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AQUATIC HABITAT AND CRITTERS IN A DRY STATE

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INTRODUCTION

The theme of this conference encourages water-resource management adaptation to social and ecological change. Wildlife resources have become an increasingly important and controversial component of change related to water management and water quality. Because changes in aquatic environments and social values are inevitable, the need for proactive planning flexibility and coordination for water and wildlife managers is clear. The more difficult issue is how to follow through. Here I try to provide a brief overview of the ecological and social constraints and opportunities facing aquatic wildlife managers, and illustrate how they fit into western water management planning systems.

Past water development has both reduced and increased the extent to which habitat constrains wildlife production and diversity. Although aquatic habitat has been expanded greatly by construction of reservoirs for irrigation and flood control, that expansion has occurred at a cost in specific kinds of habitats, particularly habitats needed by certain native, rare species. Increasingly, wildlife management must encompass social values that influence water laws, economics and decision making in the western United States. New, tough laws and regulations have evolved as the perception of wildlife value has shifted (see Bean 1983 for an overview of federal wildlife law and Steinhoff et al., 1987 for economic perspective).

Values and laws are likely to continue changing, increasing the authority and responsibility of wildlife managers. Inadequate information about wildlife and other water-based values hampers the ability of wildlife managers to easily assume their expanding role in sound water management. Also, like other water-management agencies, wildlife agencies are fundamentally constrained by a lack of revenues.

Wildlife agencies are challenged with increasingly complex social demands to provide a greater diversity of wildlife habitats and life-forms. Most western wildlife agencies face stable or decreasing revenues as public demands for more diverse services increase. In response to changes in public attitude and behavior, concepts of wildlife and their management have changed dramatically. Much has occurred since the second world war, when wildlife value was virtually synonymous with a few harvested and widely observed species.

The public has never been more disturbed about environment and wildlife trends, yet the voting majority remains ambivalent about corrective costs and who should bear them. The recent flurry of proposed environmental law and wholesale rejection of environmental referenda, most notably in California, demonstrates the public's ambivalence. Concern for wildlife and environment is complicated by confusing expressions of ecological and economic values, and promotion of biocentric ethics without clear economic expression.

Wildlife and environment professionals who provide for New Mexico's ecological and public welfare will be increasingly challenged to retain appropriate local control by assuring the public that the best combination of ecological and social values is being provided. With those challenges foremost in mind, I will survey trends in wildlife-related attitudes and values, problems relating wildlife values to water quality standards, the increasing need for improved planning, and an interdisciplinary approach that provides for greater planning flexibility. First, a little about values and their measurement.

WILDLIFE VALUES

Past sport-fishery management in the western U.S. has taken advantage of reservoirs developed for other purposes, increasing the value of impounded water without diminishing other economic benefits. For the most part, wildlife managers working as public servants seek to add value to water use while otherwise encouraging the most beneficial uses. The specific objectives chosen to complete that task are, in some cases, controversial, usually due to an incomplete understanding of and agreement about wildlife and other water-based values.

Because of western water scarcity, the ecological and economic stakes associated with aquatic wildlife are high (see data presented in USFWS 1988) and continue to assume a greater share of the state's financial resources. Aquatic habitat in dry regions is more valuable than habitat in wetter regions with similar human population. Expenditures for aquatic wildlife-based activities in New Mexico average roughly $2,500/surface acre ($1,000/hectare) and about $500/acre-foot ($4,000/hectare-meter) of evaporated water. These expenditures represent economic activity but are inappropriate estimators of value.

Wildlife's economic value to New Mexico residents is more appropriately expressed by other economic measures (Bishop 1987, Steinhoff et al. 1987). The quality of in-state recreation, for example, attracts the dollars of out-of-state recreationists (who might otherwise recreate elsewhere), thereby increasing in-state net income and buying power as long as state residents also benefit enough to keep from recreating outside the state. Providing high-quality wildlife opportunity in New Mexico discourages residents from spending dollars out-of-state for water-based recreation. In economic terms, the direct benefits to resident recreationists and indirect benefits to state businesses are now much higher than if no water-based wildlife opportunity existed in New Mexico. Undoubtedly, high-quality aquatic habitat directly benefits wildlife resource users and sustains a substantial wildlife-based economy in New Mexico. Economists also can quantify public willingness to pay for non-use values such as wildlife bequests to future generations, option value associated with sustaining future wildlife choices, and simply knowing that wildlife exist in natural settings. Although estimating economic value needs refinement, acceptable or provisional methodology is available to do so for decision-making purposes.

Non-economic ecological values, associated with biocentric concepts of inherent ecological worth or good as described by Taylor (1986), cannot be estimated using economic methodology.

Certain ecological methods may be useful, however. But comparing non-economic ecological measures of inherent value and economic measures of social value for decision-making purposes is troublesome. Public attitudes and values seem to incorporate both non-economic ecological rationales and economic rationales.

Water quality standards in New Mexico and elsewhere are designed partly to protect existing and attainable economic values of wildlife and do it reasonably well. Water quality standards, however, are not always designed to maximize social welfare as indicated by economic benefits. In some cases, they appear to protect non-economic ecological values, whether or not that was the intent. The uncertainty illustrates the need for a clearer definition of the values actually assigned by the standards to wildlife and other water-based resources.

Water quality standards are not easily expressed in ecological or economic terms partly due to the diverse conditions that exist in the west compared to the region where most standards developed and evolved. Water standards most effectively protect social values where demand for wildlife resources and the aquatic environment are both spatially and temporally uniform. In the eastern U.S., where most standards were first applied, the water supply is uniformly close to sea level, stable, low in carbonate-based salinity, and usually flows to the sea without first drying up. The topographic, geologic and climatic variety of western states creates diverse habitats occupied by a mix of unique natural and highly modified communities with diverse ecological and economic values. This ecological and economic diversity complicates development of appropriate water quality standards.

As shown in Figure 1, public attitudes, values and behavior are interrelated as described by Steinhoff (1980). Public attitudes and preferences determine values and motivate behaviors which in turn reinforce or reform preferences and attitudes exhibited later. Behavior is expressed mostly through economic activity, education including research, and the legal process. Usually, when economic activity is insufficient for behavioral expression, education and law are shaped by concerned interests to promote new attitudes and values. For planning purposes, understanding the dynamics of human attitudes helps narrow the range of anticipated social behavior.

According to Kellert and Berry (1980), most people's attitudes toward animals can be classified as naturalistic, ecologistic, humanistic, moralistic, utilitarian, or negativistic. Scientistic and doministic attitudes are more rare. People usually incorporate more than one attitude into their values structure. People with naturalistic and ecologistic attitudes view animals as part of an ecological whole. The humanistic attitude embraces sentient animals much as if they were human. People with a moralistic attitude toward animals believe that animals have an inherent worth independent of economic value and deserving of human respect. Utilitarian people typically assign material or economic value to wildlife. When combined with ecologistic attitudes, utilitarian people tend to view

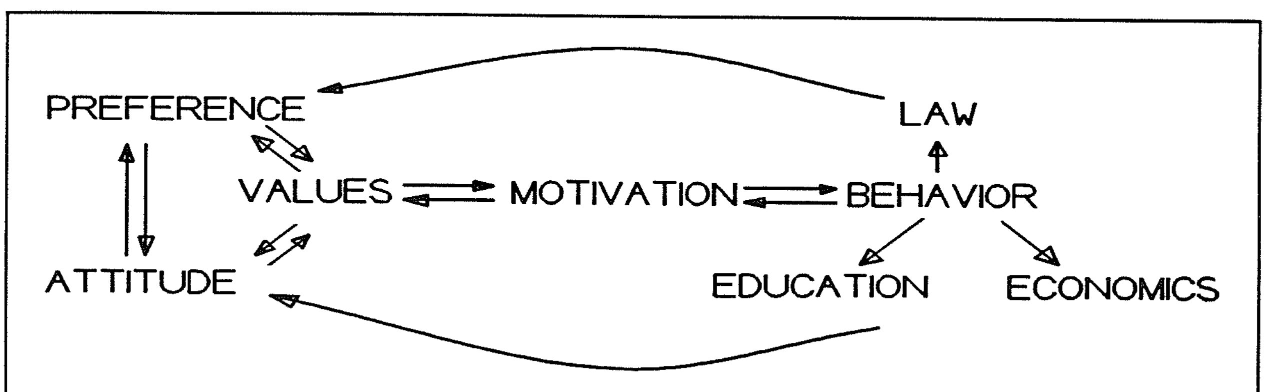

Figure 1. General relationships among social attitude, preference, values and behavior that influences aquatic wildlife issues (modified Steinhoff 1980).

ecological value in a social framework, believing that healthy ecosystems promote beneficial social systems. Nearly one third of the attitude expressed by people in the surveys of Kellert and Berry (1980) was negativistic. This attitude reflects total disinterest, fear and loathing for animals.

Attitudes shape ethics and values that motivate educational outreach and legislation designed to redirect economic activity. Utilitarian and negativistic attitudes shape anthropocentric ethics and values, which focus on human needs. Ecologistic and moralistic attitudes shape biogeocentric ethics and values that consider the inherent worth of ecosystems independently from human needs. Humanistic and moralistic attitudes shape biocentric ethics and values more specifically oriented toward animals. The ethics of many wildlife and environment professionals are based mostly on a mix of ecologistic, utilitarian, and moralistic attitudes toward the wildlife they manage. A growing number are becoming more moralistic and less utilitarian. For increasing numbers of managers, biogeocentric values are gaining with respect to anthropocentric values. Many wildlife and environment professionals seem to believe, like a growing portion of the public, that the non-economic inherent worth of ecosystems and the biosphere deserves protection, even at substantial social expense—the equivalent of an existence value greater than most people are willing to pay.

Future attitudes and values may continue to shift more in favor of biocentric reasoning. The young and the highly educated are more likely to express naturalistic, ecologistic, humanistic, and moralistic attitudes than are older or less educated people (Kellert and Berry 1980). This distribution of attitudes may indicate that the most economically and politically active part of our future society will move farther away from utilitarian and negativistic attitudes and anthropocentric values toward more ecologically based biocentric values. But human preferences and attitudes are dynamic and uncertain, and planning must account for that uncertainty.

Recent environmental events have generated concern for human welfare, some related to wildlife values. Because the market economy does not readily lend itself to many of these issues, public education and legislation are increasingly justified based on the biocentric inherent worth of wildlife in ecosystems rather than anthropocentric values. Preservation of biodiversity is a rallying concept. Wildlife professionals and lay public with biogeocentric agendas are encouraging management that focuses more on the ecological value represented by sustained or enhanced biodiversity. Although much of this ecological value can be translated into economic benefit, some cannot.

A recent Time magazine essay by Gup (1990) addressed this issue with specific regard to modifying the Endangered Species Act by incorporating greater economic perspective.

> Man cannot manage nature through a series of ad hoc rescue attempts, ignoring the underlying causes for the loss of biodiversity. The answer is not to dilute the Endangered Species Act but to better anticipate the consequence of human activity, focusing on entire ecosystems rather than on single species... The anthropocentric arguments legitimatize the notion that species must justify their right to exist by proving their utility to man. That leaves the vast majority of species defenseless and debases the fundamental reason for preserving them—their intrinsic worth.

Biogeocentric ethics are gaining wider acceptance. Further biodiversity protection is in the legislative process along with numerous related issues. The Endangered Species Act, a tough act to follow, enjoys widespread support despite the controversy that frequently circles it.

With recent changes in social and professional attitudes, it is not surprising that widespread transformation appears to be underway within wildlife and environment agencies. Most eastern agencies have already metamorphosed, redirecting much of their traditional emphasis on a few valued game species toward a wider diversity of game and nongame species. In the west, where wildlife agencies are striving to adapt, communication within and among agencies and public advocates is frustrated by inadequate information about environmental values and how those values relate to ecological, economic, and political processes. Exactly where western wildlife and water management is headed remains unclear.

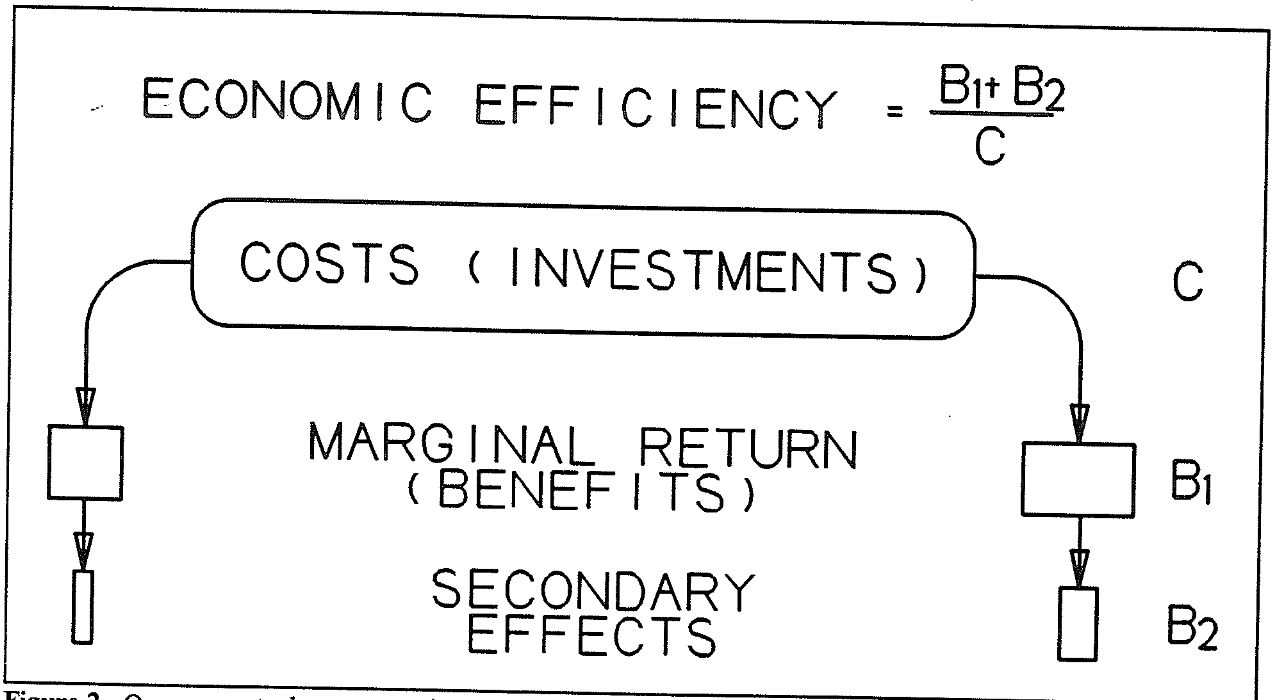

Figure 2. One conceptual representation of economic efficiency as the fraction of public investments returned in net public benefits (after cost is deducted).

For more effective aquatic wildlife planning, those with water resource interests need information to compare different water-based values directly. For social welfare values, a variety of economic measures are available, including various measures of economic efficiency usually used in benefit-cost analyses.

One of many possible economic efficiency measures, shown in Figure 2, reflects the increment of value added for the cost investment, the value added being the sum of all economic measures of social welfare including bequest, option and existence values. The unusual expression of economic efficiency presented in Figure 2 is analagous to the concept of ecological efficiency pictured in Figure 3. Many agencies and advocacy groups have been slow to accept economic efficiency, via benefit-cost analysis, as a valid measure of the ecological management impact on social welfare. But the impediments to wider acceptance and use of economic efficiency measures are few compared to alternative measures of non-economic ecological value.

Ecological welfare may be measured in various ways but biodiversity has dominated the recent thinking of conservation biologists (Wilson 1988). A related concept, based on ecological efficiency of aquatic community production, is an estimator more directly comparable to economic efficiency.

The efficiency with which total available energy in a feeding level (herbivores, first-level carnivores and so on) of an aquatic community is converted to production is one measure of ecological efficiency, shown in Figure 3 (see Ricklefs 1990 for a general review). Because biodiversity usually varies directly with ecological efficiency calculated for entire natural communities, ecological efficiency may serve as a more quantifiable measure of the ecological welfare associated with biodiversity.

WATER QUALITY VALUES

Using ecological and economic efficiency measures, I will present some generalized examples to contrast expected responses of ecological and economic values to changes in oxygen concentration. Oxygen was chosen because it is closely associated with aquatic wildlife values.

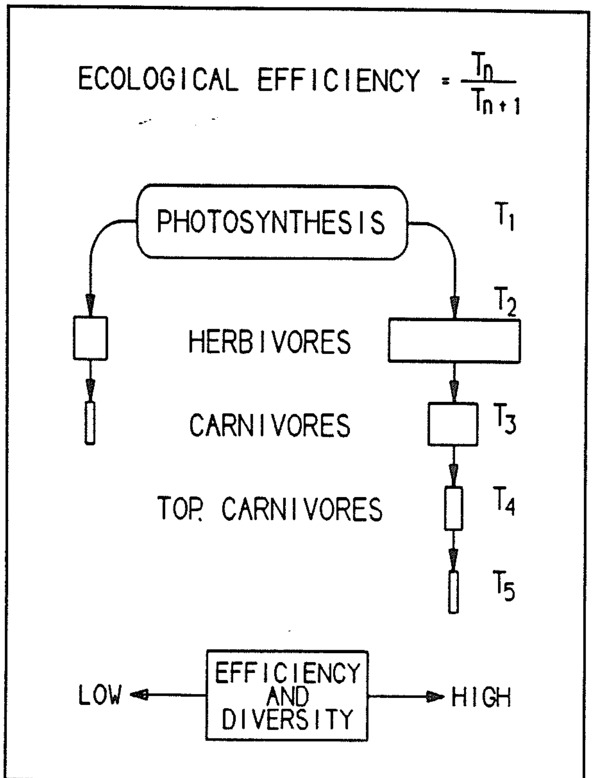

Figure 3. One conceptual representation of ecological efficiency as the fraction of energy biologically fixed in one trophic level that is accumulated in the next trophic level. Efficiency, number of trophic levels and diversity are usually positively correlated.

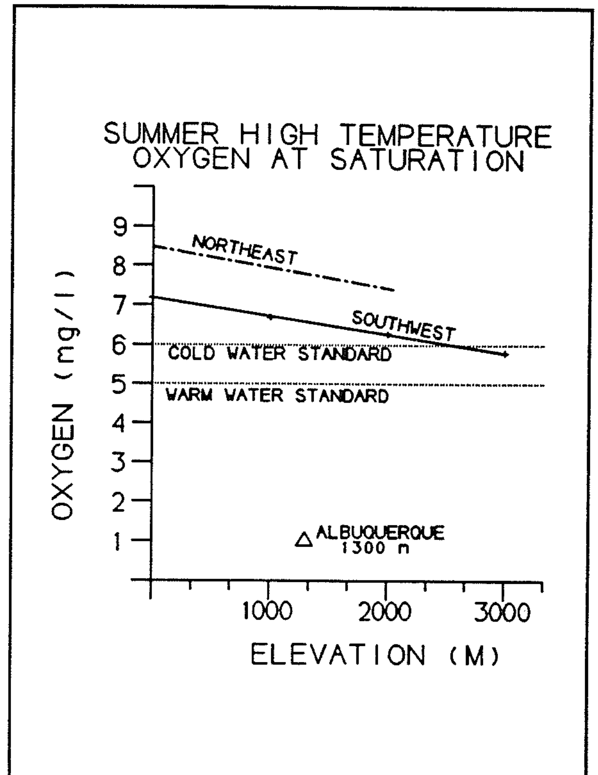

Figure 4. The relationship between topographic elevation and the concentration of oxygen sustained in water at equilibrium with summer conditions in the northeastern and southwestern U.S. Oxygen standards for cold- and warm-water habitats are shown.

As shown in Figure 4, the oxygen that can be held in water at saturation depends on the atmospheric pressure exerted by oxygen, which in turn depends on the elevation. New Mexico water standards for most warm and cold water aquatic habitats are also indicated, along with common saturation values encountered in the cooler northeastern U.S. The oxygen standards are based mostly on needs of recreationally valued fish species.

The water quality regulations allow oxygen to be removed down to the minimum allowable concentration, usually 5 to 6 mg/L, if it is socially justified; in other words, if it is economically prudent. The value of prudently used oxygen, therefore, is negotiable if social benefit can be shown. Below the minimum allowed, the oxygen is reserved entirely for the aquatic community even if it is not economically valued. Once an elevation of around 2,000 meters (6,500 feet) is reached, no oxygen is available above the standards and none can be justifiably used for economic benefit beyond the existing use of the aquatic resource. More oxygen is available above the standard for economic benefit at lower elevations because the warmwater fish that live there can do with less oxygen.

Existing water quality standards allow oxygen reduction because oxygen is rarely irreplaceable when waste is properly treated. The option of using oxygenated habitat for fish is not permanently forefeited when the oxygen in water is used instead to assimulate treatable wastes. In other words, the oxygen has no option value. In purely economic terms, the decision to treat the wastes so that oxygen is sustained depends on the benefits accrued from anthropocentric economic value or biocentric ecologic values. The decision does not depend on protecting oxygen from irreplaceable loss. If endangered species are present, however, the option value associated with the oxygenated habitat may be high and prevention of oxygen loss to protect endangered species may therefore be warranted. Otherwise, option values associaed with oxygenated water are hard to demonstrate. Depending on the variation in utility of the aquatic community that is protected by the minimum oxygen allowed, the minimum standard may protect either or both non-economic and economic values. Two examples follow for demonstration purposes.

Many of the most attractive fisheries in New Mexico are in high elevation reservoirs, none of which existed at the turn of the century. Virtually no oxygen can be removed from these lakes without violating standards because of their high elevation.

Figure 5 illustrates a modeled relationship between ecological and economic efficiencies in high elevation lakes inhabited by fish. This model shows that the economic efficiency of aquatic wildlife in this type of ecosystem is reduced more quickly than the ecological efficiency as the oxygen is depleted. The game fish in the lake are among those species that least tolerate oxygen depletion. Therefore, once the gamefish have been killed by oxygen loss, economic value has been greatly diminished, even though ecological value, as measured by efficiency, remains little changed.

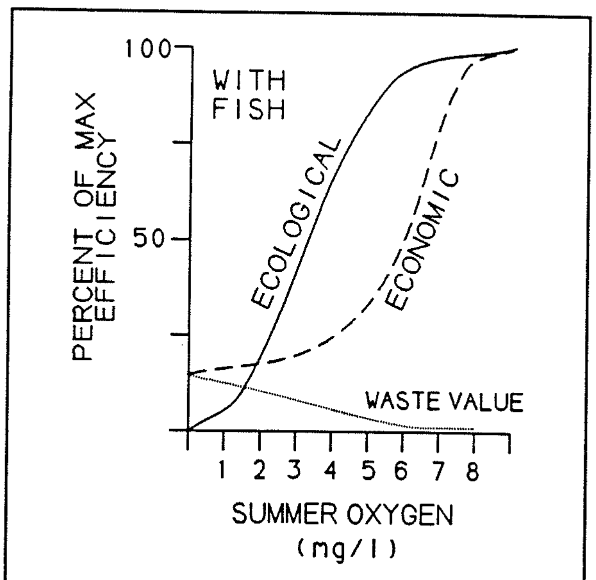

Figure 5. General model relationships among ecological efficiency, economic efficiency, oxygen-demanding waste assimilation value, and the summer oxygen concentration in a high elevation lake that supports New Mexico cold-water sport fish.

In Figure 6, representing waters with no game fish or where fish are inaccessible, the oxygen standards still apply. But in this case the economic potential is mostly associated with the use of oxygen for other purposes, such as the oxygen demand caused by camper activity. If enforced, the oxygen standard would appear to protect non-economic ecological values, as long as no option value for protection of endangered species were involved. For many high altitude lakes, virtually any human use of the watershed (including recreation and livestock grazing) could cause material loadings and oxygen depletion in violation of oxygen standards. Anthropocentric ethics would encourage oxygen use if it increased the total social welfare. Biocentric ethics would be less inclined to give up the non-economic inherent worth of the intact aquatic community sustained by the oxygen. That many of our lakes are artificial reservoirs occupied by non-native fish species simply confounds the issue.

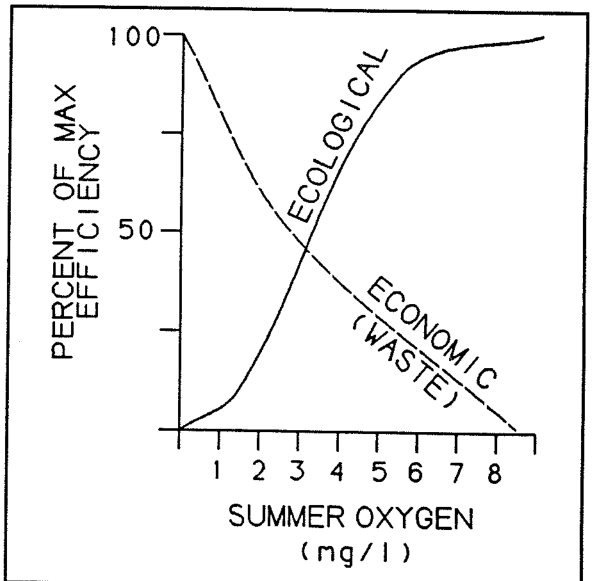

Figure 6. General model relationships among ecological efficiency, economic efficiency and oxygen-demanding waste assimilation in a cold-water lake without any sportfish where aquatic value is equal to waste assimilation value. This model assumes waste assimilation in no way detracts from aesthetic or alke values other than the ecological values inherent in integrity of the aquatic community.

In the future, this example could become more relevant if fishery management of remote waters is reduced to provide greater social welfare at more accessible and closer sites. As the economic value of the oxygen for sportfish becomes less relevant, maintenance of the oxygen standards must be based on other considerations.

Another example of poorly understood relationships between values and standards pertains to some of the lower elevation river reaches found in New Mexico's mainstream big rivers. Here natural and artificial accumulation of fine sediments in river channels often causes unstable bottom substrates and poor habitat. Many of these reaches are dewatered seasonally for irrigation purposes.

Past research (Donaldson 1987, for example) has shown that the natural productivity of sediments with small particle size is much lower than for larger, more stable sediment. All else held constant, a sandy bottom supports a small fraction of the productivity that is supported by a rocky bottom. Particularly when combined with dewatering by water diversions, these habitats have low ecological and economic efficiencies.

Although whatever remains of ecological efficiency is protected by oxygen standards in both stable and unstable river bottoms, the economic efficiency is much higher where stable bottoms occur, wherever water flow is sustained. As shown in Figure 7, again as a general model of relationships, most of the economic efficiency is eliminated by an unstable bottom. The oxygen standard mostly protects non-economic ecological value of an unused aquatic community, as long as no endangered species are present. Whether or not protection of non-economic ecological values is worth the cost remains unclear.

Other water-related decisions also influence the valuation. Greater reservation of instream flow could substantially increase the potential attainable use for wildlife. Actions that reduce sediment erosion and transport into stream beds would substantially increase both ecological and economic efficiency.

Figures 6 and 7 show the complexity of the values associated with standards and the need for standards that better reflect underlying values. The data that form the bases of these models are limited and more detailed understanding is needed. Although water quality standards and various other wildlife management strategies appear to have provided for economic and non-economic values, the values are not as clearly quantified as existing techniques allow. Improved wildlife and water management will require more precise measures of values in various environments at a time when the public is especially cost conscious and demanding greater government accountability for its revenue expenditure. The role of non-economic ecological value remains a stumbling block in a decision-making process designed to provide for social welfare.

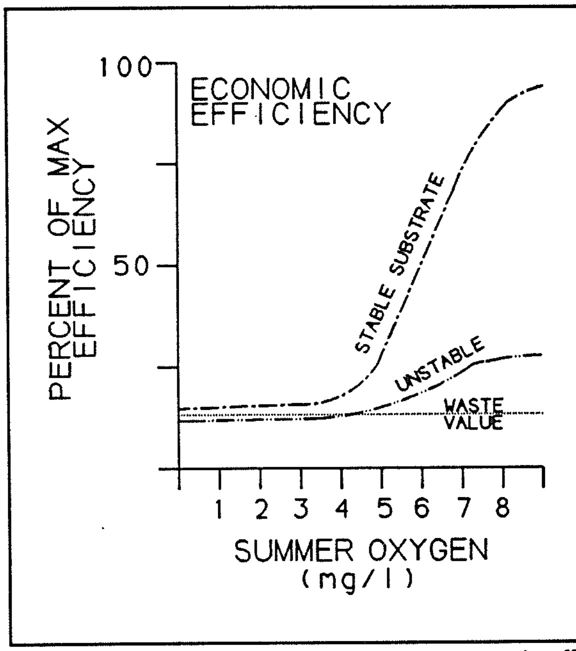

Figure 7. General model relationships among economic efficiency, bottom substrate stability, waste assimilation value and the summer oxygen concentration in rivers supporting sport fisheries.

IMPROVING PLANNING TECHNIQUES

Solving these problems requires improved planning that identifies appropriate objectives and strategies. One of the most difficult planning challenges is reducing complex socio-ecosystems to their critical planning elements. As shown in Figure 8, wildlife and environment agencies manage ecological and economic efficiency to improve ecological and social welfare. Wildlife management and water quality standards form parts of strategies used to modify efficiencies that determine ecological and social welfare. As already discussed, ecological and social welfare do not necessarily respond in parallel to management

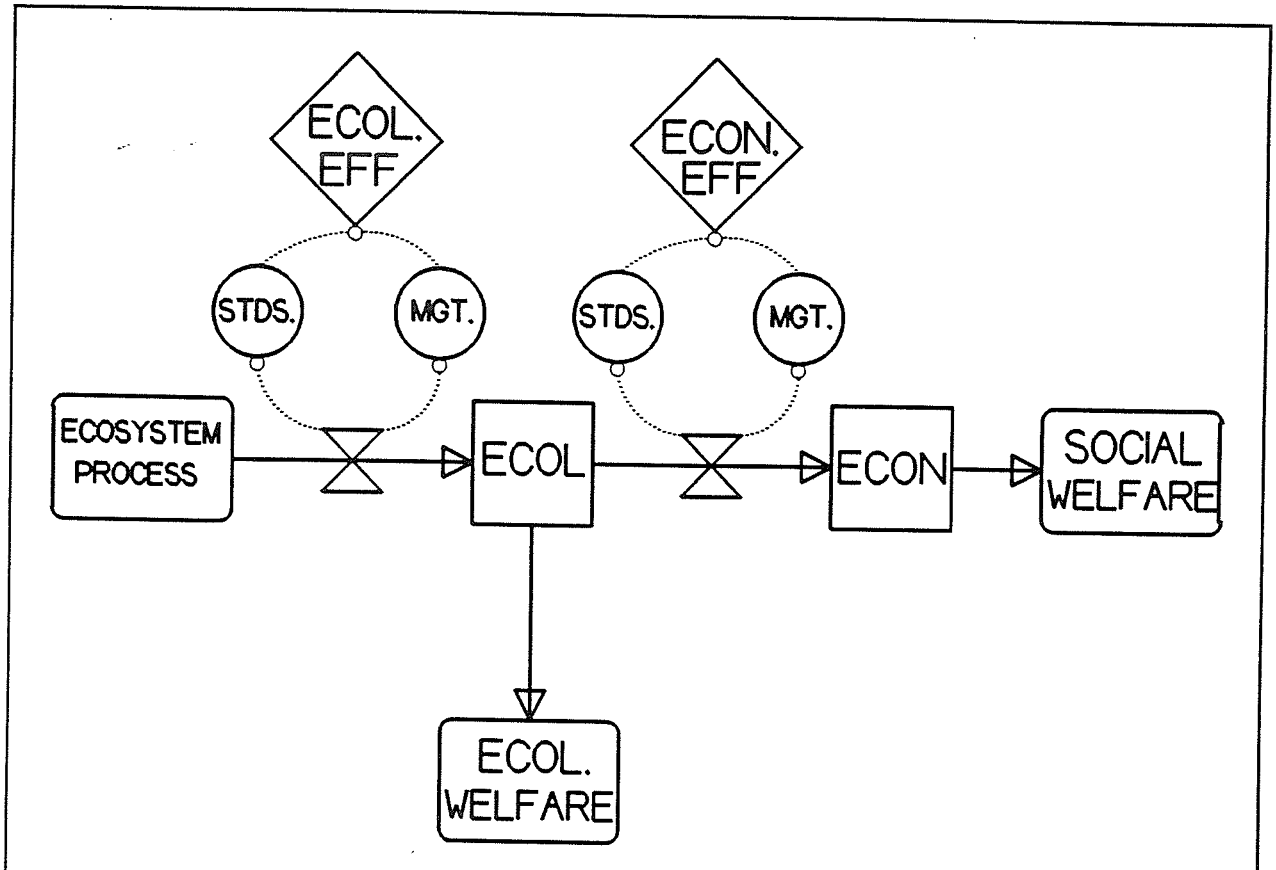

Figure 8. Systems diagram illustrating interactions among ecological and economic process in determining ecological and economic system structure and ecological and social welfare. Both ecological and economic efficiencies are influenced by the water standards used and other management tactics (ECOL EFF= ecological efficiency, ECON EFF=economic efficiency, STDS=water quality standards, MGT=management).

strategies. Welfare-related objectives become disoriented and planning breaks down when divergence is perceived between ecological welfare and social welfare. Therefore, a critical planning challenge is improved measurement of both ecological and social objectives, costs, and benefits. Some optimum distribution of ecological and social objectives needs to be identified to provide long-term public satisfaction.

Planning too often has been paralyzed by overly limiting views of planning environments and overemphasizing simple trend extrapolation toward a single future. Too often, plans for a single future become outmoded as trends change before the plans are completed. Greater flexibility is provided by planning for several possible futures. Manageable computing systems has greatly expanded the potential for alternative futures planning.

Another impediment has been over reliance on procedural objectives instead of welfare objectives. Stocking fish and treating wastewater does not automatically provide improved economic and ecological welfare, and it is the improved welfare that is the true product.

Although wildlife and environment agencies should be applauded for their dedication to improving opportunities at reduced user costs, they have been hamstrung with inadequate planning tools. The agencies must be able to predict the benefits of their management. They need more interdisciplinary integration of ecosystems and social systems designed for analysis of a variety of possible futures influenced by different management strategies. Much ultimately useful data remain out of reach of environmental planners and managers. There is a critical need for data synthesis, interdisciplinary task force analysis, and useful packaging of user-friendly software and other applications. The New Mexico Department of Game and Fish and the New Mexico Water Resources Research Institute have led in promoting data integration and planning advances.

Solving these problems will require more rigorous methods designed to focus, coordinate, and integrate interdisciplinary expertise into workable strategies that meet quantifiable objectives. Part of the solution is further development of cross-disciplinary simulation models that enable analyses of the social opportunities foregone by protection of non-economic ecological values. A prototype example of a sportfishery planning model is described by Cole et al (1990). Such models, developed to their potential, can incorporate a wide variety of management strategies into social and ecological system structures. These models can be used to forecast management impacts on social and ecological welfare. Perhaps more importantly, they encourage improved communication across disciplines as relevant information is distilled from the data.

CONCLUSION

The need and the potential exists for improved integration of water quality and wildlife management into strategies designed to accomplish appropriate economic and ecological objectives. Although the costs of such planning will require considerable investment, the benefits are likely to be great. Accurate ecological and sociological information is needed to represent water-based values more fully. Planning objectives need to be based more securely on welfare resulting from management and less on the tactics used.

The diversity of western environments, which contributes much to western lifestyle, requires refinement of the present standards approach to better promote the most beneficial assemblage of management tactics, including those pertaining to wildlife-based values. Somehow in this process, non-economic ecological values should be translated into socially meaningful terms. Combined with astute politics, and caring public service, greater use of an interdisciplinary systems approach to planning appears appropriate for attaining improved integration of water management strategies for the greatest social welfare.

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