Fish Health and Diversity: Justifying Flows for a California Stream

By Peter B. Moyle, Michael P. Marchetti, Jean Baldrige, and Thomas L. Taylor

ABSTRACT

Efforts by a citizen's group, Putah Creek Council, to improve the flow regime of a California stream for ecosystem, aesthetic, recreational, educational, and research purposes led to a successful court trial in which fish conservation played a key role. A major issue around which the trial revolved was the proper interpretation of a section (5937) of the California Fish and Game Code, which states that fish must be maintained in "good condition" below a dam. We defined good condition to mean there had to be healthy individual fish in healthy populations that were part of healthy biotic communities. This definition resulted in a conceptual model for instream flows for the creek that favored native resident and anadromous fishes. The stream flow recommendations from this model had four components: living space flows for the entire creek, resident native fish spawning and rearing flows, anadromous fish flows, and habitat maintenance flows. The trial judge, in attempting to balance competing demands for the water, ordered the implementation of only the first two recommendations. The order has been appealed by the water interests, but regardless of the final outcome, the court's decision reflects the growing public interest in protecting streams, the need for innovative use of existing legal tools to try to protect aquatic resources, and the importance of biological information in developing flow recommendations for complex fish assemblages.

"Without fundamental changes in policies and environmental ethics...biodiversity will continue to deteriorate. Fishery managers must begin to make that message clear."
—American Fisheries Society
1997 Position Statement on Biodiversity

Biodiversity is being lost in aquatic environments even faster than it is being lost in terrestrial environments (Moyle and Williams 1990; Abramovitz 1996; Leidy and Moyle 1997). The problem is particularly acute in streams and rivers (Allan and Flecker 1993; Allan 1995). In the western United States, most streams of any substantial size have had their flows altered by dams, reservoirs, and diversions, with generally negative effects on the native aquatic biota (Stanford et al. 1996). The importance of quantity, quality, and timing of instream flows for maintaining fish populations in regulated rivers has long been recognized and has led to the development of various methodologies that attempt to determine through modeling how much water needs to be left in a particular stream or stream reach for fish (Gillian and Brown 1997). These methods tend to focus on single species, usually game or commercial fishes, using a limited set of physical parameters that affect fish distribution and abundance: depth, velocity, substrate, and temperature (Orth and Maughn 1982; Moyle and Baltz 1985). Application of single-species or single-life-stage instream flow models is of limited value in the face of the emerging mandates for ecosystem-based fisheries management using adaptive management strategies (Castleberry et al. 1996; Schramm and Hubert 1996).

In California, and in the West in general, aquatic biologists and managers are increasingly recognizing that reversing the loss of native aquatic organisms requires an ecosystem-based approach; stream flows not only need to be increased, but seasonal patterns of flow need to be restored to resemble the original, unimpeded patterns (Strange et al. 1992; Stanford et al. 1996; Poff et al. 1997). For example, in recent negotiations about instream flows in the lower Tuolumne River, California, the need for increased flows was never an issue; the negotiations instead centered on how large the increase should be and how flows should be timed to benefit chinook salmon (*Oncorhynchus tshawytscha*) and the riverine ecosystem (Moyle and Yoshiyama 1997). Unfortunately, legal and regulatory tools available to obtain instream flows specifically for aquatic ecosystems are limited in number and scope, and are often complex in application (Gillian and Brown 1997). In California the State Water Resources Control Board has denied all applications for water rights to protect instream flows for fish (Thomas 1996). A promising approach is to enforce the longstanding but little-used Section 5937 of the California Department of Fish and Game (CDFG) Code (Biaocchi 1980), which states the following:

> "The owner of any dam shall allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, allow sufficient water to pass over, around, or through the dam, to keep in good condition

Peter B. Moyle is professor of the Department of Wildlife, Fish, and Conservation Biology at the University of California—Davis, Davis CA 95616; 530/752-6355; pbmoyle@ucdavis.edu. Michael P. Marchetti is a research assistant and graduate student at the same university. Jean Baldrige and Thomas L. Taylor are senior fisheries consultants for ENTRIX, Inc., in Walnut Creek, California.

any fish that may be planted or exist below the dam."

The critical term *good condition* is not defined in the code, but in an historic court case that resulted in increased flows in streams flowing into Mono Lake, Mono County (Koehler 1996), a state court basically accepted the definition of CDFG Biologist Darrell Wong:

> "The instream flows necessary to keep fish in good condition include those which will maintain a self-sustaining population of desirably sized adult...fish which are in good physical condition.... The fish populations should contain good numbers of different age classes; and habitats for these age classes should not be limiting....The ecological health of a stream will determine if the fish...are to be kept in good condition (Unpublished testimony, 1993, State Water Resources Control Board)."

Another section of the Fish and Game Code defines both fish and aquatic invertebrates as *fish*, expanding the ecosystem enhancement possibilities of Section 5937 even further.

In 1996 a state trial court used an ecosystem-based version of Wong's definition of *good condition* under Section 5937 to order the release of more water down Putah Creek in Solano and Yolo counties, California, to improve aquatic habitat conditions. One of this paper's authors, Peter Moyle, used this ecosystem-based approach during the trial while testifying as an expert witness. We present it here not only because of its broad applicability in California, but also because it contains goals that should be useful elsewhere when ecosystem-based management is required. The court decision also is important because it implicitly recognized that the

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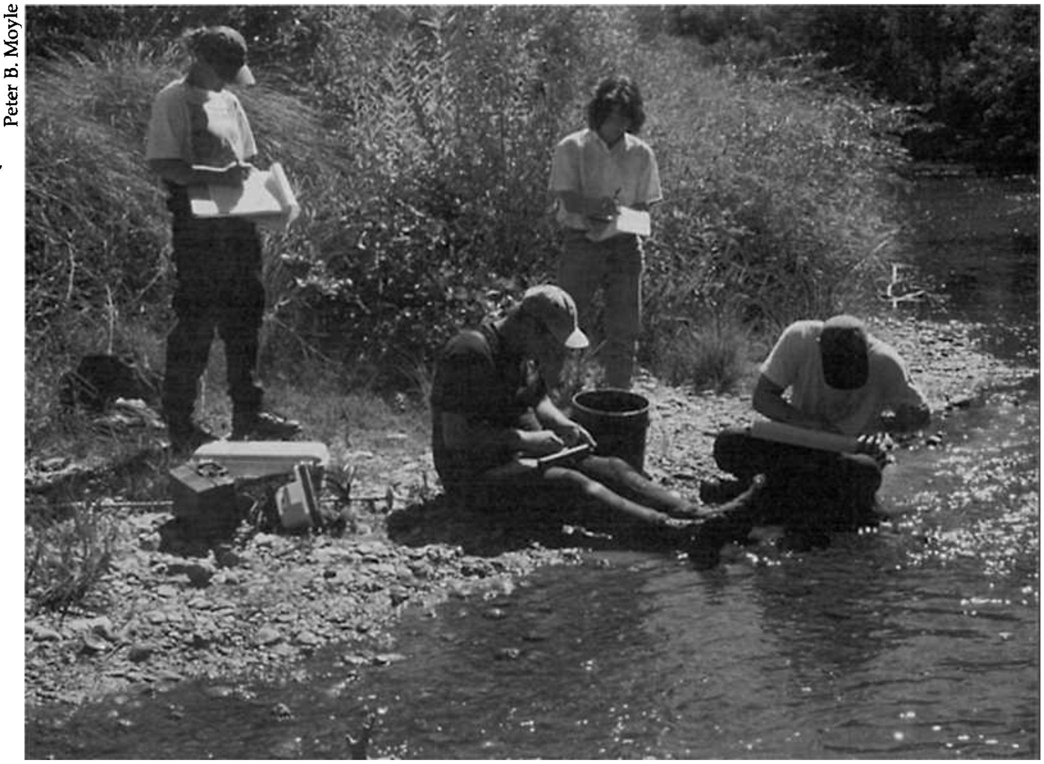
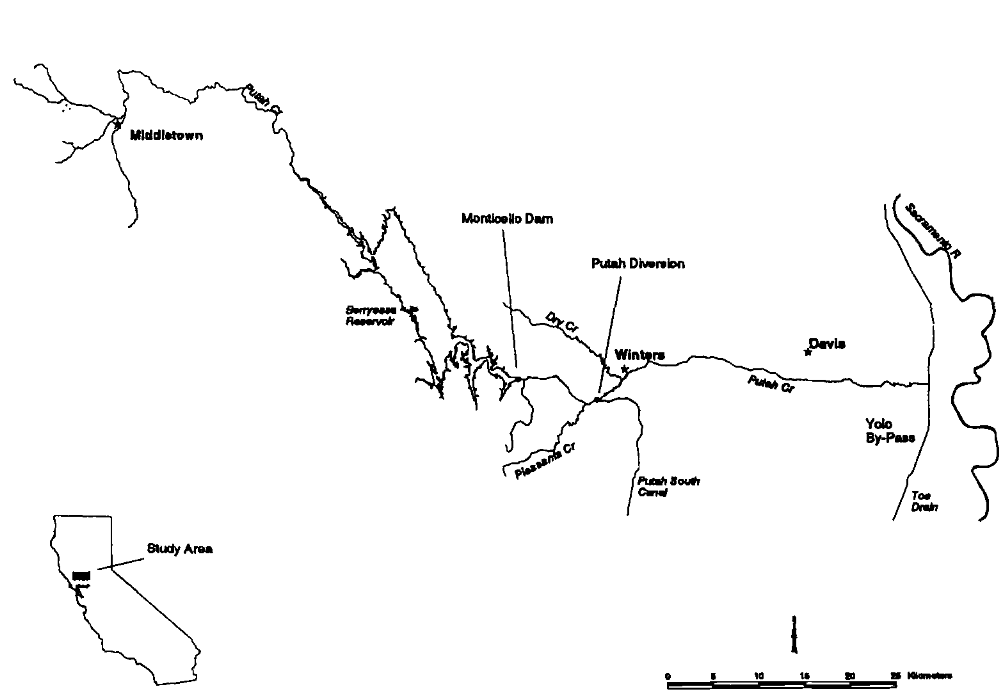


Undergraduates Lisa Konyecsni (standing), Pat Crain, and Ryon Kurth process samples of fish from Putah Creek, while *Sacramento Bee* reporter Nancy Vogel takes notes on their findings. Increased public interest in and support for healthy aquatic ecosystems have made fisheries-related trials newsworthy.

Figure 1. Putah Creek, Solano and Yolo counties, California, was dammed in 1957, creating Berryessa Reservoir and drastically changing the flow regime downstream of the reservoir.



conservation of native fish communities, even if no endangered species are present, is appropriate under the *good-condition* term in Section 5937. In this paper we first describe (1) the Putah Creek watershed, (2) the events leading to the judicial order to increase instream flows, and (3) the three-tiered definition for fish in good condition used during the trial. We then discuss the implications of the definition for managing aquatic biodiversity.

Putah Creek

The Putah Creek watershed drains the Macaymas Mountains in Napa and Lake counties in west-central California and eventually flows through Solano and Yolo counties into the Yolo Bypass, a flood control channel that empties into Sacramento River just above its estuary (Figure 1). Most water in the system enters from rainfall in the winter. Historically, most of this water ran off quickly, causing frequent floods on the valley floor. Because the mountains are too low to accumulate snow, summer flows were quite low (usually <20 cfs), and the lowermost reaches of Putah Creek were often intermittent by late summer, although there was always enough deep water in pools to support a diverse fish assemblage. In the reach now flooded by Berryessa Reservoir, the stream was perennial. Other perennial reaches were found downstream of the site of Monticello Dam, including a short segment near Davis. Putah Creek once supported populations of all native resident fishes of the Sacramento Valley (Moyle 1976) in a series of assemblages that changed with elevation (Figure 2). Anadromous fishes also were present in low numbers, mainly steelhead (*O. mykiss*), fall-run chinook salmon, and Pacific lamprey (*Lampetra tridentata*) (Shapovalov 1947).

Before Euro-American settlement of the region, the watershed was home to the Patwin people; archaeological studies indicate they relied on both the resident and anadromous fish for food (P. Schultz, California Department of Parks and Recreation, pers. comm). As the area became more heavily agricultural in the nineteenth century, the creek became increasingly treated as a ditch for flood control, drainage, gravel mining, and trash disposal. For example, to reduce flooding near the town of Davis, part of the creek was channelized in the 1870s, and several miles of the original stream channel were abandoned, including the reach currently in the central campus of the University of California —Davis (UCDavis). Many nonnative fishes were introduced or spread into the creek starting in the late nineteenth century, and species such as white catfish (*Ictalurus catus*), bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieui*), and common carp (*Cyprinus carpio*) came to dominate the fisheries in the lower creek (Shapovalov 1947). Even though the lowermost reach of the creek became increasingly degraded in the first half of the twentieth century, it continued to support substantial populations of native and nonnative fishes.

In response to the need for flood control and for a reliable regional source of water for farms, cities, and military bases, the Bureau of Reclamation built the Solano Project during the 1950s, completing it in 1957 (Smith 1991). The off-stream water supply from the

Table 1. Past monthly flow regimes and recommended monthly flow regimes for Putah Creek, California, are based on releases from the Solano Project. All flows are in cubic feet per second (cfs). Values above the 1970 release schedule in years after 1970 are due to unregulated "spills" during higher rainfall years.

Past Flows

Median daily flows, 1934–1956, near Winters (pre-Solano Project flows)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All years	794	1075	736	281	125	42	7	5	6	6	37	296

Average annual total of water flowing down the creek: 374,725 acre feet.

Required minimum daily flows, 1970 Solano Project release schedule

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Normal years	25	16	26	46	43	43	43	34	20	20	25	25

Annual amount of water required to be released: 22,137 acre feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry years	25	16	26	46	33	33	33	26	15	15	25	25

Annual amount of water required to be released: 19,217 acre feet.

Actual post-Solano Project median daily releases (1971–1981 and 1985–1990)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All years	38	41	33	46	43	43	43	34	20	20	25	25

Average annual total of water flowing down the creek: 82,519 acre feet

Recommended Flows

Flows for maintaining a living stream at all times

A. Solano Dam releases in all years should equal or exceed the 1970 normal-year release schedule.
B. The minimum daily flows below must be met at river miles 11.5, 14, and 15.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All years	15	15	25	30	20	15	15	10	5	5	10	10

C. Continuous flow must be maintained year-round to the Yolo Bypass.

Spawning and rearing flows for resident native fish

A. An annual three-day pulse release from Solano Diversion Dam must be 150-100-80 cfs to initiate spawning behavior.
B. Immediately following the pulse release, 30 days of flows at 50 cfs must be instituted, followed by gradual ramping of flows through 7 days down to the minimum flows for that month.
C. The releases must occur between 15 February and 31 March but can be coordinated to coincide with uncontrolled releases during that same time period.

Habitat maintanence flows

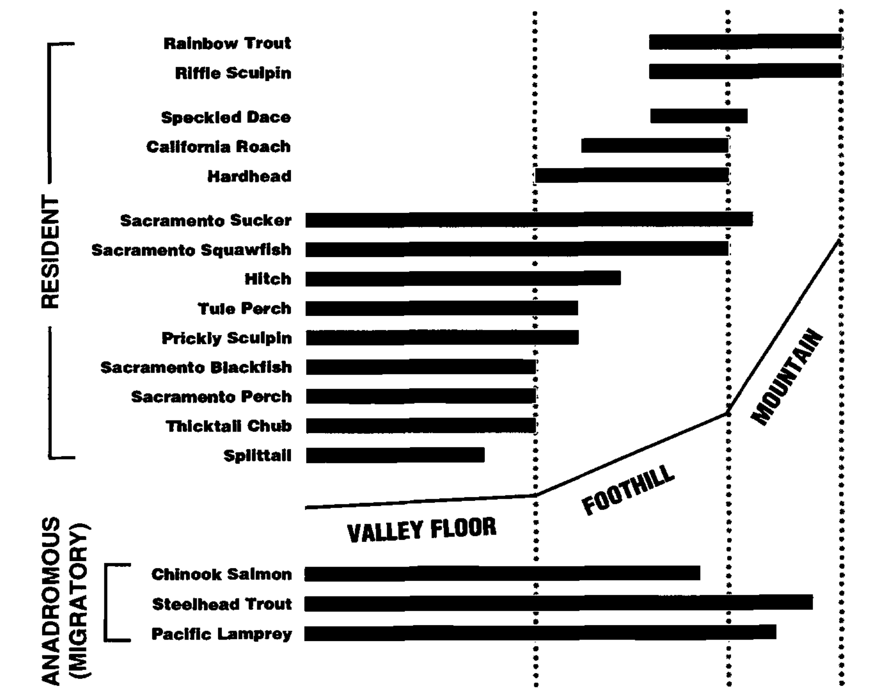
A. One year in three, 1,000 cfs must be released for 15 days if a similar, natural high-flow event has not occurred by 10 February.

Anadromous fish flows

A. Attraction flows of 150 cfs at the mouth of Putah Creek (river mile 24) must be released for 5 days by 15 November.
B. Spawning, rearing, and outmigration flows of 50 cfs must be released from the time of cessation of attraction flows through 15 April.

Solano Project is managed under contract with the Bureau of Reclamation by the Solano Irrigation District (SID), which is the biggest water user in the Solano County Water Agency (SCWA). The centerpiece of the Solano Project is Monticello Dam, which impounds Berryessa Reservoir. This reservoir has a capacity of 1.6 million acre feet of water storage and covers almost 14 mi of the original channel of Putah Creek. Water released from Berryessa Reservoir flows eastward in the creek channel for close to 8 mi before it reaches Solano Rerservoir and the Putah Diversion Dam (PDD), where most of it is diverted south through the Putah South Canal to users in Solano County. The reach between the two dams has cold water and substantial flows year-round, and supports a fishery for both wild and domestic rainbow trout. Below PDD, only minimal flows have been required under a fixed release schedule imposed by the State Water Resources Control Board in 1970 (Table 1), mainly to recharge groundwater and satisfy riparian rights, resulting in a permanent stream for approximately 3 mi. The creek continues east for 20 mi until it reaches the Yolo Bypass and, ultimately, the Sacramento River. The CDFG failed to make any special requests for water or flow regimes in the lower creek, although the State Water Resources Control Board (order 81-11) had authorized the agency to do so in 1981 (Smith 1991). Under the 1970 schedule, releases were allowed to be reduced even further during dry years so large sections of the creek below the diversion dam were completely dewatered during some years.

Figure 2. This generalized diagram of the historic distribution of common native fishes in the Central Valley drainage of California reflects the historic situation in Putah Creek.



Native fish fauna managed to persist in the post-project period, both in the short permanently watered reach below the diversion dam and in a few isolated large pools further downstream that were sustained by subsurface flow, irrigation tail water (imported from the neighboring Cache Creek watershed), and effluent from a sewage treatment plant and aquaculture operations on the UCDavis campus (Figure 3). However, the downstream pools were dominated by nonnative freshwater fishes such as bluegill, white catfish, and largemouth bass (*M. salmoides*) (Figure 4).

The Putah Creek trial

The controversy regarding the need for increased flows in Putah Creek below PDD arose because of two factors. First, the creek had become increasingly recognized by the local citizenry as an amenity with positive values for education, research, recreation, and aesthetics after years of neglect. This resulted in such events as UCDavis declaring the reach along university land to be the Putah Creek Riparian Reserve (officially in 1984, *de facto* since 1979) and a citizen's environmental group, the Putah Creek Council (PCC), forming in 1987. Second, California was hit with a major drought from 1987 to 1992. The drought led to a decrease in flows released into the

Figure 3. The typical distribution pattern of native fishes in lower Putah Creek, 1980-1995, shows how they were concentrated immediately below the Putah Diversion Dam.

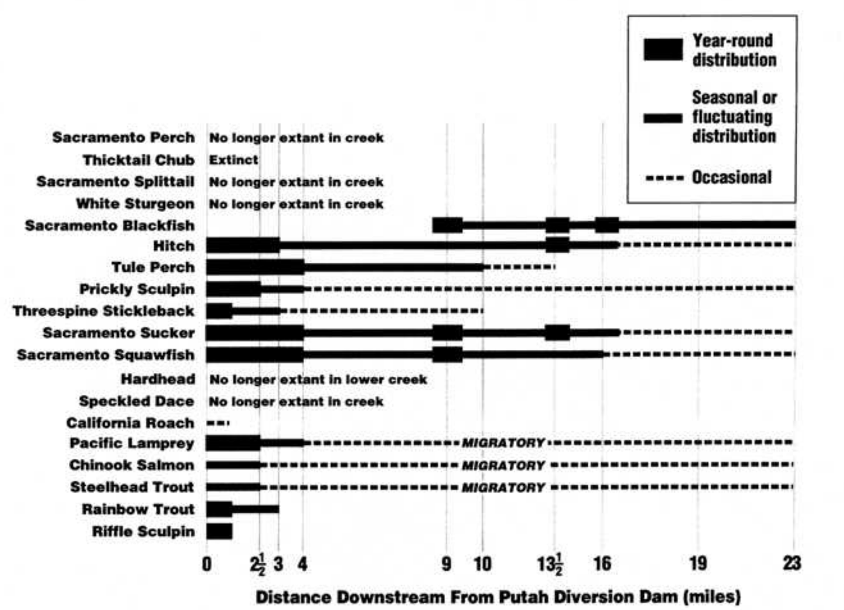
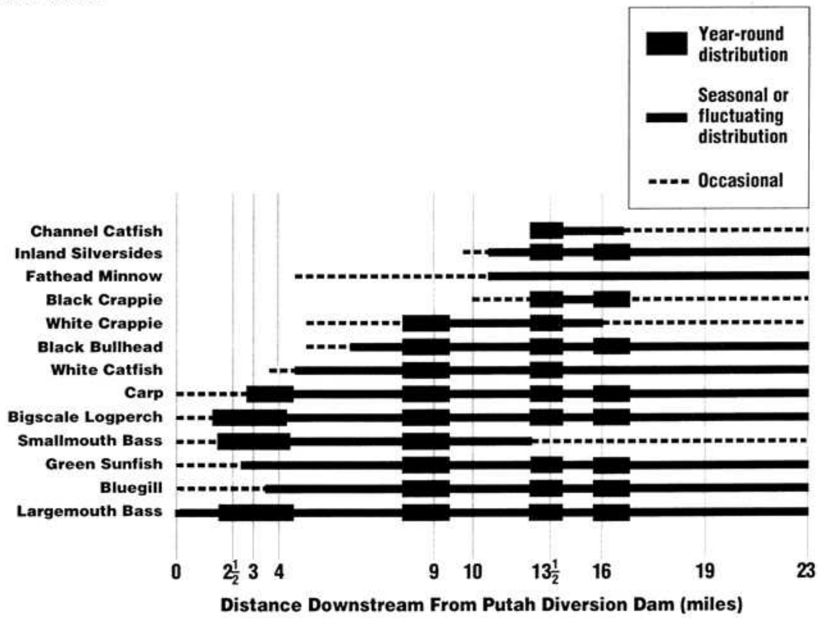


Figure 4. The typical distribution pattern of common nonnative fishes in lower Putah Creek, 1980-1995, shows they were most abundant in the large pools of the lowermost reaches of the creek.



to represent all water users in Solano County.

The trial resulted in Judge Richard K. Park ordering a 50% increase in the minimum release schedule from the diversion dam (approximately 10, 000 additional acre feet of water per year) to keep the creek flowing all the way to its mouth in the Yolo Bypass and to provide additional water for spawning and rearing of native fishes (Anonymous 1996, Table 1). This was less water than the plaintiffs had asked for, but it was nevertheless considered to be a victory because the additional water would keep Putah Creek a living stream. In his decision Park recognized that Putah Creek had high value for the preservation of biodiversity:

"...the present release schedule has impaired the continued viability of this unique assemblage of native fish... [and has] had a negative effect on the educational resources of the creek and on the birds and animals that call it home."

The legal basis for his decision was Section 5937, the Public Trust Doctrine, and Article 10, Section 2 of the California Constitution. The Public Trust Doctrine and California Constitution will not be discussed here, although they are other important tools for restoring flows to streams in California and elsewhere (Koehler 1996; Thomas 1996; Gillian and Brown 1997). The SCWA, SID, and other Solano Project member units are appealing Park's decision, but a decision in the near future is not likely. Two of the benefits of the trial were (1) intense examination of the concept of fish being in "good condition," with an emphasis on ecological health, and (2) development of ecosystem-based flow recommendations.

lower creek from the diversion dam and a reduction of other sources of water as well. Long reaches of the creek began to dry up in 1989, and major die-offs of fish began occurring. The remaining fish were temporarily saved through a combination of interim court-ordered flows; the purchase of water by the City of Davis, Yolo County, and UCDavis; negotiated releases of additional water by SID; continued discharge of effluent into the creek by UCDavis; and other emergency measures. However, attempts to negotiate a permanent solution to the problem failed, and as a result the Putah Creek Council, joined later by UCDavis and the City of Davis, sued SCWA, SID, and other Solano Project member units for additional water in August 1990 (Putah Creek Council v Solano Irrigation District, Sacramento County Superior Court No. 515766). An injunction briefly increased releases during the summer of 1990, keeping some parts of the creek from drying up, but the injunction was lifted in the fall (Smith 1991). In 1991, as legal maneuvers continued, the creek largely dried up, except for the reach immediately below the diversion dam and a few large pools fed by effluent and groundwater. The drought continued in 1992, but the creek was kept flowing by water donated by UCDavis and the Alhambra Pacific Company, arranged by the City of Davis. In 1993 the drought broke, and the creek has experienced higher flows in the years since.

The trial spanned five weeks in March and April 1996. For complex reasons, the university advocated a somewhat different position during the trial in regard to flow recommendations than the Putah Creek Council (PCC) and City of Davis. In this paper we discuss only the PCC position, which we developed. However, for the most part the three complainants presented a unified case, and we use PCC mostly as a shorthand for the entire group. Likewise, the Solano County Water Agency (SCWA) and the Solano Irrigation District (SID), the main defendants in the case, are used in this paper

Fish in good condition: a three-tiered approach

Because Putah Creek has substantially more complex fish assemblages than other streams to which the Section 5937 good-condition criterion had previously been applied, we developed a definition that encompasses three levels of fish health: individual level, population level, and community level.

Individual level

At the individual level most fish in a healthy stream environment should have a robust body conformation; should be relatively free of diseases, parasites, and lesions; should have reasonable growth rates for the region; and should respond in an appropriate manner to stimuli (Sprague 1990). In other words, a healthy fish is one that obviously looks good to a human observer, is not stunted, and will take appropriate evasive action when a predator or angler approaches. Because water quality is fairly high when Putah Creek is flowing, fish typically have few deformities or obvious health problems. Student studies directed by the senior author and length frequency analyses indicate that growth rates of most species are typical for the region. Thus, most individual fish appear to be in good condition when they are allowed to live in the creek. Obviously, fish killed as the result of the creek drying up were not in good condition.

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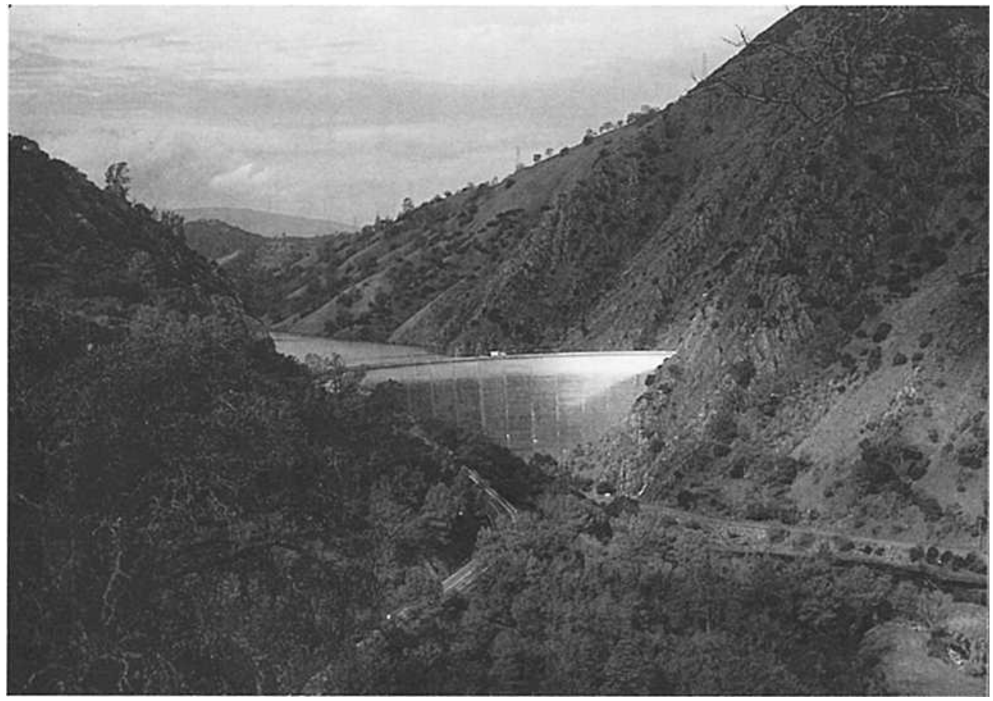

Competed in 1957, Monticello Dam captures most of the water in the Putah Creek drainage and stores it in Berryessa Reservoir.

Population level

Previous interpretations of Section 5937's phrase *good condition* were applied at the population level to single species. For example, during testimony at the 1993 Mono Lake trial, CDFG Biologist Darrell Wongs defined it in relation to the nonnative brown trout (*Salmo trutta*), the principal fish species present. Wong considered *good condition* to mean that each population must have (1) multiple age classes (evidence of reproduction), (2) a viable population size, and (3) healthy individuals (as above). Viable population size is a hard number to nail down (both in theory and practice), so two surrogate indicators were relied on in the case of Putah Creek. The first was that extensive habitat should be available for all life history stages. The second was that all life history stages and their required habitats should have a broad enough distribution within the creek to sustain the species indefinitely (barring stream-long catastrophes). For Putah Creek we found that most native fishes did not meet this definition of *good health* at the population level. Sacramento blackfish (*Orthodon microlepidotus*) were usually found only in small numbers in one or two size classes, indicating infrequent reproduction (M. Marchetti, personal experience). Other native fishes, especially those found just below the diversion dam, had very limited habitat available to them, indicating that long-term persistence was doubtful considering their isolation from other populations and their potential to be devastated by natural or unnatural disasters.

Community level

Good condition or health at the community level is a complex concept because fish communities are naturally dynamic in structure and composition. It is essentially equivalent to the biotic integrity concept of Karr (1981, 1993). *Community health* is a necessary condition to define in streams with multiple species because not just any collection of species is sustainable through time. In California a fish community in good health (with a high value for an Index of Biotic Integrity such as those in Moyle and Marchetti, in press) is one that

(1) is dominated by co-evolved species,
(2) has a predictable structure as indicated by limited niche overlap among the species and by multiple trophic levels,
(3) is resilient in recovering from extreme events,
(4) is persistent in species membership through time, and
(5) is replicated geographically.

In other words it is a dynamic assemblage of fishes that will predictably inhabit a given range of environmental conditions. In the long run the most predictable communities will be those with species that evolved together within a region. However, assemblages that contain nonnative species,

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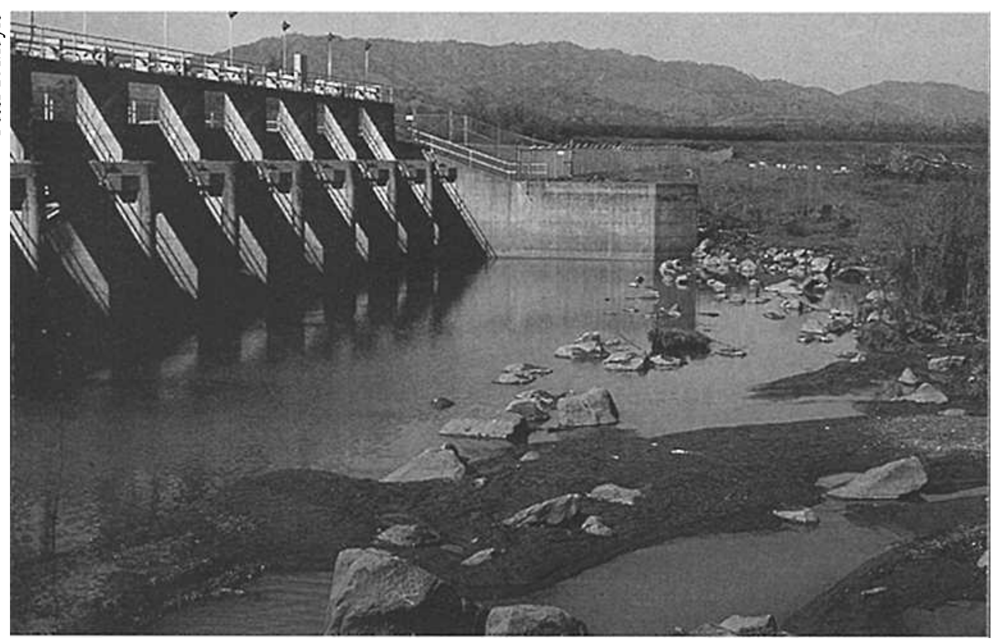

This picture of Putah Diversion Dam was taken in February 1995, after large amounts of sediment were flushed from behind the dam. It diverts most of Putah Creek's water south into Solano County.

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Much of lower Putah Creek dried up during 1989 and 1990, leaving fish in a few remnant pools. This picture was taken in August 1990. (left)

Putah Creek in the reach above Stevenson Road Bridge, almost 10 miles below the Putah Diversion Dam, historically had year-round flows. This picture was taken September 1994. (below)

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including assemblages made up largely of nonnative species, can behave for short periods similarly to a native assemblage (e.g., Meng et al. 1995). Of course, persistence of non-coevolved assemblages has not been tested through long stretches of time (>50 years). In the case of Putah Creek, the *good-community-health* definition is not even met by the native fish assemblage immediately below the diversion dam (Figure 3) because that assemblage's persistence and resilience is doubtful, given its limited distribution and its isolation. In addition, the particular complex assemblage of native species present in the reach, while once common, appears to have largely disappeared from the region and to have been replaced by subsets of the native fauna or by mixtures of native and nonnative species (Leidy 1984). The rarity of this native fish assemblage made its protection important and a focus of the evidence presented at the trial. While the nonnative assemblages of fish in the lowermost reaches of the creek (Figure 4) also would not be considered in good health by the above criteria, they are in no danger because the species, in various combinations, dominate the waters of the Sacramento Valley floor (Moyle 1976). Also, many of the combinations of nonnative species found in California are naturally widespread in the eastern United States.

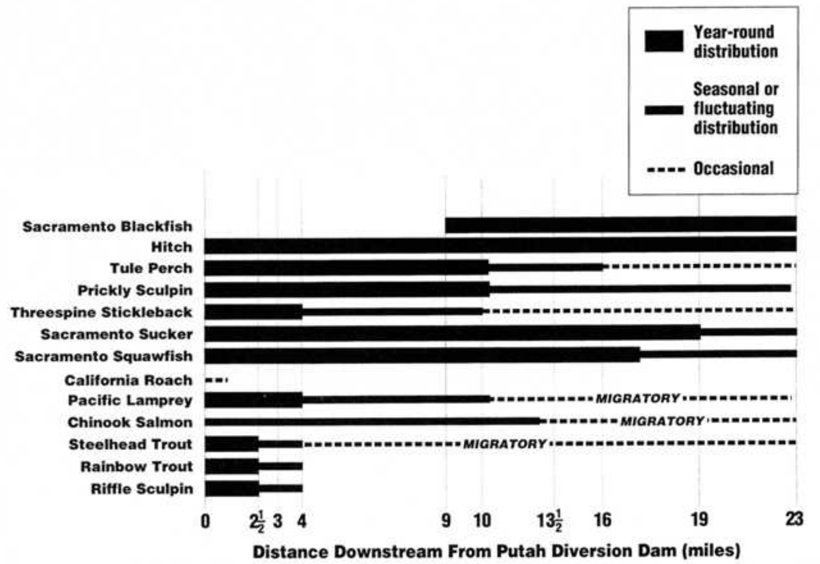
Ecosystem-based flow recommendations

Historically, management of regulated streams has focused on economically important species, usually trout and salmon (*Salmonidae*). This type of management often has contributed to the population declines of other native fishes that typically require different flow regimes. In Putah Creek the native fishes were not considered when the Solano Project was built, and flow releases from PDD were used to satisfy riparian water right holders and provide groundwater recharge (Smith 1991). The trout fisheries in the coldwater reach between Monticello Dam and the diversion dam—as well as the trout and introduced panfish fisheries in Berryessa Reservoir—had been considered by the California Department of Fish and Game as adequate replacements for fisheries lost from the 37 mi of stream either depleted of water or flooded by the reservoir. Prior to the closing of Monticello Dam in 1957, much of the creek was poisoned with rotenone in an unsuccessful effort to rid the upper drainage of common carp and native "rough" fish, according to CDFG file reports. Despite these efforts, an assemblage of native fishes managed to persist in the permanent water below the diversion dam, some anadromous fish continued to run up the creek, and fisheries for warmwater nonnative fishes developed in pools in the lower reaches of the creek that were maintained by various sources of water.

During the trial, PCC argued that these remnant populations of native fish represented a remarkable restoration opportunity and advocated a broad ecological approach to stream management that could maximize the benefits from limited amounts of water. The PCC requested flows to provide for anadromous fishes, a native fish assemblage, and fisheries for nonnative fishes as well as to improve overall biodiversity in the creek and its riparian zone. The flow recommendations had four components (Table 1): (1) sufficient water in the creek at all times to keep a continuous flow to its mouth in the Yolo By-pass; (2) enhanced flows in February and March to favor the spawning and rearing of native resident fishes; (3) habitat maintenance pulse flows every three to five years to improve stream habitats and reduce numbers of exotic species not adapted to extreme flow events; and (4) enhanced flows from November through April for the spawning and rearing of anadromous fish, especially chinook salmon.

Under the recommended flows, only small runs of anadromous fish would be maintained, but at least Putah Creek could contribute to the overall recovery of salmon and steelhead, species that are in serious decline in the Central Valley (Fisher 1994). The flows would definitely allow for expanded populations of native fishes so they could continue to exist in a distinct assemblage (a valley floor transitional assemblage) that has now become rare. The longer stream reach that would be occupied by the assemblage would make it more resistant to disruption by natural and unnatural disasters. Although the emphasis was on maintaining native fishes, PCC also recognized the value of the fishery for bass, catfish, and other fishes in the lower reaches of the creek. Therefore, the recommended flows aimed to keep water in the lowermost sections of stream that dry up most years, creating warm, slow-moving pools that favor non-native game fishes. Overall, the PCC approach sought to ensure lower Putah Creek maintained a high diversity of fishes of all types and sustained angling opportunities for local residents.

Figure 5. The distribution of native fishes predicted for lower Putah Creek if recommendations of the Putah Creek Council are adopted, shows a likely increase in the abundance of native resident fishes in the lower reaches of the creek. Under the flows ordered as the result of the Putah Creek trial, anadromous salmon, steelhead, and lamprey are likely to have more fluctuating distributions than shown here.



Restoration or improvement?

One of the main arguments used by SID and SWCA against the PCC proposal to restore fish health in Putah Creek was that the required stream flows would represent a substantial improvement over the natural (historic) conditions in the lower creek. The pre-project lower creek was intermittent in flow (SID and SWCA stated it was sometimes dry) and highly degraded by human activity in and outside the channel. Because releases below the diversion dam already provided several kilometers of permanent stream, SID and SWCA argued that the project had already improved the stream and was responsible for the existence of the native fish assemblage. In effect, they argued that fish were in "good condition" immediately below the dam, even using our criteria, and that what happened to the fish in the rest of the lower creek was not their responsibility. In addition, they argued that the permanent flows in the interdam reach and the existence of Berryessa Reservoir both provided good sport fisheries and habitat for some native fishes.

The PCC response was that the Solano Project had done major damage to the entire creek ecosystem and that a fixed release of water to a short stretch of creek was not enough to make up for this damage. The PCC response was essentially that water agencies needed to accept more responsibility for the cumulative damage that had been done, and they should have a major role in restoring some of the lost, declining, or at-risk biodiversity. The PCC arguments included the following:

(1) Increased flows are needed to ensure that the fish populations and assemblages will truly be sustainable no matter what else happens to the creek or watershed. The fish must be in good condition in both wet years and dry years at all three levels of health. This means habitat conditions that allow a diverse fish fauna must be maintained throughout the creek below the diversion dam.

(2) Construction of Berryessa Reservoir flooded a substantial portion of the Putah Creek watershed, eliminating or reducing populations of native fishes as well as valuable riparian habitats. Nonnative game fishes and planted trout are not an adequate substitute for the loss of native fishes and their habitats.

(3) Putah Creek is one of many creeks that has been thoroughly altered by human activity. It is different from most other streams in the region in that a remarkably intact native fish fauna has persisted in a small section. Therefore, this creates a special responsibility to enlarge this relict assemblage.

(4) Putah Creek is increasingly an urban stream and a site for recreation, education, and research. These values are only going to increase, and the lessons learned from managing Putah Creek should be transferrable to other streams with less of a constituency at this time.

(5) The undammed Putah Creek once provided many downstream benefits such as improved conditions for salmon and other fish in the Sacramento-San Joaquin Estuary and annually flooded wetlands, benefits that have largely been lost. A healthy stream with healthy, diverse fish populations is partial restoration of those lost benefits.

(6) The Solano Project was built largely with public funds and is part of the total water development package in the Central Valley. Combined state and federal projects have decimated the native fish fauna of central California, an

impact that was poorly appreciated at the time the projects were built. Lower Putah Creek provides an unusual opportunity to restore some of that lost fauna.

Implicit in all these arguments is a change in public attitudes toward the importance of providing water for noneconomic benefits. There seems to be greater public acceptance of the ideas that we need to maintain native fish assemblages and other indicators of biodiversity because it is time to start making stronger connections to our local environment and to accept our responsibility for the continued existence of other creatures that share the planet with us.

Instream flows and biodiversity

Key aspects of the case presented by PCC were instream flow recommendations that attempted to integrate many needs of the creek ecosystem. These were based on expert opinions, a few stream transects made under different flows, a long-term set of data from Moyle's annual fish sampling of the creek with an ichthyology class, and intense sampling of the lower creek by both sides during the three years preceding the trial. The Bureau of Reclamation abandoned a study using the Instream Flow Incremental Methodology (IFIM) presumably because the complex channel geometry was impossible for its engineers to model and because the high turbidity of the water and the complexity of the fish fauna made data collection for developing habitat suitability (PHABSIM) curves extremely difficult. Nevertheless, we thought we presented a reasonable set of flow recommendations that would ensure the long-term survival of the native fish assemblage and maintain or improve the fishery for nonnative game fishes (Figure 5). Equally important, the team of biologists working with PCC thought the increased flows would enhance riparian and other natural values of the creek and help further change public perception of the creek from a dry ditch to a living ecosystem with high amenity values. The considerable local publicity surrounding the trial helped to increase public awareness of the value of the creek. The trial judge agreed with the PCC analysis of the situation in lower Putah Creek and with our definition of *good condition* when applied to the fish. While he endorsed the idea that restoring native fish communities was a highly appropriate goal, he also recognized the water supply needs of the water agencies. Therefore, he ordered a flow regime that attempted to balance the two types of interests:

(1) Sufficient flows should be released during the summer to keep even the lowermost reach of the creek as a living stream, essential for maintaining all resident fish in good condition.

(2) Spring flows, essential for maintaining the resident native fishes in good condition, should be increased for spawning and rearing of native fishes.

(3) The increased fall and winter flows requested for spawning and rearing of chinook salmon and other anadromous species were not justified because of the naturally small or intermittent nature of the runs. Park ruled that because the historic role of anadromous fish in the creek was small, the water costs of restoring them were too high, even in the context of regionwide salmon declines.

(4) The requested habitat maintenance flows would not be ordered because the water costs were too high and because natural high-flow events occur periodically that might satisfy the need.

When SID and SWCA appealed the decision, the Putah Creek Council and the City of Davis filed a cross appeal asserting that Park should not have denied the requests for habitat maintenance and anadromous fish flows. The council and the city argued that Section 5937 does not permit sacrificing fish to meet the water demands of the water agencies. Rather, Section 5937 requires that *all* fishes, including salmon, must be maintained in good condition.

Peter B. Moyle

Leaders of the Putah Creek Council, Susan Sanders (right) and Robin Kulakow (center), hold a press conference in the dry stream bed in August 1990.

Conclusions

The Putah Creek trial is representative in many ways of actions being taken throughout North America to protect and restore aquatic ecosystems (Doppelt et al. 1993). In this case, as in many others, a local citizen's group was the catalyst in a successful challenge to the way water was allocated by a major water project. A key to the success of the Putah Creek Council, besides a willingness on the part of its leadership to invest huge amounts of time in fund raising and leadership activities, was its ability to get local institutions (such as the City of Davis and UCDavis) to join its efforts and to find highly qualified scientists willing to work with them in developing defendable, rational restoration policies. But it is unlikely that the trial would have been so successful if widespread public support for restoring Putah Creek as a public amenity for aesthetics, recreation, teaching, and research had not existed. From a legal and political perspective, the Putah Creek trial also showed that acceptable instream flow recommendations can be made using qualitative, as opposed to quantitative, models. In addition, a fortuitous series of wet years have at least partially valided the biology behind the model we developed, including successful spawning of chinook salmon in the creek.

We hope that the broad definition of keeping fish in *good condition* presented here can be used in resolving other conflicts about allocation of water in regulated streams to provide more water for aquatic ecosystems and their inhabitants. We agree with Park, whose 5 April 1996, opinion stated,

> "Putah Creek...is a treasure. It is a home for birds, for wildlife, for waterfowl, fishes, trees, and vegetation. It's an entire ecosystem in the middle of a heavily farmed agricultural environment. It's a place for people to watch birds, fish, canoe, to kick back and enjoy the sights, sounds, and the smells."

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