical Memo, Ecosystem Recovery Planning for Listed Salmon: An Integrated Assessment Approach for Salmon Habitat, which is currently available in draft form on the web at http:// www.nwfsc.noaa.gov/ec/wpg/reports.htm. This document provides a template, scientific considerations, and examples of analyses for developing the habitat component of recovery plans. The document aims to provide tools that can aid in initiating restoration activities that provide for ecosystem-based recovery rather than single-species, short-term, or engineered solutions (Beechie et al. In Prep). A general framework for understanding relationships between watershed processes, land-use, in-stream habitat, and fish populations is provided in the document and forms the underlying working hypothesis of our modeling framework (Figure 2).

The Salmonid Watershed Analysis Model (SWAM)

Relating watershed-scale habitat conditions to fish population response is challenging. Methods based on habitat capacity have been developed in the Pacific Northwest (Reeves et al. 1989, Beechie et al. 1994), but have not been used for regional analyses because they require detailed field data that are not available across all watersheds. Various methods of stream habitat classification also have been used to predict salmon response to habitat condition. For example, a priori classification of channel types can explain substantial variance in salmonid spawner densities (Montgomery et al. 1999), but other important habitat variables also influence salmonid population dynamics such as stream temperature and land-use. Salmon population size usually varies dramatically from year to year due to changes in marine survival and correlation between cohorts. This variability further complicates efforts to link habitat conditions to fish response.

The Salmonid Watershed Analysis Model (SWAM) was developed in response to these challenges. It is a series of spatial and statistical analyses that relate salmonid population counts (e.g., redd counts, adult counts, juvenile counts) at index reaches in a particular basin to coarse-scale habitat characteristics derived from existing geospatial data layers. SWAM identifies large-scale habitat features (anthropogenic and natural) correlated with fish abundance in a given subbasin. It provides a predictive model of where the highest densities of fish in a particular basin are likely to occur, a series of ecological hypotheses about factors driving salmon abundances in a particular basin, and a list of important factors to control for when setting up monitoring projects or management experiments.

SWAM characterizes the relationship between habitat and salmon populations in a given subbasin. The response variable is a time series of fish or redd (salmon nest) counts collected at numerous reaches in that subbasin. Predictive variables consist of habitat data characterized from geospatial data layers of land use type (e.g., grazing, water diversions, logging, mining, urbanization), landscape characteristics (e.g., geology, topography, vegetation), and climatic conditions (e.g., air temperature, precipitation). Consistent relationships between habitat and salmonid abundance over time are then used to predict relative salmonid densities in areas of the subbasin that lack abundance data.

SWAM has been applied in the Salmon River basin in Idaho (Feist et al. In Review), the Snohomish (Pess et al. 2002), Yakima, and Wenatchee River basins in Washington, and the John Day and Willamette River basins in Oregon. The spatial and statistical analyses are similar between basins and are comprised of five steps. (1) Conceptual relationships between coarse-scale habitat features and population abundance during freshwater life-history stages are identified from the literature and from local habitat biologists. These conceptual relationships define which available habitat characteristics will be used as potential predictor variables in the spatial analysis. (2) Spatial heterogeneity in the salmonid abundance data over time is examined to determine if particular areas in the basin consistently exhibit higher fish densities than other areas (Figure 3). (3) Habitat characterization data layers are overlaid with the geo-referenced fish abundance data (e.g., redd counts) (Figure 4). By defining multiple areas of influence, habitat can be characterized at multiple spatial scales, for example, reach and landscape scales. (4) A statistical model is developed to describe annually consistent relationships between habitat characteristics and fish abundance. (5) Predictions based on the model are made for areas within the basin for which no fish data exists.

The SWAM approach differs from previous extrapolation attempts in three important ways: (1) It uses

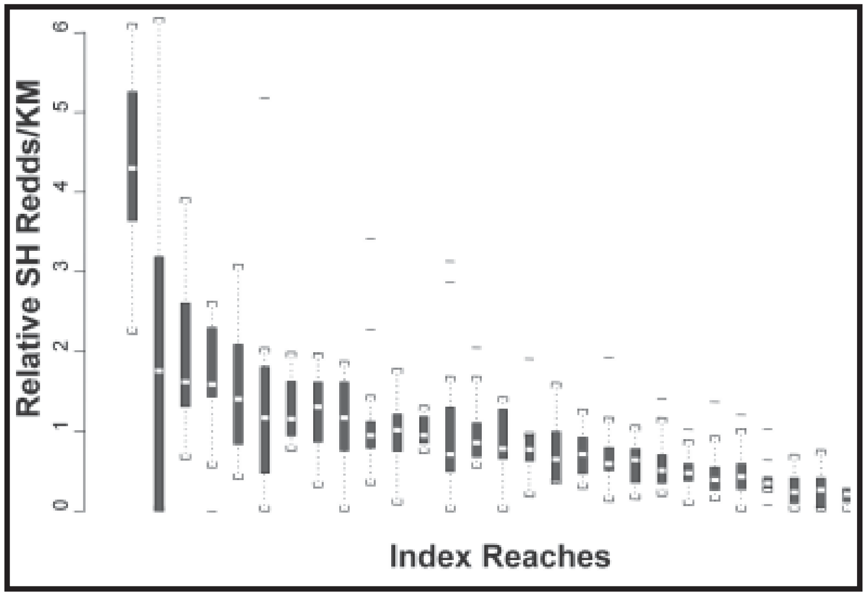


Figure 3. Distribution of steelhead redds by index reach from 1979-1999 in the Santiam, Calapooia, and Molalla watersheds within the Willamette River basin. Relative number of steelhead redds was calculated as the fraction of redd density observed in a particular year within a particular reach divided by the redd density observed over all reaches surveyed in that year.

salmon abundance rather than presence/absence data and is based on existing long-term surveys, (2) It measures habitat from existing GIS data layers using a flexible area of influence, (3) It uses a statistical technique that extracts the most information from the data and explicitly describes model and prediction uncertainty.

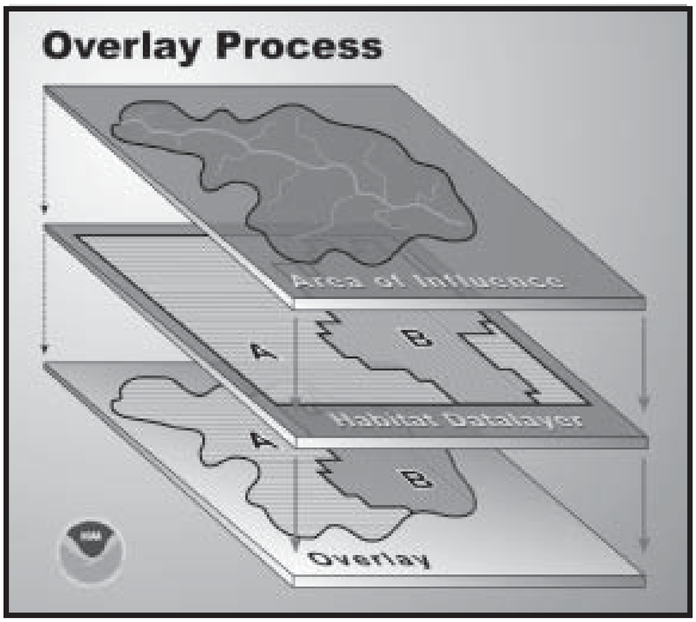


Figure 4. Schematic representation of GIS datalayer overlay process used to determine the fraction or percent area covered by various habitat categories in a given watershed associated with a given index reach.

General SWAM Results

We found that salmonid distribution across basins is temporally consistent. In all basins, certain reaches consistently supported a larger fraction of the population than other reaches (Figure 3). This pattern could be detected through years of both high and low population abundance. Identifying the pattern is dependent on having a long time-series of fish or redd counts at a consistent set of index reaches.

We also found that conclusions about which habitat attributes had the greatest influence on salmon abundance were a function of the area of influence. For example, if we had done our analyses using only a reach area of influence (characterizing habitat within 500 m of the stream channel) in the Salmon River, we would have concluded that ambient air temperature was the primary driver of spawner density. By also running our analyses for the watershed area of influence (characterizing habitat over the entire watershed that drains to the index reach), we learned that descriptors of vegetation as well as geology and terrain influence salmon abundance (Feist et al. In Review). Analysis scale also influences model fit. In analyses of chinook salmon in the Wenatchee River basin, models using habitat data characterized over the reach area of influence had a poor fit as compared to models using habitat data characterized over the entire watershed.

In all the basins, our results are consistent with our underlying working hypothesis that watershed-scale features describing climate, geology, and land-use affect many of the in-stream conditions determining fish abundance (Table 1). Geomorphic features control such site-specific factors as stream width, alkalinity and stream slope (Isaak and Hubert 2001), each of which affects the suitability of a particular reach for spawning or rearing. Climate can regulate flow and water temperature, and land-use has the potential to modify nearly every aspect of instream habitat conditions.

Potential Uses of SWAM for Recovery Planning

Recovery planning for listed salmonids is being carried out in two phases. Phase I recovery-planning actions consist of setting recovery benchmarks such as biological de-listing goals. Phase II actions are aimed at developing a detailed list of actions (e.g., habitat protection or restoration, and harvest or hatchery regulations) required for recovery of each ESU. Models are being employed in both steps because of the broad geographic areas involved, the complexity of salmonid life-history patterns, the lack of adequate field-based data, and the need for predictions about habitat change and population response. SWAM assessments have uses in both phases of recovery planning. In Phase I, they may provide habitat-based estimates of average population size for comparison to estimates from population viability analyses. In Phase II, they can indicate which habitat conditions are correlated with declines in salmon populations, and therefore, which categories of restoration actions might result in increased salmon populations. They can also estimate the potential of currently inaccessible or unstudied habitat for supporting salmonids.

SWAM results can help plan small-scale restoration in the context of whole watersheds. For example, removing anthropogenic barriers to fish passage has been identified as a restoration action with a high likelihood of success and a very low likelihood of negative impacts (except for impacts on the resident fish populations when they are suddenly re-exposed to competition with anadromous fishes) (Roni et al. 2002). Therefore, barrier removals are one of the best actions to initiate during the first stages of recovery management. Observations of fish use of habitats above barriers being considered for removal are not possible, presenting a difficult problem. Using remotely sensed data and SWAM-based predictions of potential occupancy in currently inaccessible areas, a series of prioritization schemes for barrier removal projects can be developed. While model-based prioritization schemes cannot substitute for detailed field analysis, they can greatly reduce the time required for such field surveys by identifying a set of projects most likely to be successful.

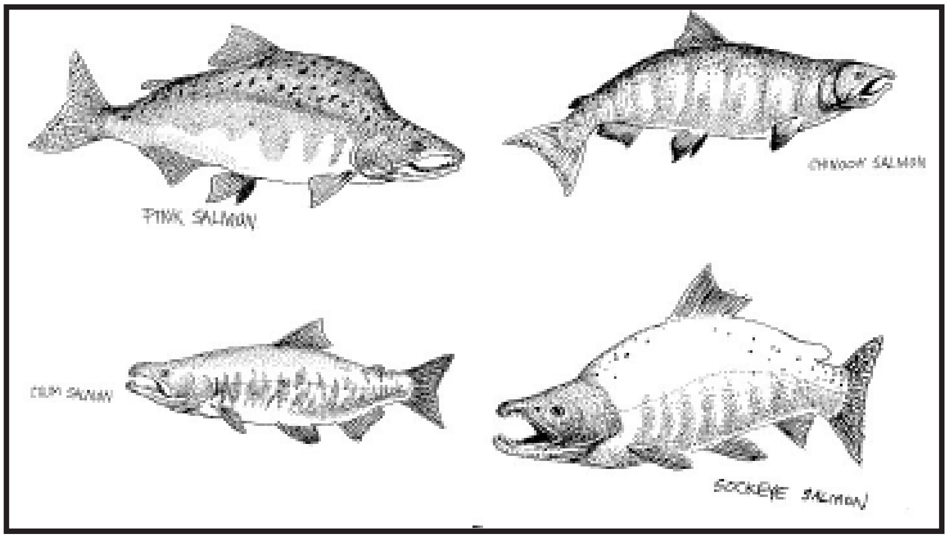
In the Snohomish River basin, our analysis provides a method to identify which habitat attributes correlate with the greatest adult coho salmon abundance (Pess et al. 2002). The SWAM results can be used as a coarse-screening tool for several purposes. For example, results could be used to identify sites, currently impaired by land use, which could potentially have greater abundance levels. Restoration activities might then be prioritized to address first those impaired locations that are predicted to have the appropriate habitat attributes for supporting high salmon abundances. Results might also be used to identify areas with a predicted high abundance of salmonids and a high risk of habitat degradation in the future. These sites might provide a first estimation of areas for conservation and protection. In both cases, on-the-ground assessments should be used to validate model predictions.

Predictor Variable	Chinook Salmon				Steelhead	
	Yakima	Wenatchee	Salmon	John Day	John Day	Willamette
Channel Gradient	X	X				
Hill Slope†		X	X			X
Riparian Vegetation	X		X			
Shrublands						X
Conifer Forest < 40 yr						
Alpine Vegetation	X				X	
Open Water		X				
Ponderosa Pine		X				
Successional Forest		X				
Agriculture	X					X
Urbanization				X		
Dam Density	X	X				
Mine Density		X				
Cattle Grazing				X	X	
Sheep Grazing					X	
Minimum Air Temp.			X			
Maximum Air Temp.			X			
Precipitation					X	
Alluvium		X				X
Landslide-derived Geology						X
Mafic Volcanics						X
Sedimentary Geology			X	X		
†< 6% for steelhead, < 1.5% for chinook salmon						

Table 1. Landscape variables used to predict redd densities in 5 subbasins of the Columbia River. All variables except channel gradient, air temperature, precipitation, dam density and mine density describe the proportion of the index reach watershed composed of that feature.

SWAM analyses describe relationships between broad-scale habitat characteristics and salmon population patterns. The models can help identify areas most likely to be successful for salmon spawning or rearing. Like all models, SWAM is limited by available data. Most abundance surveys were not conducted in low quality habitats where there are low numbers of fish. As a result, SWAM models currently characterize areas which comprise some of the better habitats for fish and predict the best of these already good habitats. Sampling protocols specifically designed to understand relationships between habitat condition or habitat change and fish populations will require random sampling procedures and time series of habitat change. SWAM models can easily accommodate such new data when it exists.

The use of large-scale analyses in management of endangered species is gaining momentum. Large-scale models predicting the presence and absence of butterflies (Cowley et al. 2000) have provided conservation biologists with management tools that can substitute for expensive, detailed field analyses where they are lacking. Other GIS-based approaches to identifying salmon spawning habitat have been or are being developed (e.g., Lunetta et al. 1997). Examining patterns of abundance or survival at larger scales represents a new opportunity for understanding patterns of fish distribution and for making predictions about where in a watershed large numbers of fish might thrive (Poff and Huryn 1998). The SWAM approach has both scientific interest for exploring and understanding how fish are distributed as well as immediate management applications.



Pacific salmons. Art by Bob Savannah. Courtesy of U. S. Fish and Wildlife Service

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Book Review
Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna

J.M. Scott, S. Conant, and C. Van Riper, III, Editors
Studies in Avian Biology No. 22
A Publication of the Cooper Ornithological Society

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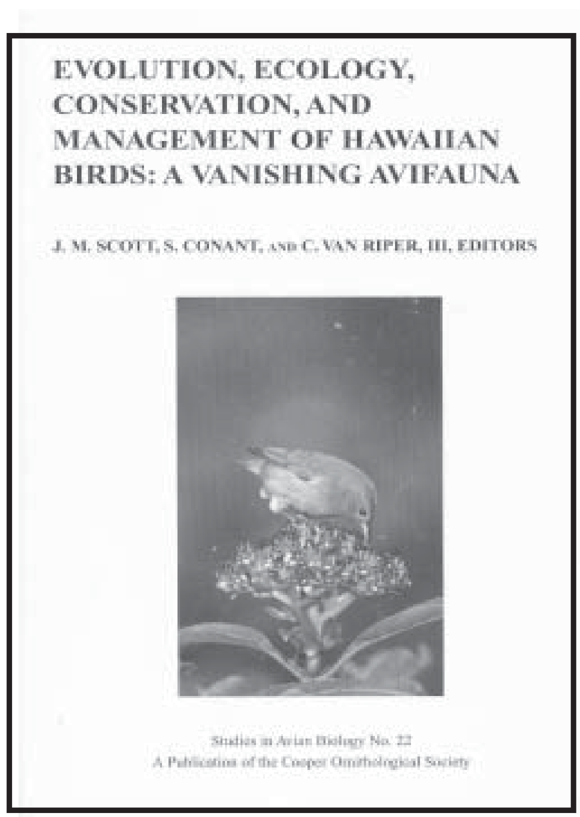
Abstract
Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna, edited by J. M. Scott, S. Conant, and C. Van Riper is a collection of 35 peer-reviewed papers chronicling numerous studies on Hawaiian birds. The topics covered include historical perspectives, systematics, population status and trends, ecology, limiting factors, and recovery and management. The sections on ecology, recovery and management, and limiting factors are particularly powerful, while the others present useful information, but are not as bold. Each section provides case studies from which both novice and professional biologists can learn. This collection of essays could be used as a template for future studies on the birds of the Hawaiian Islands.



Resumen
"Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna" (Evolución, Ecología, Conservación y Manejo de las Aves de Hawaii: Una Avifauna que desaparece), editado por J. M. Scott, S. Conant y C. Van Riper es una colección de artículos revisados por jurado, los cuales describen numerosos estudios sobre aves de Hawaii. Algunos de los tópicos que se incluyen son: perspectivas históricas, sistemática, estatus y tendencia de poblaciones, ecología, factores limitantes, recuperación y manejo. Las secciones sobre ecología, recuperación y manejo, y factores limitantes son particularmente interesantes, mientras que las otras secciones presentan información valiosa, pero no son tan innovadoras. Cada sección provee estudios de campo de los cuales tanto biólogos novatos como experimentados pueden aprender. Esta colección de ensayos pudiera ser usada como modelo para futuros estudios sobre aves de las islas hawaianas.

Résumé
"Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna" (L'évolution, l'écologie, la réservation, et la gestion des oiseaux hawaiiens : Une Avifaune Disparaît) corrigé par J.M. Scott, S. Conant, et C. Van Riper, elle est un recueil de 35 essaies critiquent par pairs, qui fait la chronique de plusieurs études. Les sujets traitaient inclus des points de vues historiques, des systématiques du statut et des tendances de la population, d'écologie, des facteurs restrictif et le rétablissement et la gestion. Les sections d'écologie, de rétablissement et de gestion et des facteurs restrictifs sont particulièrement puissants, alors que les autres sujets offrent l'information utile, mais ils ne sont pas aussi forts. Chaque section fournit les études de cas dont les biologistes novices et professionnels, les deux apprennent. Ce recueil d'essais peut commencer à se servir d'un gabarit pour des futures études des oiseaux des îles Hawaii.

Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna is a comprehensive collection of 35 peer-reviewed studies on Hawaiian birds. The scope of the book includes sections devoted to historical perspectives on bird populations, systematics, species' status and trends, ecology, factors limiting bird survival, and recovery and management. Although the amount of information included in each section varies, readers will find a plethora of fascinating research covering each topic. Altogether, this essay compilation is a very enjoyable and eye-opening piece. I recommend it to anyone who is even slightly interested in Hawaiian wildlife or biological conservation. It also has applicable uses for land managers and conservation biologists, and will serve as a powerful educational tool for wildlife students. Since all of the articles are research oriented, it includes scientific terms and techniques that may be difficult to comprehend by readers not familiar with the subject. The article "Phylogenetic Placement of the Po'ouli,Melamprosops phaeosoma, based on Mitochondrial DNA sequence and Osteological Characters" in the systematics section is particularly difficult to understand. The results section of each paper will provide a good synopsis, so I recommend reading this part first if the topic is new to you. In that way, your reading experience will not be severely hindered.

The ecology section is the strongest part of the book. The ecological research provides readers a brief look into the intricacies and complexities of species' interactions with their environment. It demonstrates very well how species rely on each other and specific elements of their environment, and how change in one piece of the ecosystem can have a devastating effect on species' survival. For example, Leonard A. Freed's paper describes the 'akepa's (*Loxops coccineus coccineus*) reliance on old-growth forests for nesting trees. The methodology of the research presented in each paper appears to be very thorough. Students of wildlife and conservation would benefit a great deal from examining these case studies in Hawaiian bird ecology.

Twenty-nine species of birds are threatened or endangered in Hawaii, thus it is appropriate that the book includes a large section on recovery and management. The topics in this segment include predator control, vegetation regeneration, exotic species control, population supplementing, reintroduction, and captive breeding programs. For the most part the individual papers focus research on a single aspect of species recovery. I feel that this is somewhat limited, because recovery must incorporate all of the ecological factors in a given area. However, it works fine for the purpose of the book, which is to educate both the public and the experts on the dire condition of Hawaiian avifauna and to make them strive for conservation of these precious birds. The final article from this section, William W. M. Steiner's "Evaluating the Cost of Saving Native Hawaiian Birds" examines the costs and benefits of Hawaiian avian research and management over the years. Steiner talks about everything from the boost in local economies to some pressing problems that still need to be studied. It is a good concluding chapter, encompassing all the ideas previously talked about in the book and relaying their relevance to everyone.

The opening section on historical perspectives includes two papers, one focusing on past populations and species, the other concentrating on introduced species to the Hawaiian Islands. "How Many Bird Species in Hawaii and the Central Pacific before First Contact?," reveals estimates on the historic bird populations of different areas and numbers of endemic bird species that may have gone extinct. This is a depressing subject, yet a necessary opening article. The material presented is fascinating, but as the article states, the data is very limited. "Patterns of Success among Introduced Birds in the Hawaiian Islands," a paper on invasive species, explores the common adaptations and circumstances that have allowed certain introduced species to thrive, versus those species that have failed. Family characteristics and range size are discussed in terms of the ability of a species to survive on the islands. I found this article useful as an analytical tool, because its evaluation of the traits that determine an exotic species' survival can be applied to other island communities as well.

Systematics is a field that is undergoing a rapid revolution due to the new molecular techniques available, and birds have long been the subject of these studies. The papers under this topic delve into the relationships of several honeycreepers and part of the mallard complex. Because of its extensive species radiations, Hawaii serves as an ideal location to conduct this research. Those interested in the variation and beauty of the honeycreepers may find these studies especially intriguing, for it provides insight into the many evolved characteristics of this family. Fleischer et al.'s "Phylogenetic Placement of the Po'ouli, Melamprosops phaeosoma, based on Mitochondrial DNA Sequence and Osteological Characters" tries to resolve the recent controversy surrounding the proper taxonomic placement of the endangered Po'ouli, long believed to be part of the subfamily Drepanidini. The next three papers take a closer look at status and trends of specific species. The following article conveys the status and trends of Hawaiian bird species by detailing the results of a large-scale rare bird survey that took place between August 1994 and April 1996. The extremely low detection rate of the survey conveys how truly bleak the current situation is for some species. This study could be used effectively in an educational public program for endangered species.

Two of the editors J.M. Scott and C. Van Riper, III, provide the opening paper on limiting factors of Hawaiian bird survival. They divide the factors into six categories and discuss each in relative detail: habitat change, human predation, nonhuman predation, avian competition, avian parasites and disease, and abiotic factors. Each of these factors is talked about in time periods of pre-human contact, post-Polynesian contact, and post-European contact. In this way readers get a picture of how the threats to species have evolved with changing circumstances. Following a similar organization, the rest of the articles in this division specify how one or more of these factors relate to the survival of a species or group of species. "Immunogenetics and Resistance to Avian Malaria in Hawaiian Honeycreepers (Drepanidinae)" and "Newly Emergent and Future Threats of Alien Species to Pacific Birds and Ecosystems" deal with two of the major current threats facing Hawaiian avifauna. If you are interested in conservation and management, or just concerned over Hawaiian birds' plight, this is a section you must read.

As a student of wildlife and conservation, I found Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna to be a very unique educational tool. It can be seen not only as a broad study of Hawaiian birds, but also as an example of the dynamics of island avifauna in general. I thoroughly enjoyed the book and feel that the editors did an admirable job putting it together. I recommend it to anyone interested in Hawaiian birds or case studies in conservation biology.

Tooth Cave Species

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Abstract
The Tooth Cave spider (*Neoleptoneta myopica*), Tooth Cave pseudoscorpion (*Tartarocreagris texana*), and Tooth Cave ground beetle (*Rhadine persephone*) are endangered invertebrates of specific karst formations in Texas. The limited distribution, ecological specialization, and low population density of these species pose a high risk to their survival. Human development activities are severely threatening karst habitats by filling in caves, altering drainage patterns, disrupting surface plant and animal communities, and producing chemical contamination. Human quarrying and mining are degrading and destroying possible habitat and, in addition, imported fire ants could pose problems through competition. These perils led to the federal listing of these species as endangered in 1988 and the formation of a recovery plan in 1994. The recovery plan aims to downlist these species to threatened status through further surveying and research, protecting and managing targeted habitats, creating educational programs, and continually monitoring involved programs.

Resumen
La araña de la cueva Tooth (*Neoleptoneta myopica*), el pseudoscorpion de la cueva Tooth (*Tartarocreagris texana*), y el escarabajo de tierra de la cueva Tooth (*Rhadine persephone*) son invertebrados en peligro de extinción que se encuentran en formaciones cársicas específicas en Texas. La distribución limitada, la especialización ecológica y la baja densidad poblacional de estas especies crea condiciones de alto riesgo para su supervivencia. Las actividades de desarrollo humano están amenazando severamente los hábitats cársicos al tapar cavernas, alterar los patrones de drenaje, irrumpir comunidades de plantas y animales, y al producir contaminación química. La minería y la explotación de canteras por el hombre están degradando y destruyendo posibles hábitats, además de que hormigas de fuego no nativas provocan problemas de competencia. Estos riesgos llevaron al listado de estas especies como especies en peligro de extinción en 1988 y a la formación de un plan de recuperación en 1994. El plan de recuperación tiene como objetivo cambiar el estatus de estas especies de especies en peligro de extinción a amenazadas a través de un mayor muestreo e investigación, protegiendo y manejando hábitats de interés, creando programas educativos y continuando programas que involucran "monitoreo."

Résumé
L'araignée de Caverne Tooth, (*Neoleptoneta myopica*), le pseudoscorpion de Caverne Tooth (*Tartarocreagris texana*), et le coléoptère de terre de Caverne Tooth (*Rhadine persophone*) sont des invertébrés en voie de disparition des formations de karst spécifiques au Texas. La distribution limitée, la spécialisation écologique, et la basse densité de population représentent une grande menace pour leur survie. Les activités de développement par les humains menacent sévèrement les habitats karst par bouchant les cavernes, modifiant le système de fosses, dérangeant les communautés des plantes et des animaux à la surface, et produit la contamination chimique. L'extraction et l'exploitation minière dégradent et détruisent les habitats éventuels et de plus des fournis de feu seront un problème par la concurrence. À cause de ces dangers, ils sont sur la liste fédérale des espèces en voie de disparition depuis 1998, et demandent la création d'un projet de rétablissement vise à déclasser des espèces en voie de disparition à statut menace par inspection et recherche, protége et dirige les habitats cibles, crée des programmes éducatifs et suivit de près continuellement les programmes impliqués.

Tooth Cave ground beetle	Tooth Cave pseudoscorpion	Tooth Cave spider
Kingdom: Animalia	Kingdom: Animalia	Kingdom: Animalia
Phylum: Arthropoda	Phylum: Arthropoda	Phylum: Arthropoda
Class: Insecta	Class: Arachnida	Class: Arachnida
Order: Coleoptera	Order: Araneae	Order: Psuedoscorpiones
Suborder: Adephaga	Infraorder: Araneomorphae	
Family: Carabidae	Family: Leptonetidae	Family: Neobisiidae
Genus:Rhadine	Genus: Neoleptoneta	Genus: Tartarocreagris
Species: *Rhadine persephone*	Species: *Neoleptoneta myopica*	Species: *Tartarocreagris texana*

Geographic Range

The present distributions of the Tooth Cave spider (*Neoleptoneta myopica*), the Tooth Cave pseudoscorpion (*Tartarocreagris texana*), and the Tooth Cave ground beetle (*Rhadine persephone*) are confined to Williamson and Travis Counties in central Texas (Figure 1). The species are troglobitic invertebrates that only inhabit karst formations. They seem to prefer the dark zones of these caves and subterranean crevices where the relative humidity is about 100%. The first described specimen of each species was collected from Tooth Cave in Travis County, thus their common names.

The ranges of *N. myopica* and *T. texana* are very limited. These two species have been found at only four caves, coexisting in two of them. All four caves are located at the Jollyville Plateau in Travis County. The distribution of *R. persephone* is much greater, including at least 27 localities in both the Jollyville Plateau and the Cedar Park region, which spans parts of Travis and Williamson counties. The Jollyville Plateau and Cedar Park areas are two of the many karst fauna regions found in Texas (FWS 1994).

Physical Characteristics

The Tooth Cave spider is a true spider member of the Leptonetidae family. Leptonetids are small spiders that usually have long legs, six eyes, and live in subterranean habitats (Gertsch 1974). *N. myopica* is pale in color, has a body length of approximately 1.6mm, and its first pair of legs is 6.1 times the length of its carapace. The Tooth Cave spider resembles several similar karst species in Texas, but can usually be distinguished by the length of its legs and by certain eye characters. Positive identification can be obtained through the examination of the male or female genitalia. (FWS 1994)

Pseudoscorpions are tiny arachnids that somewhat resemble scorpions, but differ from the latter in their internal structure and mouthparts, as well as in the lack of a tail appendage (stinger). The Tooth Cave pseudoscorpion is light brown in color and lacks eyes. It is a relatively large pseudoscorpion (4.1 mm female body length) and has elongated appendages. *T. texana* is not easily identified and can only be distinguished from other similar species through very close examination, often only through dissection of the genitalia (FWS 1994).

The genus Rhadine in the family Carabidae (ground beetles) includes many species in North America. Species in this genus are rather small compared to many other beetle species, with a large disparity in the sizes of individuals between species. *R. persephone* has a body length of about 8.0 mm and is considered stout for this genus. It is reddish-brown in color and convex in shape. The species also has long antenna (6.8 mm) and a wide pronotum (1.18 mm). These morphological characters help to distinguish it from other close relatives (FWS 1994).

Natural History

There is little known about the natural history of these species. Karst terrain is difficult to work in and the species are not easily found. It is known that they are troglobites and spend their entire life cycle underground. They prefer the dark zones of caves and other karst formations with humidity near 100%. Thus they are most likely sensitive to changes in humidity. Troglobites are also usually found in the warmer parts of caves. The microhabitat preferences of each species are not known. Collections from different times throughout the year have shown no lifecycle seasonality for any of the species. This is a common characteristic of many karst species that spend their entire lives beneath the surface.

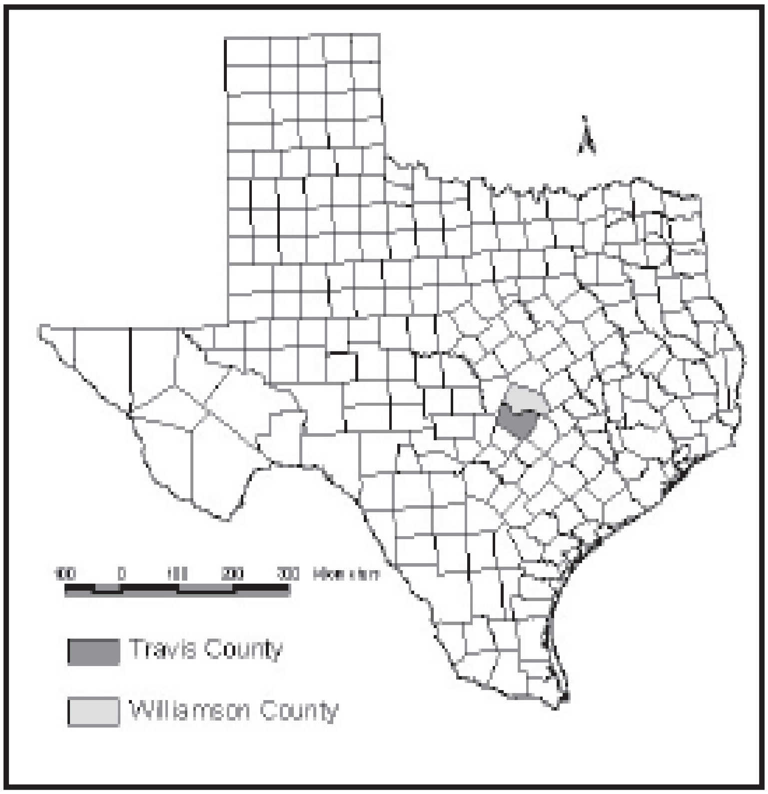

Figure 1. Counties in Texas where the Tooth Cave species are found.

N. myopica, T. texana, and *R. persephone* are predators and feed on microarthropods. Their cave habitat must have a nutrient source for prey species, which most likely comes from surface plants and animals. Caves with internal layers of calcite or some other type of surface barrier can prevent water and nutrient infiltration, so they are not inhabited by these species. Nutrients from plant roots or leaf debris may be used, as well as animal feces and carcasses. Cave crickets and raccoons have been noted as key nutrient suppliers, for they often use the caves in this region of Texas (FWS 1994).

The exact prey species are not known, but because so many other predators live in the same environment, it is believed that the feeding strategies of these three invertebrates may be species-specific. Species of collembolans, which reproduce at a high rate when organic material is around, are probably important prey. The fecal material from raccoons may provide such a source for a collembolan bloom. The Tooth Cave ground beetle may also feed on the eggs of cave crickets, for a very similar species, *R. subterranean,* was observed feeding on them (FWS 1994).

The Tooth Cave spider is a sedentary predator that awaits prey while hanging from its sheet web. Similarly, the Tooth Cave pseudoscorpion is also a sedentary predator, but is usually found underneath rocks. The Tooth Cave ground beetle is a much more active predator, and has been seen running rapidly while hunting on the cave floor (FWS 1994). While not hunting, *R. persephone* is also generally found under rocks. Because of its active behavior, food may be a limiting factor for the ground beetle. Food is probably not a major limiting factor for the spider and pseudoscorpion due to their more sedentary lives, which makes them less dependent on energy sources.

Conservation Status

The Tooth Cave spider, Tooth Cave pseudoscorpion, and the Tooth Cave ground beetle were all proposed for endangered status in April 1988 and officially listed in September 1988 as endangered under the Endangered Species Act, along with four other karst invertebrates (FWS 1994). Other conservation organizations have yet to make a formal judgment on their status. For example, the International Union for the Conservation of Nature (IUCN) believes that not enough data have been collected on *N. myopica* or *T. texana*'s distribution and population to assign them a conservation status.

Limited distribution, ecological specialization, and low population density make these three species very susceptible to environmental threats. Urban development is the biggest threat to the survival of the Texas karst species. The species' habitats are all located near developed or developing areas. The United States Fish and Wildlife Service (FWS) noted several current threats that stemmed from urban development: the filling in and collapsing of caves; alteration of drainage patterns; alteration of surface plant and animal communities; contamination; and human visitation (FWS 1994). Other threats to these species' survival include competition from exotic red fire ants (*Solenopsis invicta*) and mining, and quarrying in caves. Although there have been no direct observations, red fire ants, a very invasive species in Texas, may compete for food sources or even feed directly on the endangered species. Also, the mining and quarrying within Texas caves could render possible habitat for these species unsuitable.

Conservation Action

FWS completed and approved a recovery plan for the endangered karst invertebrates of Travis and Williamson counties in August 1994. Conservation measures before the approval of the recovery plan emphasized surveying known and possible habitats for the three species to get a clear idea of the boundaries and locations of each species. In addition, studies were conducted on fire ant control and hydrogeologic processes (FWS 1994). The objective of the current recovery plan for these species is a downlisting to threatened status, not for complete recovery. The tasks needed to complete the objective are a) identify karst fauna areas needed to meet recovery criteria; b) determine the appropriate size and configuration of karst fauna areas targeted for recovery; c) provide areas targeted for recovery; d) implement conservation measures and manage karst fauna areas targeted for recovery; e) conduct additional research; f) develop educational programs; and g) develop a monitoring program. In order to protect karst fauna in the long-term, the recovery team must work cooperatively with private landowners and must acquire land for governmental protection. The conservation and management measures may have to include fire ant control, protection of nutrient inputs, and prevention of human disturbances to the caves. As far as further research needed in order to implement new conservation programs, biologists will have to collect more distribution information, study the hydrogeology of each area and conduct studies on individual species' ecology (FWS 1994).

As a specific criteria to achieve the downlisting of the three Tooth Cave species, FWS has established the protection of three karst fauna areas within each karst fauna region, such as the Jollyville Plateau and the Cedar Park regions. This protection must be maintained for five consecutive years, at which point it will be considered perpetually protected.

Economic Importance

None known.

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Tooth Cave ground beetle	Tooth Cave pseudoscorpion	Tooth Cave spider
Reino: Animalia	Reino: Animalia	Reino: Animalia
Phylum: Arthropoda	Phylum: Arthropoda	Phylum: Arthropoda
Clase: Insecta	Clase: Arachnida	Clase: Arachnida
Orden: Coleoptera	Orden: Araneae	Orden: Psuedoscorpiones
Suborden: Adephaga	Infraorden: Araneomorphae	
Familia: Carabidae	Familia: Leptonetidae	Familia: Neobisiidae
Género:Rhadine	Género: Neoleptoneta	Género: Tartarocreagris
Especie: *Rhadine persephone*	Especie: *Neoleptoneta myopica*	Especie: *Tartarocreagris texana*

Rango Geográfico

La distribución actual de la araña de la cueva Tooth (*Neoleptoneta myopica*), el pseudoescorpión de la cueva Tooth (*Tartarocreagris texana*) y el escarabajo de tierra de la cueva Tooth (*Rhadine persephone*) está limitada a los condados de Williamson y Travis en la parte central de Texas (Figure 1). Las especies son invertebrados troglodíticos que habitan únicamente en formaciones cársicas. Parecen preferir las zonas oscuras de las cuevas y hendiduras subterráneas donde la humedad relativa es cercana al 100%. Su nombre se debe a que el primer especimen descrito de cada especie fue colectado de la cueva Tooth en el condado de Travis.

Los rangos geográficos de *N. myopica* and *T. texana* son muy limitados. Estas dos especies han sido encontradas en sólo cuatro cuevas, coexistiendo en dos de ellas. Las cuatro cuevas se localizan en el altiplano de Jollyville localizado en el condado de Travis. La distribución de *R. persephone* es más extensa, incluyendo al menos 27 localidades en el altiplano de Jollyville Plateau así como también en la región del parque Cedar Park, la cual abarca partes de los condados de Travis y Williamson. El altiplano de Jollyville y las áreas del parque Cedar son dos de las muchas regiones cársicas que se encuentran en Texas (FWS 1994).

Características Físicas

La araña de la cueva Tooth es una araña verdadera que pertenece a la familia Leptonetidae. Los leptonétidos son arañas pequeñas que usualmente tienen patas largas, seis ojos y viven en hábitats subterráneos (Gertsch 1974). *N. myopica* es de color pálido, con un tamaño de cuerpo de aproximadamente 1.6 mm y su primer par de patas es 6.1 veces la longitud de su cuerpo. La araña de la cueva Tooth se asemeja a varias especies cársicas similares en Texas, pero usualmente se puede distinguir por la longitud de sus patas y por ciertas características de los ojos. Una identificación exacta se puede obtener a través del examen de la genitalia del macho o de la hembra (FWS 1994).

Los pseudoescorpiones son arácnidos muy pequeños que se asemejan a los escorpiones, pero que difieren de éstos en su estructura interna y en las partes bucales, así como también por carecer de un apéndice abdominal (aguijón). El pseudoescorpión de la cueva Tooth es de color café claro y carece de ojos. Es un pseudoescorpión relativamente grande (4.1 mm de longitud de cuerpo en las hembras) y tiene unos apéndices alargados. *T. texana* no se puede identificar fácilmente y se puede distinguir de otras especies similares únicamente por medio de un examen riguroso, que frecuentemente implica la disección de genitalia (FWS 1994).

El género Rhadine dentro de la familia Carabidae (escarabajos de tierra) incluye muchas especies en Norteamérica. Las especies de este género son en general pequeñas en comparación con muchos otras especies de coleópteros, con una disparidad en el tamaño de los individuos entre las especies. *R. persephone* tiene una longitud de cuerpo de cerca de 8.0 mm, lo que se considera grande para este género. Es de un color café rojizo y el cuerpo tiene una forma convexa. Esta especie tiene también antenas largas (6.8 mm) y un pronoto ancho (1.18 mm). Estas características morfológicas ayudan a distinguirlo de otras especies similares (FWS 1994).

Historia Natural

Se conoce muy poco de la historia natural de estas especies. Es muy difícil de trabajar en un terreno cársico y las especies no se encuentran fácilmente. Se sabe que son especies trogloditas y que pasan su ciclo de vida completo en el subsuelo. Estas especies prefieren las zonas oscuras de cuevas y otras formaciones cársicas con una humedad cercana al 100%. Por lo que se infiere que es muy probable que sean muy sensibles a los cambios de humedad. Las especies troglodíticas se encuentran usualmente en las partes más cálidas de las cavernas. Las preferencias de microhábitat de cada especie son desconocidas. Las colectas hechas en diferentes épocas del año muestran que no existe una época específica en el ciclo de vida para ninguna de las especies. Esta es una característica común de muchas especies cársicas que pasan la vida entera debajo de la superficie del suelo.

N. myopica, T. texana y *R. persephone* son depredadores y se alimentan de microartrópodos. Su hábitat dentro de las cuevas debe tener una fuente de nutrientes para las presas, la cual muy probable provenga de animales y plantas de la superficie. Las cuevas con capas internas de calcita u otro tipo de barrera en la superficie pueden evitar infiltración de agua y nutrientes, por lo que no son habitadas por estas especies. Los nutrimentos de raíces de plantas y hojarazca pueden ser usados, así como también heces y restos de animales. Se ha observado que grillos de cuevas y mapaches son proveedores clave de nutrimentos, pues estos organismos frecuentemente utilizan las cuevas en esta región de Texas (FWS 1994).

No se conocen las especies que específicamente sirven de presa, pero debido a que muchos otros depredadores viven en el mismo medio ambiente, se cree que las estrategias de alimentación de estos tres invertebrados pudiesen ser específicas en cuanto a presas. Las especies de colémbolos, que se reproducen a un ritmo elevado cuando existe materia orgánica, son probablemente presa importante. El material fecal de mapaches pudiese proveer de tal material para una abundancia de colémbolos. El escarabajo de tierra de la cueva Tooth pudiese también alimentarse de huevecillos de grillos de cuevas debido a que una especie similar, *R. subterranean,* ha sido observada haciéndolo (FWS 1994).

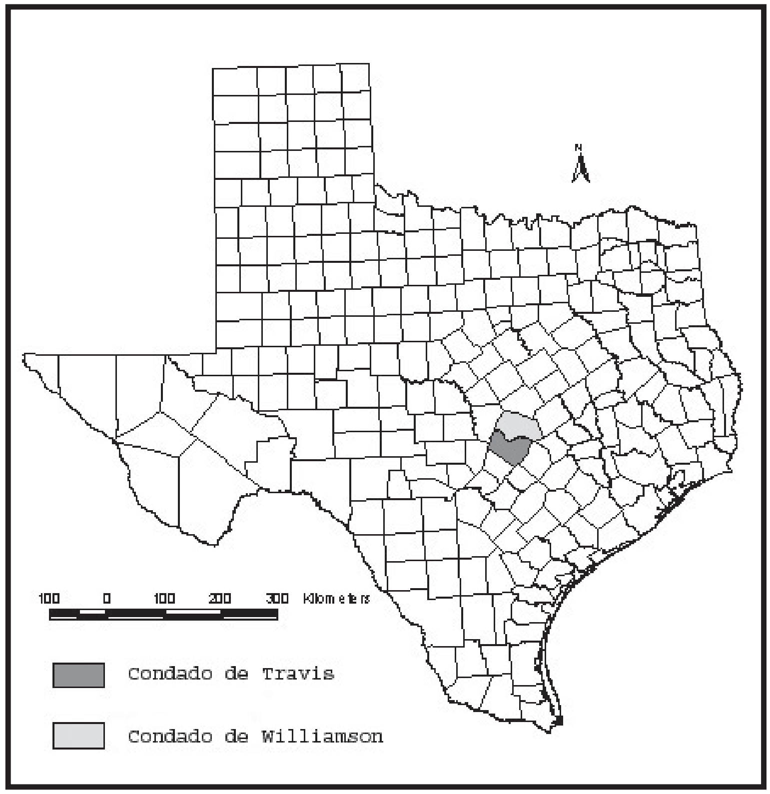

Figura 1. Condados en Texas donde se localizan las especies de la cueva Tooth

La araña de la cueva Tooth es un depredador sedentario que espera la presa mientras cuelga de su telaraña. En forma similar, el pseudoescorpión es también un depredador sedentario, pero usualmente se encuentra debajo de rocas. El escarabajo de la cueva Tooth es un depredador mucho más activo, el cual ha sido visto corriendo rápidamente al momento de cazar en la superficie de la cueva (FWS 1994). *R.*

persephone se encuentra debajo de rocas cuando no está cazando. Debido a su comportamiento activo, el alimento pudiese ser un factor limitante para este escarabajo. La comida no es probablemente un factor limitante para la araña y el pseudoescorpión debido a su vida sedentaria, lo que los hace menos dependientes de fuentes de energía.

Estatus de Conservación

El estatus de peligro en extinción de la araña de la cueva Tooth, el pseudoescorpión de la cueva Tooth y el escarabajo de tierra de la cueva Tooth fue propuesto en abril de 1988 y oficialmente fueron listados en septiembre de 1988 en el "Endangered Species Act" (Acta de Especies en Peligro de Extinción) como especies en peligro de extinción junto con otras cuatro especies de invertebrados cársicos (FWS 1994). Otras organizaciones de conservación no han hecho una determinación formal del estatus de estas especies. Por ejemplo, la "International Union for the Conservation of Nature" (Unión Internacional para la Conservación de la Naturaleza, IUCN) cree que no se han colectado suficientes datos sobre la distribución y estatus poblacional de *N. myopica* or *T. texana* para asignarles un estatus de conservación.

La distribución limitada, la especialización ecológica y la baja densidad poblacional hace muy susceptibles a amenazas ambientales a estas especies. El desarrollo urbano es la más grave amenaza para la supervivencia de las especies cársicas de Texas. Los hábitats de las especies se localizan cerca de areas desarrolladas o en desarrollo. El "United States Fish and Wildlife Service" (Servicio de Pesca y Vida Silvestre de Estados Unidos, FWS) ha detectado varias amenazas actuales que provienen del desarrollo urbano: el rellenado y el colapso de cuevas; la alteración de patrones de drenaje; la alteración de comunidades de plantas y animales en la superficie; contaminación; e incursiones humanas (FWS 1994). Otras amenazas para la supervivencia de estas especies son la competencia de hormigas rojas de fuego (*Solenopsis invicta*) y la minería y explotación de cantera en las cuevas. Aunque no existen observaciones directas, las hormigas de fuego, una especie exótica en Texas, pudiese competir por fuentes de alimento o alimentarse directamente de estas especies en peligro de extinción. Además, la minería y explotación de cantera en las cuevas de Texas pudiese ocasionar que el hábitat de estas especies se convierta inapropiado.

Acción para la Conservación

FWS completó y aprobó un plan de recuperación para las especies cársicas en peligro de extinción en los condados de Travis y Williamson en agosto de 1994. Las medidas de conservación antes de la aprobación de este plan enfatizaron la inspección de hábitats conocidos y probables para las tres especies para tener una idea clara de los límites y ubicación de cada especie. Además, se hicieron estudios sobre control de la hormiga de fuego y de procesos hidrogeológicos (FWS 1994). El objetivo del plan de recuperación actual para estas especies no es una recuperación completa sino cambiar el estatus de las especies a amenazadas. Las tareas necesarias para completar este objetivo son a) identificar áreas de fauna cársica necesarias para cumplir el criterio de recuperación; b) determinar el tamaño y configuración apropiados de las áreas de fauna cársica señaladas como objetivo; c) proveer áreas que puedan ser señaladas como objetivo para la recuperación; d) implementar medidas de conservación y manejo de áreas de interés que contengan fauna cársica; e) llevar a cabo investigación adicional; f) desarrollar programas de educación; y g) desarrollar programas de "monitoreo." Para poder llevar a cabo la protección de fauna cársica a largo plazo, el equipo de recuperación debe trabajar en cooperación con los dueños de tierra y debe adquirir terrenos para la protección gubernamental. Las medidas de conservación y manejo pudieran incluir control de la hormiga de fuego, protección de suministro de nutrientes y la prevención del disturbio a las cuevas ocasionado por humanos. En lo que respecta a la investigación necesaria para implementar nuevos programas de conservación, los biólogos tendrán que colectar una mayor información sobre la distribución de las especies, estudiar la hidrogeología de cada área y llevar a cabo estudios sobre la ecología de especies individuales (FWS 1994).

Como un criterio específico para lograr el cambio de estatus de las tres especies de la cueva Tooth, FWS ha establecido la protección de las áreas cársicas dentro de cada región faunística cársica, tales como el altiplano de Jollyville y las regiones del parque Cedar. Esta protección debe mantenerse por cinco años consecutivos, después de los cuales serán consideradas perpetuamente protegidas.

Importancia Económica
Desconocida

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News from Zoos

Red Wolf Fostering is a Success

Two red wolf pups, born at the North Carolina Zoo and inserted into a wild wolf den earlier this year, have been confirmed to be alive and in excellent health. This success marks new potential for fostering as an effective tool in red wolf recovery.

In May of this year, the North Carolina Zoological Park donated two red wolf pups to the U.S. Fish and Wildlife Service Red Wolf Recovery Program to help foster the captive-born pups into the world's only wild red wolf population. The two-week-old siblings, one male and one female, were transferred to the Alligator River National Wildlife Refuge, and later inserted into the den of a wild wolf female. The adult female, who was already raising two wild pups, accepted the two zoo pups as her own, and went about the daily business of raising a litter of four pups of similar age. Throughout the summer, red wolf biologists monitored the pack from a distance using radio telemetry. However, the pups were routinely well hidden in thick vegetation, and attempts to confirm their status visually were unsuccessful.

Recently, all four pups of this litter were not only seen, but also captured, and found to be in excellent health. Each pup was given a physical exam and vaccinations against parvo-virus, distemper and rabies. Each was also fitted with a radio collar and released back into the wild. All four pups returned to their original territory and rejoined their family group.

Fostering has been a successful practice within the red wolf captive-breeding program, but this marks the first time zoo-born red wolves have been placed into the wild at a very young age. To date, all red wolves released into the wild have been young adult wolves, often coming from island propagation sites in South Carolina and Florida. The ability to foster captive–born red wolves into the wild population holds many positive implications for their recovery. Fostering enhances the genetic diversity of the wild red wolf population and increases their overall chance of survival because it allows the pups to be raised by a wild mother.

Through its participation in the Red Wolf Species Survival Plan (SSP), the North Carolina Zoological Park plays an essential role in red wolf recovery. This zoo and 36 other American Zoo and Aquarium (AZA)-accredited zoos and aquariums who also participate in the Species Survival Plan provide housing, care and breeding expertise for captive red wolves. Bud Fazio, Team Leader for the Red Wolf Recovery Program, praises their work, "We work hard to restore red wolves back into the wild. Participants in the Captive Breeding Program are vital to red wolf recovery. We thank our SSP cooperators for maintaining the red wolf population long enough for us to develop and implement an effective plan to restore red wolves to the wild, where they can live out their lives wild and free." [Adapted from an article on the Red Wolves of Alligator River Web site, *www.ncredwolf.org*]

Saint Louis Zoo Awarded Two Grants for Sustainability Project in Bosawas Reserve, Nicaragua

The Saint Louis Zoo has been awarded a five-year USAID grant of $250,000 through the Nature Conservancy and has also received a Conservation Endowment Fund (CEF) grant of $36,868 from the AZA, partially funded by Walt Disney World Company. Both grants will be used for a community-based program in the Bosawas Biosphere Reserve in Nicaragua.

Bosawas, a 2,000,000-acre reserve in northeast Nicaragua, is home to 13,000 Miskito and Mayangna Indians. This area was relatively untouched by outsiders until the end of the Nicaraguan civil war. Now the indigenous tribes of Bosawas are striving to resist the invasion of mestizo colonists with their slash-and-burn agriculture. The tribes have sought the help of anthropologists and biologists to document their hunting practices and determine whether they are sustainable. Since 2000, the Saint Louis Zoo has helped native peoples on a Mayangna territory within the reserve document their wildlife and the impact hunting practices are having on that wildlife.

Working with Saint Louis Zoo field researcher Dr. Paule Gros, a group of park rangers records data on mammals and helps set mist nets for capturing birds for identification and banding. Gros has documented that among endangered mammals living in the reserve are jaguar, ocelot, margay, Baird's tapir, white-lipped peccary, Central American spider monkey and giant anteater. Important bird species include the harpy eagle, great green macaw, scarlet macaw, mealy parrot, red-fronted parrot, chestnut-mandibled toucan and keel-billed toucan.

Now, with the USAID grant, the Saint Louis Zoo will continue Gros' groundbreaking work in the Mayangna territory. The CEF/Disney grant will expand her study to a Miskito territory and develop another facet of training in Bosawas - conservation education in the primary schools. At the same time, the Zoo will work with the national zoo in Managua to create programs that highlight the importance of maintaining the nation's biodiversity. A third goal of the project is to use Bosawas to interest U.S. students and teachers in methods of scientific inquiry and in the Nicaraguan community's search for a sustainable lifestyle.

Lake Superior Zoo to Add Renewable Energy Sources

Lake Superior Zoo, in Duluth, MN, has been chosen as the first site for northeastern Minnesota's first Rebuild Minnesota Renewable Energy demonstration project. The project is designed to improve energy and environmental performance at the zoo, while demonstrating the benefits to a large and diverse audience.

Each component of the $300,000 project will not only upgrade existing facilities, but also provide a unique education on renewable energy. Some of the improvements include: solar hot water and space heating for the animal barn; a photovoltaic (cells which convert sunlight directly into electricity) fueling station for electric vehicles; and a geothermal heat exchanger which will cool the polar bear and seal pools.

"Thousands of people will have the opportunity to learn first-hand about the value of energy and its relationship to our environment and the creatures that live in it," said Mike Janis, Lake Superior Zoo director. "It is also a great opportunity to showcase the Rebuild Minnesota initiative to zoos all over the world."

Rebuild Minnesota is part of the U.S. Department of Energy's Rebuild America program, creating partnerships to conserve energy in the buildings where we live, learn, and work.

Information for News and Zoos is provided by the American Zoo and Aquarium Association

Instructions to Authors

The Endangered Species UPDATE is committed to advancing science, policy, and interdisciplinary issues related to species conservation, with an emphasis on rare and declining species. The UPDATE is a forum for information exchange on species conservation, and includes a reprint of the U.S. Fish and Wildlife Service's *Endangered Species Technical Bulletin*, along with complementary articles relaying conservation efforts from outside the federal program.

The UPDATE welcomes articles related to species protection in a wide range of areas including, but not limited to:

-Research and management of rare and declining species;
-Theoretical approaches;
-Strategies for habitat protection and reserve design;
-Policy analyses and approaches to species conservation;
-Interdisciplinary issues;
-Emerging issues (e.g., wildlife disease ecology).

In addition, book reviews, editorial comments, and announcements of current events and publications are welcome.

Subscribers to the UPDATE are very knowledgeable about endangered species issues. The readership includes a broad range of professionals in both scientific and policy fields including corporations, zoos, and botanical gardens, university and private researchers. Articles should be written in a style that is readily understood but geared to a knowledgeable audience.

Acceptable Manuscripts

The Endangered Species UPDATE accepts several kinds of manuscripts:

1. Feature Article — on research, management activities and policy analyses for endangered species, theoretical approaches to species conservation, habitat protection, and interdisciplinary and emerging issues. Manuscripts should be approximately 3000 words (8 to 10 double spaced typed pages).

2. Opinion Article — concise and focused argument on a specific conservation issue; may be more speculative and less documented than a feature article. These are approximately 450-500 words (About 2 double spaced typed pages).

3. Technical Notes/Reports from the Field — ongoing research, application of conservation biology techniques, species conservation projects, etc., at the local, state, or national level. These are approximately 750 words (3 double spaced typed pages).

4. Species at Risk — profiles of rare and declining species, including the following information: taxonomy, distribution, physical characteristics, natural/life history, conservation status, and economic importance. These profiles are approximately 750-1500 words (3 to 6 double spaced typed pages).

5. Book Reviews — reviews should include such information as relevant context and audience, and analysis of content. Reviews are approximately 750-1250 words (3 to 5 double spaced typed pages). Please contact the editor before writing a book review.

6. Bulletin Board — submissions of news items that can be placed on the back page. These items can include meeting notices, book announcements, or legislative news, for example.

Manuscript Submissions and Specifications

Submit the manuscript to:
Editor, Endangered Species UPDATE
School of Natural Resources and Environment
University of Michigan
430 E. University
Ann Arbor, MI 48109-1115

To submit your manuscript electronically, e-mail the manuscript as a Word file or rich formatted text (.rft) attachment to: esupdate@umich.edu.

Manuscripts should be typed, double-spaced, with ragged right margins to reduce the number of end of line hyphens. Print must be in upper- and lower-case letters and of typewriter quality. Metric measurements must be given unless English measurements are more appropriate, in which case metric equivalents must be given in parentheses. Statistical terms and other measures should conform to the *Council of Biology Editors Style Manual*. All pages should be numbered. Manuscripts must be in English.

Initial acceptance of a proposal or manuscript does not guarantee publication. After initial acceptance, authors and editors work closely on all revisions before a final proof is agreed upon.

Citations, Tables, Illustrations, and Photographs

Literature citations in the text should be as follows: (Buckley and Buckley 1980b; Pacey 1983). For abbreviations and details consult the Editor and recent issues of the Endangered Species UPDATE.

Illustrations and photographs may be submitted as electronic documents or as hard copies. If hard copies are submitted, the author's name and the figure number should be penciled on the back of every figure. Lettering should be uniform among figures. All illustrations and photos should be clear enough to be reduced 50 percent. Please note that the minimum acceptable resolution for all digital images is 300dpi.

Author credit instructions for each author of the article should accompany the manuscript.

Policy on Reviewing Proofs

Authors are asked to do the final copy editing of their articles. It is in the authors' power to save themselves and the journal the embarrassment of having to explain mistakes that could have been avoided.

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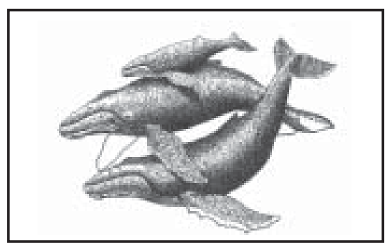
FOCUS ON NATURE ™ *by Rochelle Mason*

Insight into the lives of animals



The HUMPBACK WHALE (*Megaptera novaeangliae*), a marine mammal, measures 14-16 m in length. It is black above with white patches on its throat, belly, flukes and massive fins. With expandable throat grooves, the humpback takes in vast amounts of water and squeezes it through comb-like baleen in the upper jaw filtering out tiny krill and small, schooling fish. This feeding occurs in the rich polar waters during the summer months. In the winter months, females and calves follow the males to warm, tropical waters around the equator to mate and give birth. Hunted almost to extinction for its baleen and oil prior to the Marine Mammal Protection Act of 1972, this endangered whale's populations are slowly increasing. To help continue recovery efforts, please donate your time or money to a nature/marine conservation organization.

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