From T.P. Simon, ed., 1999. Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities.
CRC Press Boca Raton, FL

14 Applications of Indices of Biotic Integrity to California Streams and Watersheds

EXHIBIT CT 73

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14.1 INTRODUCTION

Indices of Biotic Integrity (IBIs) are measures of the health of streams and other aquatic systems that have been developed as an alternative to physical and chemical measures of water quality (Karr, 1981; Karr et al., 1986; Karr, 1993). Biotic integrity is defined as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley, 1981). Despite this broad definition, in practice IBIs have mostly used measures of fish abundance and diversity to determine biotic integrity; the assumption behind IBIs is that the responses of an integrated community of fishes adequately reflect both major environmental insults, such as a large pollution event, and more subtle long-term effects, such as chronic nonpoint source pollution and changes in land use.

IBIs are most widely used in eastern North America, where fish communities are complex and largely composed of native species (Miller et al., 1988; Steedman, 1988). In western North America, IBIs have been difficult to develop for a combination of reasons: (1) fish species richness is low, making the development of adequate numbers of metrics for use in IBIs difficult; (2) endemism is high, so it is difficult to transfer IBIs from one region to another; (3) introduced fishes are often abundant, even in relatively "pristine" waters; (4) dams and diversions are a major cause of

0-8493-4007-1/98/$0.00+$.50

environmental change; and (5) measures of biotic integrity are often needed that cover entire watersheds, yet there is typically inadequate site-specific information to make a measure based on mean IBI scores.

The purpose of this chapter is to discuss these problems and their solutions, and to demonstrate the application of IBIs to three very different situations in California: (1) evaluation of watersheds in the entire Sierra Nevada range for setting conservation priorities; (2) long-term evaluation of a regulated stream (Putah Creek); and (3) evaluation of a fairly pristine stream (Dye Creek) that has been extensively invaded by exotic species (Figure 14.11).

14.2 IBI PROBLEMS

Three very different case studies were used as situations in California to demonstrate the application of the IBI: (1) evaluation of watersheds in the entire Sierra Nevada range for setting conservation priorities; (2) long-term evaluation of a regulated stream (Putah Creek); and (3) evaluation of a fairly pristine stream (Dye Creek) that has been extensively invaded by exotic species (Figure 14.1). California streams are characterized by low species richness, high endemism, increased numbers of introduced species, and increased anthropogenic disturbance by the construction of dams and diversions. These stream effects have created an emerging need in California for the ability to assess entire watersheds rather than reach specific areas.

14.2.1 LOW SPECIES RICHNESS

A general assumption of most IBIs is that there is a positive relationship between species richness and IBI score. However, west of the Rocky Mountains, it is unusual for undisturbed streams to contain more than five or six native fishes. At high elevations, it is typical for streams to contain only one or no native fish species, usually a trout (*Oncorhynchus* spp.). In coastal streams, many of the species are anadromous and might be present only seasonally or have their abundances difficult to assess. The low diversity and shifting nature of the fish faunas make it difficult to develop metrics based on species diversity, trophic specialization, and reproductive strategy that are typical of IBIs for eastern streams (Miller et al., 1988). Three solutions to this problem have been suggested: use standard IBI metrics anyway, reduce the number of metrics, or develop metrics based on aquatic organisms other than fish.

The first solution was used by Lyons et al. (1995), who developed an IBI for streams of west-central Mexico with 2 to 10 species per sampling site. Their 10-metric IBI was correlated with environmental quality at their sites. Their success could have been partly related to high taxonomic diversity among the three basins sampled: a pool of 23 native fish species in 10 families. In California, poor success was obtained in developing IBIs using standard metrics (Miller et al., 1988, but see Putah Creek example below) despite considerable trophic specialization among the native fishes (Moyle and Herbold, 1987). The causes of this appeared to be related to: (1) low taxonomic diversity (pools of 5 to 15 species in 4 to 8 families) with a strong domination by cyprinid and salmonid species; (2) the near universality of spring-time spawning of the native fishes in response to high flows, resulting in similar responses to many environmental perturbations; (3) the abundance and diversity of nonnative species at many sites; and (4) the strong segregation of native species in response to gradients of elevation and temperature, reducing the taxonomic pool at each site even further.

One response to these problems is to reduce the number of metrics used to calculate the IBI, although there is presumably a relationship between the number of metrics and the sensitivity of the IBI as a measure of environmental change. This approach was used (five metrics) by Lyons et al. (1996) for Wisconsin coldwater streams because species diversity decreased as habitat and water quality improved. Hughes and Gammon (1987) reduced the 12 metrics of Karr (1981) to seven for

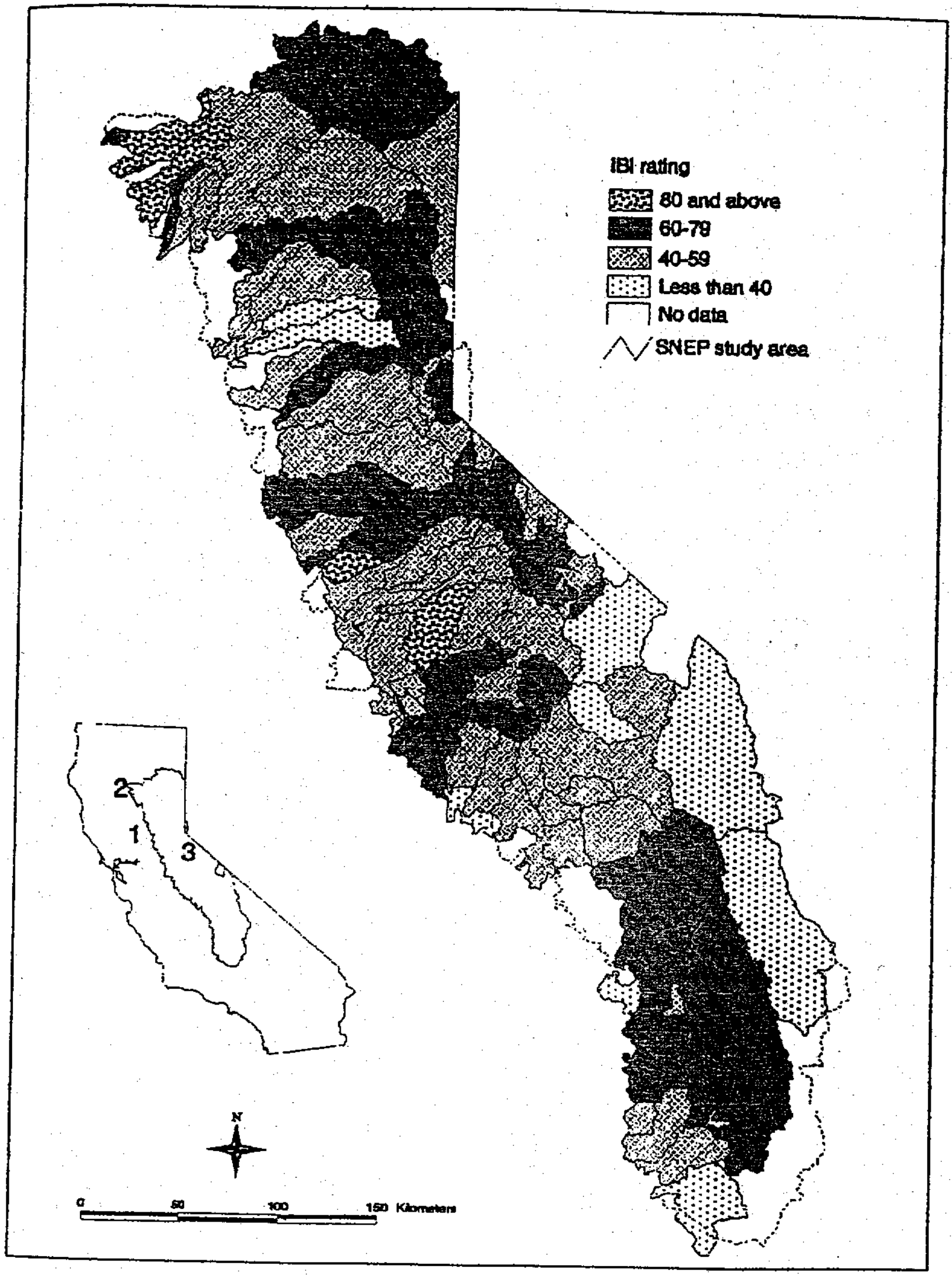

FIGURE 14.1 W-IBI ratings for 100 Sierra Nevada watersheds, California, from Moyle and Randall (in press). The insert map shows the general location of the three study areas: (1) Putah Creek, (2) Dye Creek, and (3) the Sierra Nevadas.

the moderately rich (19 native species) Willamette River drainage of Oregon, and found that the new IBI was a good predictor of water and habitat quality. For many California streams, just two metrics based on number of native fish species and the abundance of native fish is a good descriptor of biotic integrity of the fish community (Miller et al., 1988), but they may say little about habitat or water quality because native fish can be displaced from good habitat by nonnative fishes. In order to increase the number of metrics, metrics based on taxa other than fish may be needed. In California, diversity and abundance of amphibians with aquatic larvae may make especially appropriate measures because two to four species are often present in or near streams and they show a strong sensitivity to environmental change. The use of amphibians has not yet been attempted systematically, but the possibility of their use is demonstrated in examples below. It may also be possible to use benthic invertebrates for additional metrics. For California, stoneflies (Plecoptera), mollusks, and crayfish might be especially useful for this purpose because they are easy to collect along with fish and are sensitive to environmental change. The use of benthic invertebrates for an IBI has been proposed by Kerans and Karr (1994), but as an independent "B-IBI."

14.2.2 HIGH ENDEMISM

Coupled with the low species richness found in the drainage basins of western North America is high endemism. Adjacent drainages may share only a few species or may contain different species combinations because of zoogeographic events (Moyle, 1976a). This makes the development of widely applicable regional IBIs difficult and increases the difficulty of cross-drainage comparisons. One solution is to essentially have a pool of possible metrics for regional use, choose the appropriate metrics for a particular watershed, and then use standardized scores for comparisons (Miller et al., 1988). Metric "pools," for example, could be developed for each of the ecoregions discussed by Hughes et al. (1994). Another solution would be to use some measure of endemism as a metric. Such measures may have to be below the level of species. Brown et al. (1992) point out that California roach (*Lavinia symmetricus)* populations in the San Joaquin River drainage of central California show morphological divergence among tributary drainages, and indicate that a conservation strategy for this watershed should take this diversity into account. Li et al. (1995) point out the value of using genetic information in setting up any system of aquatic reserves in western North America, especially to protect the diversity of anadromous fishes that have frequently hybridized with introduced hatchery strains. Perhaps, a metric could be developed that gives a high score for the continued presence in abundance of all endemic forms (including genetically or morphologically distinct forms that are not formally described as a named taxon) and a low score for their absence. Such a metric, of course, would presuppose a high level of knowledge of the genetics and morphology of species throughout the region to which it was being applied.

14.2.3 INTRODUCED FISHES

Introduced fishes present a particular problem in the West because they frequently dominate local faunas. They are particularly likely to be dominant in highly disturbed warmwater streams at low elevations and in lightly disturbed montane streams, although their presence is pervasive (Moyle, 1976). Because introduced fishes tend to predominate in highly disturbed and polluted streams, it makes sense to use their diversity and abundance as a measure of loss of biotic integrity (as defined by Karr and Dudley, 1981, using native fishes in natural habitats) (Hughes and Gammon, 1987; Miller et al., 1988). Measures of introduced fish abundance are particularly likely to be useful for reflecting the degree to which dams and diversions have altered flow regimes. In California, natural flow regimes strongly favor native fishes adapted to the extreme seasonal patterns (Baltz and Moyle, 1993). In high mountain streams, introduced salmonids represent a strong disturbance to biotic integrity, especially in waters that were originally fishless, where introduced trout may eliminate large invertebrates and amphibians (Moyle et al., 1996).

The problem with using introduced fish as an entirely negative factor is that their abundance might provide a great deal of information about water and habitat quality, particularly if the native species have been displaced or eliminated through competition and predation, rather than habitat change. This represents a conflict between using an IBI to measure diversity and abundance of native organisms versus using an IBI to measure water and habitat quality. Thus, a montane stream in which native cutthroat trout (*Oncorhynchus clarki*) have been replaced by introduced rainbow trout (*O. mykiss*) will presumably respond to most environmental insults in a similar fashion to the way it would have if cutthroat trout were still present. Other species, especially brown trout (*Salmo trutta*), may respond quite differently (e.g., Strange et al., 1992). One solution for trout streams is to have one metric that gives a high score for the abundance of native trout and other metrics that score total trout abundance and abundance of large trout, regardless of species (Miller et al., 1988; Lyons et al., 1996). As the Putah Creek example below shows, a similar approach may have to be taken as well to warmwater streams and lowland rivers, especially where some native species are extinct and are therefore not available to be used as measures of habitat recovery. A California river or stream that supports some native fishes, a diversity of nonnative fishes, and a good fishery for introduced centrarchid bass, sunfish, and catfish would probably obtain fairly high IBI scores if metrics developed for eastern streams were used to evaluate it. The historic biotic integrity of such a system, of course, would be low because of the nearly complete disintegration of the original fish communities.

14.2.4 DAMS AND DIVERSIONS

Most of the larger streams in California and the West have flows regulated by dams and diversions to some degree. While in some cases a dam may cause a stream to dry up completely, the effect of most dams is to alter the amount and pattern of flow. In California, typically, peak winter and spring flows are captured and summer flows are augmented; the augmentation is often provided in order to improve or sustain fisheries for salmonids. The more uniform flow regimes that typically result do not favor native fishes, which need high spring flows for spawning and can survive through summer low-flow conditions (Moyle, 1976; Baltz and Moyle, 1993; Strange et al., 1992). The native fishes are also well adapted for persisting through winter flood events, which may greatly reduce abundances of nonnative warmwater species. Occasionally, as in Putah Creek, releases below dams may favor native fishes and be important in their conservation, because they allow native fishes to become abundant in areas in which they may have originally been present only in small numbers, seasonally, or during wet years. Thus, there is the possibility that a site below a dam, requiring flows that depend on dam operation, can receive as high an IBI score as a site in an unregulated stream, which is less dependent on human decisions for persistence of its fish community. Likewise, a stream below a dam that has become intermittent because of dam operations can receive an IBI score comparable to that of naturally intermittent streams and not reflect the major change that has taken place (Miller et al., 1988). There are no easy solutions to these problems of applying an IBI to regulated streams, except to provide caveats about the precarious nature of fish communities in such streams and to generally recognize that the more a stream has a flow regime resembling its original regime, the more likely it will have its original fish assemblage (Stanford et al., 1996).

14.2.5 WATERSHED EVALUATION

IBIs are typically site-specific measures of biotic integrity. However, a growing need in the West is to evaluate entire watersheds in order to make decisions about priorities for conservation and restoration (Li et al., 1995; Frissell et al., 1996; Frissell and Bayles, 1996; Stanford et al., 1996). One way to produce a watershed-level IBI is to take the mean of all site-specific IBIs, which Steedman (1988) found had a high correlation with factors such as forest cover. Another approach, especially useful when adequate site-specific data are in short supply, is to develop an IBI using watershed-wide metrics, as given below for Sierra Nevada watersheds. These metrics are developed using expert opinion to evaluate broad distribution and abundance information. Because an IBI of this type is different in scoring and application than standard IBIs, Moyle and Randall (in press) follow the convention of Kerans and Karr (1994) in putting an additional letter in front of IBI, in this case W-IBI, to indicate the differences.

14.3 USE OF THE IBI IN CALIFORNIA

In earlier work (Miller et al., 1988), there was considerable skepticism about the ability to apply the IBI concept to California, for many of the reasons discussed above. The three examples below represent our first attempt to use IBIs since that time. The three situations are very different from one another, ranging from 100 watersheds over a large area (Sierra Nevada), to a regulated stream with a large number of native and introduced fish species (Putah Creek), to a small unregulated stream that has been extensively invaded by nonnative fish and frogs (Dye Creek). Future work will determine if the idiosyncratic IBIs developed for these situations have broader applicability.

14.3.1 SIERRA NEVADA WATERSHEDS

The Sierra Nevada is a range of mountains that makes up much of the eastern third of California and is the source of much of the state's water developed for human use. A congressionally mandated evaluation of the range and its biota found that aquatic habitats and ecosystems were among the most altered (Sierra Nevada Ecosystem Project, 1996). This finding was based in part on an analysis of 100 large watersheds by Moyle and Randall (in press), using a Watershed Index of Biotic Integrity (W-IBI). The W-IBI consists of six metrics, using both fish and amphibians (Table 14.1). It attempts to deal with both the problems of trout introductions into fishless waters, the absence of anadromous fish from many areas because of dams, the major differences between the watersheds on the west and east sides of the range (e.g., there were no anadromous fish on the east side), and the disappearance of native frogs due to a variety of factors. Of the 100 watersheds evaluated, 7 were found to be in excellent condition, 36 in good condition, 48 in fair condition, and 9 in poor condition (Moyle and Randall, in press). These ratings correlated well with various measures of disturbance to the watersheds and with subjective evaluations by agencies and environmental groups. They were used to develop recommendations for the systematic protection of aquatic biodiversity in the Sierra Nevada (Moyle, 1996), along the general lines recommended by Moyle and Yoshiyama (1994).

14.3.2 PUTAH CREEK

Putah Creek drains a large watershed in Lake, Napa, Solano, and Yolo Counties, on the east side of the Sacramento Valley, in central California. The creek feeds Berryessa Reservoir, backed up by Monticello Dam. Below Monticello Dam, the water flows in its original channel for about 13 km before being diverted into Solano County at Putah Diversion Dam. Below the diversion dam, only minimal releases have been made, mainly to satisfy needs for groundwater recharge and water for riparian landowners for 3 to 4 km below the dam (Marchetti and Moyle, 1996; Moyle et al., 1998). During drought years, releases are reduced even further, and much of the 35 km of the creek has gone dry, except for pools maintained by wastewater effluent and other sources of water. Despite this release schedule, a remarkably diverse assemblage of native fishes has maintained itself below the dam, and a fishery for nonnative fishes has developed in the lower and middle reaches of the creek. During a period of extended drought, loss of both these assemblages seemed imminent, and they were saved mainly through emergency releases of water from the dam (Moyle et al., 1998).

TABLE 14.1
Metrics and Scoring System for an Index of Biotic Integrity for Sierra Nevada Watersheds

I. Native ranid frogs
  1 Absent or rare
  3 Present
  5 Abundant and widely distributed
II. Native fishes
  1 Absent or rare *or* introduced where not native
  3 Present in much of native range
  5 Abundant, in most of native range within watershed
III. Native fish assemblages (excluding trout-only assemblage)
  1 Largely disrupted
  3 Present but scattered or containing exotic species
  5 Largely intact
IV. Anadromous fishes (if historically present)
  1 Absent or rare
  3 Present mainly below dams or uncommon
  5 Found in original range
V. Trout
  1 Range greatly expanded, mixture of nonnative and native species *or* range greatly reduced
  3 Range expanded but includes native species *or* range about the same but native populations reduced, exotics present.
  5 Mostly native species in original range
VI. Stream fish abundance
  1 Substantially lower than presumed historic levels *or* widespread and abundant in originally fishless areas
  3 Somewhat lower overall than historic levels *or* present in fishless areas
  5 About the same as or higher than historic levels

IBI score = [Total points possible/number of metrics] × 20

80–100	Aquatic communities in very good to excellent condition
60–79	Aquatic communities in good condition
40–59	Aquatic communities in fair condition
<40	Aquatic communities in poor condition

Note: See Moyle and Randall, in press, for detailed explanations of the metrics.

In order to develop a more permanent strategy for the conservation of the native fishes and maintenance of the fishery, sampling was performed 35 km below Putah Diversion Dam for 3 years. An IBI was developed along the lines of standard IBIs, but recognizing both the positive and negative aspects of introduced species (Table 14.2). A preliminary analysis of the data indicates a strong upstream-downstream trend in biotic integrity, with assemblages made up mostly of native species having the highest scores (Table 14.3). The IBI scores demonstrate (1) the rapid loss of native fishes below the point where releases from the dam provide significant flows to the creek; (2) the presence of a diverse assemblage of nonnative fishes in the lower reaches of the creek, and (3) downward shifts in biotic integrity during drought years. likewise, an analysis of a long-term (15 years) sampling program at one site on the creek indicates that IBI scores tend to decline during extended periods of drought, which favor nonnative fishes that can live in stagnant, eutrophic pools (Table 14.4). Low flows during drought periods apparently also reduce the ability of native fishes to spawn and decrease survival of their young.

TABLE 14.2
Metrics for an Index of Biotic Integrity for Putah Creek, Yolo Co, CA

- I. Percentage native fish species
    - 1 <20%
    - 3 20–80%
    - 5 >80%
- II. Number of native species present
    - 1 0–1
    - 3 2–4
    - 5 >4
- III. Number of age classes, native cyprinids and suckers
    - 1 0–1
    - 3 2
    - 5 3+
- IV. Total number of fish species present
    - 1 <5
    - 3 5–7
    - 5 >7
- V. Total fish abundance
    - 1 Low numbers present
    - 3 Common, small numbers captured without difficulty
    - 5 Abundant, easy to capture in large numbers
- VI. Percentage top carnivores
    - 1 <1%
    - 3 1–5%
    - 5 >5%
- VII. Percent tolerant species[a]
    - 1 >20%
    - 3 5–20%
    - 5 <5%
- VIII. Percent introduced lentic or "pond type" species[b]
    - 1 >40%
    - 3 10–40%
    - 5 <10%

IBI Score = [Total points/number of metrics] × 20

Note: Scoring classes are as presented in Table 14.1.

[a] Tolerant species include the following: common carp, goldfish, fathead minnow, green sunfish, black bullhead, red shiner, and golden shiner.

[b] Introduced lentic and "pond type" species were chosen due to their tendency to dominate backwaters, impoundments, and stagnant pools in altered warmwater streams. They include the following species: white crappie, black crappie, bluegill, largemouth bass, and inland silverside.

This analysis indicates that at least in some situations, a more or less conventional IBI can be used in California to demonstrate changes in fish communities as the result of human disturbances. The relatively high diversity of both native and introduced fishes in Putah Creek, however, is unusual, and this or similar IBIs will probably only be usable in lowland streams of the Central Valley.

TABLE 14.3
Scores for Individual Metrics and the IBI for Eight Sampling Sites on Lower Putah Creek, for a Drought Year (1994), an Average Water Year (1995), and a Wet Year (1996)

		IBI Metrics								
Site	**Year**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IBI**
0.0	1994	5	5	5	5	5	1	5	5	90
	1995	5	5	5	5	5	5	5	5	100
	1996	5	5	5	5	5	3	5	5	95
3.5	1995	5	5	3	5	5	5	5	5	95
	1996	5	5	3	5	5	5	5	5	95
6.4	1994	1	3	3	3	1	5	5	1	55
	1995	1	1	3	3	3	5	5	1	55
16.0	1994	1	1	1	3	1	5	3	1	40
	1995	1	1	1	5	3	5	3	1	50
18.4	1994	1	1	1	3	1	5	3	1	40
	1995	3	3	1	5	1	5	5	1	60
	1996	3	3	3	5	5	5	3	1	70
23.2	1994	1	3	1	5	5	1	5	1	55
	1995	1	1	1	5	1	3	3	1	40
	1996	1	3	1	5	1	5	5	1	55
26.4	1994	1	1	1	3	5	3	5	1	50
	1995	3	3	1	5	1	1	3	1	45
32.8	1994	1	1	1	3	5	1	1	1	35
	1995	1	1	1	5	5	1	3	1	45
	1996	3	3	1	5	1	3	3	1	50

Note: All samples were taken in August. Sites are listed by approximate river kilometers downstream from Putah Diversion Dam. All sites were not sampled in 1994 and 1996. Explanations of metrics and the calculation of the IBI score are given in Table 14.2.

14.3.3 DYE CREEK

Dye Creek, Tehama County, is a small Sierra Nevada tributary to the Sacramento River in northcentral California that is almost entirely within a preserve of The Nature Conservancy (TNC). The preserve is managed for seasonal livestock grazing and for hunting, as well as for natural values. The creek flows through rugged lava canyons that have limited accessibility, even for livestock, so the creek has remained lightly disturbed. Flows are low (1 to 5 cfs in summer), and some sections of its two major forks become intermittent by late summer. To assist TNC in developing a management plan for the watershed, a survey of the fish and amphibians was conducted in August and September 1996 (P. Crain and P.B. Moyle, unpublished data). The principal native fish in both forks was California roach, although small numbers of Sacramento sucker (*Catostomus occidentalis*) and rainbow trout were also present, and speckled dace (*Rhinichthys osculus*) and Sacramento squawfish (*Ptychocheilus*

TABLE 14.4
Annual Variation of IBI Scores over a 15-yr Period at One Sampling Site on Putah Creek, Located on the UC Davis Campus about 23 River Kilometers Downstream from the Putah Diversion Dam

Year	IBI Metrics I	II	III	IV	V	VI	VII	VIII	IBI Score
1980	3	3	3	5	3	3	3	1	60
1981*	3	3	1	5	3	1	3	1	50
1984#	3	3	5	5	5	5	5	3	85
1985	3	5	3	5	5	5	3	1	75
1986#	3	3	3	5	5	5	5	1	75
1987	3	3	2	5	3	3	5	1	63
1988*	1	5	1	5	3	3	3	1	55
1989*	1	3	1	5	3	5	3	1	55
1990*	1	3	3	5	5	3	5	1	65
1991*	1	3	1	5	5	3	5	1	60
1992*	1	3	3	5	5	3	5	1	65
1993*	1	3	1	5	5	5	5	1	65
1994*	1	3	1	5	5	1	5	1	55
1995	1	3	1	5	5	3	5	1	60
1996#	1	3	3	5	5	5	5	1	70

Note: Explanations of metrics are given in Table 14.2. Note decreases in scores during drought years (*) and increases in scores during or following wet years (#). All samples taken in October.

grandis) were common in the mainstem. Remarkably, the south fork of the creek was dominated by nonnative green sunfish (*Lepomis cyanellus*) and bullfrogs (*Rana catesbeiana*), while the north fork contained almost entirely native fish and amphibians, especially the foothill yellow-legged frog (*Rana boylei*). This dichotomy was particularly evident in the middle reach of the south fork, which becomes a series of rockbound pools in summer, with no connecting flow, leaving habitats in which there were few refuges for California roach from predation by green sunfish. Green sunfish, as a consequence, were the only fish in many of these pools and even bullfrog populations seem to be suppressed here. Low abundances of bullfrogs at some sites in the south fork were associated with a die-off (Crain and Moyle, unpublished observations) of unknown cause. The mainstem below the confluence of the forks was largely dominated by native fishes, but the principal amphibians present were bullfrogs. The number of both native and introduced fish species increased in a downstream direction, although, except for the green sunfish, the nonnative fishes seemed to originate from farm ponds, rather than being a permanent part of the creek fauna. An IBI developed for the watershed, using both amphibian and fish data, reflects these trends (Tables 14.5 and 14.6). In this case, low IBI scores mainly reflect successful invasions by nonnative species and only partially reflect environmental degradation (ponds, ranch roads, and heavy grazing along the lowermost reaches). The mean IBI score for the entire Dye Creek watershed was 71 (good condition), which was only slightly lower than the W-IBI score (80, very good condition) assigned to it (Moyle and Randall, 1996) before the more detailed surveys were done that revealed the surprising extent of the invasions.

14.4 CONCLUSION

It is possible to develop IBIs for California streams for different purposes and situations. Whether the IBIs presented here are transferrable to other situations remains to be seen. The W-IBI seems

TABLE 14.5
Metrics for Scoring the Index of Biotic Integrity for Dye Creek, California

I. Percentage native fish species
  1 0%
  3 1–99%
  5 100%
II. Percentage native fish individuals
  1 0–10%
  3 11–89%
  5 90–100%
III. Overall fish abundance (1–5 rating system)[a]
  1 Rare, only one or two individuals present
  2 Small numbers present
  3 Common, fish easy to find, small numbers captured without difficulty
  4 Very common
  5 Abundant, visible in large numbers, easy to capture by the 100s.
IV. Ranid frogs[b]
  1 Bullfrogs only species present
  3 Bullfrogs and yellow legged frogs both present
  5 Foothill yellow legged frogs only species present
V. Overall amphibian abundance
  1–5 As for III
VI. Number of native fish and amphibian species present[c]
  1 0–1
  3 2–3
  5 4–5

IBI score = [Total points possible/number of metrics] × 20

80–100	Aquatic communities in very good to excellent condition
60–79	Aquatic communities in good condition
40–59	Aquatic communities in fair condition
<40	Aquatic communities in poor condition

[a] A 1–5 scoring system is used in the IBI because this system was also used in the field.

[b] Bullfrogs are introduced, while foothill yellow-legged frogs (*Rana boylei*) are native.

[c] A combined fish and amphibian metric was used because amphibian species numbers tend to decrease in a downstream direction, while native fish species numbers tend to increase.

to work as a tool for making a “first cut” at determining which watersheds should have the highest priority for management for conservation of aquatic biodiversity. The IBI developed for Putah Creek works like IBIs for eastern streams, perhaps because so much of its fauna is composed of species from the eastern U.S. Whether reaches of stream containing almost entirely nonnative fishes should receive fair to good IBI ratings is still a matter for debate. By the standard definition, based on the resemblance of the present fauna to the original fauna, virtually all biotic integrity in such reaches has been lost. On the other hand, an abundance of nonnative fishes in an assemblage containing multiple trophic groups does say something positive about the quality of the water and aquatic habitats. The application of an IBI to low-diversity situations like Dye Creek appears to be less useful because the IBI provides few insights beyond those provided by examining the distri-

TABLE 14.6
Values for Metrics and IBI Scores for Selected Sites on Dye Creek, Tehama County, California

Site	I % Native Fish Species	II % Native Fish Numbers	III Fish Ratings	IV Frog Species	V Amphibian Rating	VI No. Species	IBI Score
North Fork							
Upper	100	100	4	YLF	5	3	83
Middle	100	100	5	YLF	5	4	100
Lower	100	100	5	YLF	5	4	100
South Fork							
Upper	100	100	3	BF	3	3	66
Middle 1	50	<1	2	BF	3	1	36
Middle 2	75	78	3	BF	1	3	47
Lower	75	98	3	BF	3	4	67
Main Stem							
Upper	80	99	5	BF	1	4	73
Middle	80	99	4	BF	3	4	76
Lower (above ranch, near pond)	60	61	3	BF	3	3	56
Lower (below ranch house)	95	90	4	BF	3	5	77

Note: The metrics (I–VI) and method of calculating the IBI score are explained in Table 14.5. Upper = upper limit of fish distribution; only amphibians are found higher; YLF = foothill yellow-legged frog; BF = bullfrog.

bution and abundance of a few key species. For situations like Dye Creek, one needs to understand whether the invading vertebrates have caused wholesale changes to the aquatic invertebrate communities to know if a fairly high IBI rating based on vertebrates is in fact justified.

Despite continued misgivings about the use of IBIs in California, we believe they are a tool worth developing further. In particular, recommendations include greater use of amphibian metrics in IBIs and the development of some metrics with aquatic invertebrates to increase the number of metrics used in calculating each IBI. Serious thought needs to be given to developing two tiers of IBIs — one tier based on native species, the other tier based on community diversity, whether or not species are native. One of the prime reasons for developing IBIs is the increased interest of citizen's groups in monitoring local streams, and IBIs like those presented here have considerable potential for use by trained amateurs.

ACKNOWLEDGMENTS

The Sierra Nevada portion of this study was supported by the Sierra Nevada Ecosystem Project as authorized by Congress (HR 5503) through a cost-reimbursement agreement No. PSW-93-001-CRA between the U.S. Forest Service, Pacific Southwest Research Station, and the Regents of the University of California, Wildland Resources Center. The work on Putah Creek was largely supported by special grants from the University of California, Davis. We thank Dr. A. S. England, Office of Planning and Budget, for support and encouragement. The Dye Creek work was supported by The Nature Conservancy and much of the data collection was carried out under the direction of Patrick Crain.

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