Watersheds and Fisheries Relationships: State of Knowledge, Southwestern United States

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Abstract.—The relationships and interactions of stream courses, their watersheds, and their aquatic biota have become a contemporary paradigm. Principles and practices of these relationships are generally understood, however, understanding their implications at a landscape scale is embryonic. Because of the threatened and declining status of the native fish fauna of the Southwestern United States, understanding relationships between fish and watershed condition, and the influence of watershed management on stream habitats is critical. The native fish fauna of the American Southwest are low in diversity, unique, threatened and continually declining. The primary objectives of this paper are to briefly state what we know about fish and watershed relationships, define the status of our knowledge, discuss the effects of landscape-level management activities and natural episodic events, and provide recommendations for future habitat, fish research, and management activities.

Introduction

The relationships and interactions of streams, their watersheds, and their aquatic biota are a contemporary land management paradigm (Rosgen 1996). The principles and practices of these hydrologic, geomorphic, and ecologic relationships are generally known, however, a clear understanding of their implications at a landscape scale is incomplete. Although not completely implemented in our land management activities or research studies, the trend is to increase our understanding through integrated management and research. The recent Clean Water Action Plan, an administrative initiative, will increase our knowledge of the linkage of water quality and quantity, watershed condition, and land use. The Clean Water Action Plan, Organic Act of 1897 which established the Forest Service, and other environmental legislation enacted over the past 3 decades provides the legal basis to manage watersheds, their riparian-stream courses, and fish communities.

Because of the threatened and declining status of the native fish fauna of the Southwestern United States, understanding the relationships between fish and watershed condition, and the influence of watershed management on stream habitats is critical (Rinne and Stefferud 1999). The native fish fauna of the American Southwest is low in diversity, unique, threatened, and continually declining (Rinne and Stefferud 1998, Rinne and Minckley 1991).

This paper addresses a complex and currently contentious resource management issue. The primary objectives of this paper are to: state what we know about fish and watershed relationships, define the status of our knowledge in the Southwest, discuss the effects of landscape-level management activities and episodic events, and provide recommendations for future direction in research and land management.

Fish and Watershed Relationships

General Relationships

Early attempts to understand watersheds and their impacts on fishes and fisheries began in the 1970s from studies of the effects of timber management on salmonids in the Pacific Northwest (Chamberlain et al. 1991). The primary focus linking watershed effects on salmonid fishes and fisheries was water quality. Sediment production, including transport and deposition into stream gravels, and its effects on habitats for spawning salmonids, was a major element of study (Hicks et al. 1991). Numerous papers in the 1980s addressed the effects of this watershed management activity on salmonids. Eventually it became apparent that other watershed management activities, such as mining, road building, recreation, urbanization, grazing, and water impoundment and diversion, also impacted on aquatic ecosystems and their fish communities. For the most current discussions of all these factors and their effects on salmonid fishes and their habitats see Meehan (1991).

The Southwest

The relationships between watersheds and fish have only recently become an emphasis for management and

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research in the Southwest. Research and monitoring activity in both fields have basically evolved separately, with little effort placed on understanding the effects of watershed activities on stream ecosystems and, in turn, fish habitat and populations.

The earliest efforts in watershed research in the Southwest were in the 1950s. The Arizona Watershed Program was a joint venture of the State Land Department, the Department of Health Services, the Arizona Water Commission, the USDA Forest Service, and others (Ffolliott et al. 1998). The primary objective of this research program was to increase water yield in the arid southwestern landscape. The Forest Service initiated numerous studies at various locations throughout the state including the Beaver Creek Watershed in 1957 (Carder 1977). Research at Beaver Creek continued for over two decades and produced extensive information on the influence of land management activities (timber harvest, chaparral replacement, pinyon-juniper removal, snow pack management, etc.) on water yield. Although water quality data was a component of study, fish were not included.

During this time, the dam building era commenced with the first U.S. Bureau of Reclamation Dam (Roosevelt on the Salt River). Fisheries research was focused on the effects of mainstream structures on fish and their habitats (table 1). Accompanying the large, artificial water impoundments was an extensive introduction of nonnative fish species, largely from the Mississippi River drainage (Rinne 1991, 1994, 1995). Since the 1970s, research has been on the effects of these introduced fishes on riverine and stream habitat and on their native fish fauna. Until recently, no effort has been made to examine the relationships between watersheds and fish.

Consideration of the linkages between watersheds and fisheries began in the Southwest with passage of the National Environmental Policy Act of 1969, the Clean Water Act of 1972, and the Endangered Species Act of 1973. These acts required greater consideration of the relationships among ecosystem components and increased the focus on the effects of land use activities on fish and wildlife resources, especially threatened species (Rinne and Medina 1996). Federal agencies to give greater emphasis to examining watershed began to place greater emphasis on the effect of watershed use activities on native, listed fishes and their habitats. The earliest listings of fish were 2 native Southwestern montane species, the Apache and Gila trouts. Watershed influences on riparian-stream areas and fish continues to be a research focus. This effort is intensifying and is ddressing other listed fish in streams originating on National Forest System lands.

Unlike the Pacific Northwest, ungulate grazing rather than logging is the major land use activity that has affected the native fish fauna (table 1). However, the current research approach has been focused on studies within riparian-stream, not on watersheds. The effect of grazing on fish is not well understood (Rinne 1998), therefore the effects of grazing in watersheds on fish in turn on fishes, have not even started to be adequately addressed.

Physical Factors

The immense diversity of both the Southwest terrain and climate has and will continue to make study of watershed effects on fishes and their habitats extremely difficult. Cycles of flooding and drought together with introduced species are being demonstrated to be prime controlling factors for native fish populations in the Southwest (Rinne and Stefferud 1996, 1998; Rinne et al. 1998). These and other natural physical factors are proving to be overriding in comparison to many watershed management

Table 1. Watershed management activities, fish issues, and research needs in the Southwestern United States.

Watershed management activity	Fish concern	Research needs
Exotic fish introduction	Predation, displacement	High
Cattle grazing	Habitat alteration, erosion	High
Elk grazing	Habitat alteration, erosion	High
Groundwater development	Habitat loss	High
Wildfire	Habitat loss, erosion, water quality	High
Roads and logging	Sedimentation, water quality	High
Mining	Habitat loss, water quality	High
Diversions and dams	Habitat loss, population isolation	Medium
Recreation	Habitat alteration, water quality	Medium
Urbanization	Habitat alteration, water quality	High

activities conducted by humans. Wildfire also has had dramatic effects on fish habitats and populations in upper elevation streams (Table 1, Rinne 1996, Rinne and Neary 1996). As we move into a new century and millennium, there is increasing emphasis on the effects of watershed management on fishes. However, despite decades of watershed-scale research, efforts to link watershed management and fish population dynamics are embryonic, at best, and currently a predilection rife with faulty suppositions and hypotheses.

Future Recommendations

Ecosystem management (USFS 1992) and the watershed approach (Williams et al. 1997) are the current "buzzwords" in the Forest Service and other Federal agencies at the national level. Linking these two terms with fisheries management in the Southwest is the current challenge. The State of Arizona is in process of addressing their fisheries management in context of watersheds or river basins. The Forest Service is increasingly establishing ecosystem management areas. The key will be multi-agency approaches to watershed management such as the East Clear Creek Ecosystem Management area on the Coconino and Apache-Sitgreaves National Forests. In such management areas, all resources (timber, grazing, recreation, hydrology, fisheries, etc.) are being considered jointly. In absence of such cooperative endeavor, watersheds and fisheries will not be linked and interrelated in the near future. The recent Clean Water Action Plan has precipitated the formation of watershed demonstration areas. A half dozen river-stream demonstration areas spanning lower to upper elevation watersheds are being proposed for funding for Arizona and New Mexico. A watershed approach embraces, and is compatible with, a multi-species approach to fisheries management as opposed to single species (Rinne and Stefferud 1998).

Research and Management Cooperation

Collaborative efforts using the latest technologies such as GIS will be vital in moving forward our understanding of watershed-fishery relationships in the Southwest. Watersheds in the Southwest Region of the Forest Service are currently being converted into GIS databases. Similarly, in the very near future through collaborative efforts of Arizona State University and the Forest Service, all fish data such as location, species, life history, etc. for Arizona and New Mexico will be stored in a GIS data base. GIS layering of USFS land uses such as grazing, logging, recreation, presecribed and wild fires combined with State classified impaired watersheds, fish location data, diversions, dams and roads on watersheds, will greatly enhance the effort to intermesh watershed and fishery management and identify research additional needs. Conceptually, it will also increase the probability that native fish species will be sustained.

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Literature Cited

Carder, D.R. 1977. Multiresource management research in the Southwest--The Beaver Creek Program. Journal of Forestry 75:582-584.

Chamberlain, T.W.; Harr, R.D.; Everest, F.H. 1991. Timber harvesting, silviculture and watershed processes, pp 181-206. In: Meehan, W.R. (ed.) Influences of forest and rangeland management on salmonids fishes and their habitats. American Fisheries Society, Bethesda, MD.

Ffolliott, P.F.; DeBano, L.F.; Baker, M.B. Jr. 1998. A short history of the Arizona watershed program. Hydrology and Water Resources in Arizona and the Southwest. 28:1-12.

Hicks, J.; Hall, J.D.; Bission, P.A.; Sedell, J.R. 1991. Responses of salmonids to habitat changes, pp 483-518. In: Meehan, W.R. (ed.) Influences of forest and rangeland management on salmonids fishes and their habitats. American Fisheries Society, Bethesda, MD.

Meehan, W.E. 1991. Influences of forest and rangeland management on salmonids fishes and their habitats. American Fisheries Society Special Publication 19: 1-751.

Rinne, J.N. 1991. An approach to management and conservation of a declining regional fish fauna: southwestern USA, pp 56-60. Proceedings of the Symposium on Wildlife Conservation, 5th International Conference on Zoology, August, 1990, Yokohama, Japan.

Rinne, J.N. 1994. Declining southwestern Aquatic habitats and fishes: Are they sustainable? Sustainability sympo-

sium, U.S. Department of Agriculture, Forest Service, General Technical Reptort RM-247: 256-265. Flagstaff, AZ.

Rinne, J.N. 1996. Short-term effects of wildfire on on fishes and aquatic macroinvertebrates: Southwestern United States. North American Journal of Fisheries Management 16: 653-658

Rinne, J.N. 1998. Grazing and fishes in the southwest: Confounding factors for research. pp. 75-84. In: Potts, D.F., (ed.) Proceedings AWRA Speciality Conference: Rangeland management and water resources AWRA / SRM Specialty Conference on Rangeland and Water Resources. May 26-30, Reno, NV.

Rinne, J.N.; Medina, A.L. 1996. Implications of Multiple Use Management Strategies on native southwestern (USA) fishes. Pages 110-123, In: Meyer, R.M., (ed.) Fisheries Resource Utilization and Policy. Proc. World Fisheries Congress, Theme 2. Oxford & IBH Publishing Co. Pvt. Ltd., New Deli.

Rinne, J.N.; Minckley, W.L. 1991. Native fishes of arid lands: A dwindling resource of the desert Southwest. General Technical Report RM-206. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 45 p.

Rinne, J.N.; Neary, D.G. 1996. Effects of fire on Aquatic habitats and Biota in Madrean-type Ecosystems - Southestern USA. pp 135-145. In: Hamre, R.H., (ed.) Proceedings of the Madrean Fire Conference. U.S. Department of Agriculture, Forest Service, Rocky Mountain Station General Technical Report RM-289.

Rinne, J.N. and Stefferud, J.A. 1998. Factors contributing to collapse yet maintenance of a native fish community in the desert Southwest (USA). Pp. 157-162. In: Hancock, D.A., Smith, D.C., Grant, A., Beumer, J.P. Developing and Sustaining World Fisheries Resources, Proceedings of the 2nd World Fisheries Congress, Brisbane, Australia. July 28-Aug 2, 1996.

Rinne, J.N.; Stefferud, J.A. 1999. Single versus multiple species management: native fishes in Arizona. Forest Ecology and Management 114:357-365.

Rinne, J.N.; Stefferud, J.A.; Clark, A.; Sponholtz, P. 1998. Fish community structure in the Verde River, Arizona, 1975-1997, Hydrology and Water Resources in Arizona and the Southwest. 28:75-80.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pogosa Springs, CO U.S. Forest Service. 1983. The principal laws relating to forest service activities. U.S. Department of Agriculture, Forest Service, Agriculture Handbook 453. Washington DC.

U.S. Forest Service. 1992. Ecology-based multiple use management. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Albuquerque, NM.

Williams, J.E.; Wood, C.A.; Dombeck, M.P. 1997. Watershed restoration: principles and practices. Amer. Fish. Society, Bethesda, MD.