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Russian River Index of Biological Integrity (RRIBI) for First to Third Order Tributary Streams

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Program Manager
James M. Harrington

Project Leaders
Peter Ode
Angie Montalvo

Laboratory and Field Technicians
Doug Post
Christopher Sheehy
Mike Dawson

California Department of Fish and Game
Office of Spill Prevention and Response
Water Pollution Control Laboratory
2005 Nimbus Road, Rancho Cordova, Ca. 95670
(916) 358-2858; jharr@sna.com

An Index of Biological Integrity for First to Third Order Russian River Tributary Streams

Abstract

The conceptual model described by the U.S. Environmental Protection Agency for development of biocriteria was followed to produce a first iteration of an Index of Biological Integrity for the Russian River Watershed (RRIBI). Benthic macroinvertebrate (BMI) were collected from 35 reaches within 21 tributary streams and the mainstem Russian River during the fall 1995 and spring 1996 and 1997 using the California Stream Bioassessment Procedure. A set of core biological metrics, commonly used for bioassessment of California stream were used to describe the BMI communities in the 35 reaches. Monitoring reaches within the first to third order streams classified as similar with different channel type having no influence on mean biological metric values. The biological metrics, Taxa Richness, EPT Taxa, Modified EPT Index, Shannon Diversity, Tolerance Value and Percent Dominant Taxa were chosen as the most appropriate to be included in producing the RRIBI. These six metrics were integrated into a single scoring criteria by producing a histograms of the values for each of the biological metrics and visually determining breaks in their distribution. This approach of determining scoring criteria was more intuitive and probably most appropriate given that the data came from streams that could have been moderately impaired and not actually representative of pristine reference conditions. Although there was no indication of strong seasonal variability in the BMI communities, it was recommend that the index period for the Russian River tributary streams be in the spring. It was also recommend that the RRIBI be considered preliminary and that data on more Russian River tributaries and the mainstem be collected to 1) test the effectiveness of this scoring criteria on other first to third order Russian River tributaries, 2) test the appropriateness of using other biological metrics, 3) evaluate the use of the RRIBI in other north coast California streams to test its effectiveness at assessing biological integrity of streams outside the Russian River watershed, and 4) produce an IBI for fourth order and larger stream reaches.

Introduction

The state of California began its efforts toward biocriteria development in 1993. Because water quality regulatory authority is divided into nine autonomous Regional Water Quality Control Boards, the State of California has taken a regional approach to biocriteria development instead of a state-wide approach common in other states. The California Department of Fish and Game (DFG) helped to coordinate this approach by developing and releasing standardized sampling, laboratory and quality assurance procedures for state bioassessment programs. Called the California Stream Bioassessment Procedure (CSBP), it is a regional adaptation of the national U.S. Environmental Protection Agency's (EPA) Rapid Bioassessment Protocols for wadeable streams (Barbour et al. 1997).

Since 1994, DFG has promoted the use of the CSBP in all water quality-monitoring programs throughout the state. DFG has assisted both public agencies, and private natural resource consultants and companies throughout California in conducting water quality investigations. DFG has also conducted several demonstration projects to promote biocriteria development.

One of the largest long-running regional monitoring programs is in the Russian River watershed in the northern-most portion of California's central coast. The Russian River drains the third largest watershed in California and within its basin are a variety of land-use activities such as the wine industry and other agricultural practices, cattle grazing, logging and rural and urban development.

This on-going monitoring program began in 1995 with the primary goal to assess anadromous salmonid populations and aquatic habitat quality. As of 1997, 21 reference streams within the Russian River watershed have been surveyed. These streams were assessed by DFG Biologists to be in reference conditions based on their ability to support salmonid populations. The secondary goal of the monitoring program was to determine the general biological condition of these stream using the CSBP which centers on the structure of the benthic macroinvertebrate (BMI) community. These data represents the first large set of reference conditions for BMI communities in the central coast region of California.

In this report, the BMI data collected from the 21 Russian River tributary streams in fall 1995 and spring 1996 and 1997 were analyzed to produce an Index of Biological Integrity for the Russian River watershed (RRIBI). Karr (1981) first published the Index of Biological Integrity as a consistent means of measuring the societal goal of biological integrity. Based on a combination of tested biological attributes of water resources, the IBI provides a cumulative site assessment as a single score value (Davis and Simon 1995). The IBI is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995).

The project elements described in this report were derived from the EPA's conceptual model for biocriteria development (Gibson 1996). They were to: 1) classify similar streams and stream reaches within the Russian River watershed, 2) determine the best time of year or index period for continued sampling of BMIs in Russian River watershed 3) determine the most appropriate set of biological metrics used for describing BMI communities in the Russian River watershed, and 4) produce a workable RRIBI using a modified approach outlined by the EPA (Barbour et al. 1997) and Karr and Chu (1999).

Material and Methods

Stream Reach Characterization

There were a total of 35 reaches within the 21 tributary streams and the mainstem Russian River with a total of 71 sets of samples from all the reaches during the 3 years of sampling (Figure 1). Each stream reach was characterized by 1) how steep and narrow the channel was (channel type), 2) where the reach was located within the stream length (reach designation) and the size of the stream at the location of the reach (stream order).

Channel Type - Each of the 21 tributary streams to the Russian River were surveyed to determine their channel type based on Rosgen's classification system described in DFG's California Salmonid Stream Restoration Manual (Flossi et al. 1997). Each stream reach was

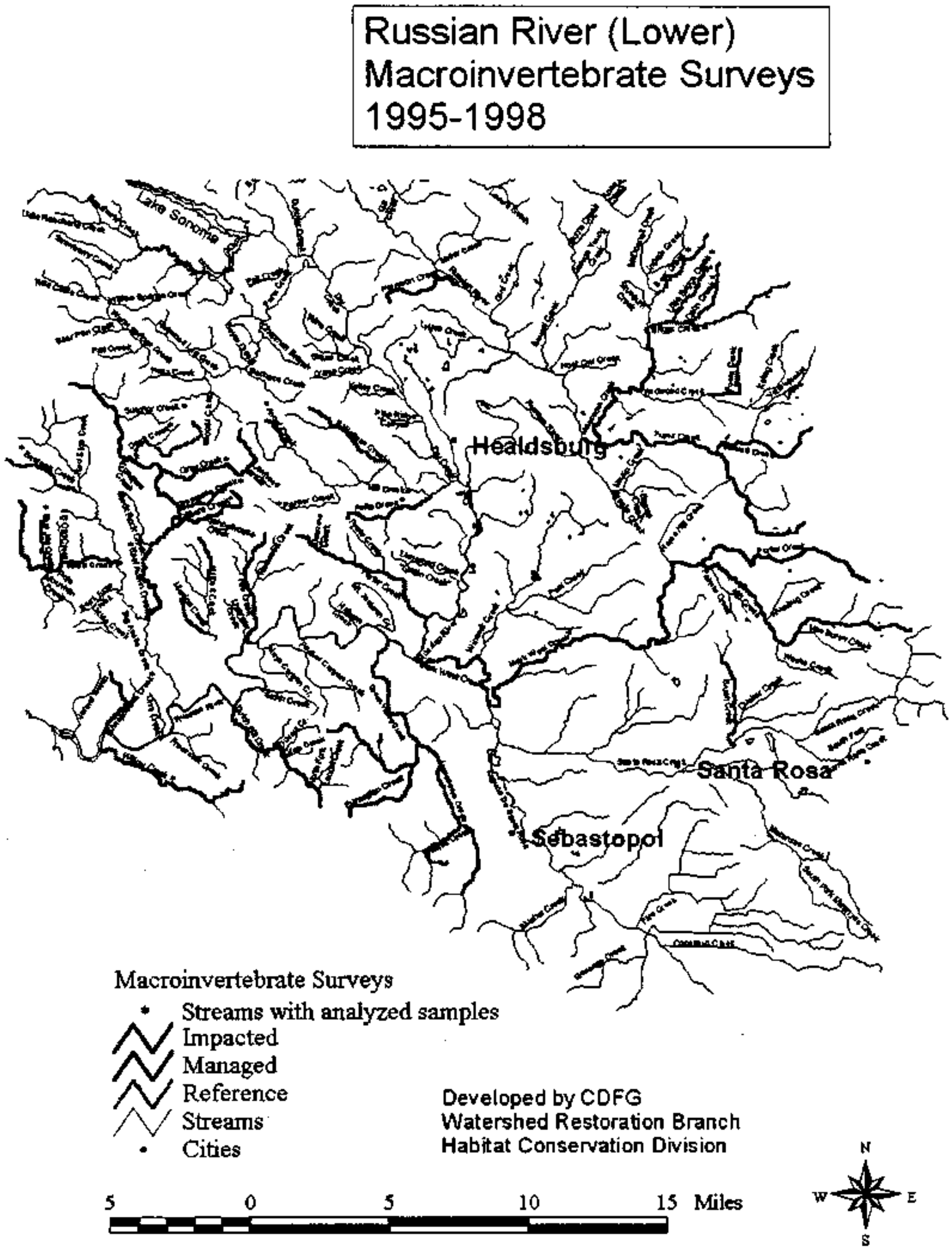

Figure 1. Russian River watershed showing locations of the 21 tributary streams where benthic macroinvertebrate (BMI) samples were collected in fall 1995 and spring 1996 and 1997 and used to develop the Russian River Index of Biological Integrity (RRIBI).

assigned a channel type of either "B" (moderately entrenched with a high gradient), "C" (slightly entrenched with a low gradient), "F" (entrenched with a low gradient) or "G" (entrenched with a moderate gradient).

Reach Designation - Each tributary stream was divided into 1 to 5 reaches depending on how many channel types were identified within the stream. The reaches were given an alphabetic designation ranging from "A" for those located in the uppermost portion of the stream's watershed to "E" for those located in the lowest portion of the stream's watershed.

Stream Order - The size of the stream within each reach was designated by a stream order based on the system described by Strahler (1957). Stream order was determined using a topographic map and ranged from first to fourth order for the tributary streams and sixth order for the mainstem Russian River reach.

Benthic Macroinvertebrate Sampling

A total of 208 BMI samples were collected from 1 reach in the mainstem Russian River and from 1 to 5 reaches in 21 tributary streams on 10-23 October 1995, 2-15 May 1996 and 9 April to 13 May 1997 (Table 1) using the CSBP for non-point source assessments (Harrington 1996).

Three riffles, randomly chosen from all available riffles in each reach of stream, were used to collect BMI samples. A single BMI sample was collected from the top third of each riffle along a randomly chosen transect running perpendicular to the flow of the stream. Three locations representing the habitats along the transect were sampled within a 2 ft^2 area upstream of a 1 ft wide D-frame kick-net with 0.5 mm mesh. The three collections were combined into a single composited sample representing a 6 ft^2 area. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net followed by "kicking" the upper layers of substrate to dislodge any invertebrates remaining in the substrates. The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrates that required rubbing by hand. This composite sample was transferred into a 500 ml wide-mouth plastic jar containing approximately 200 ml of 95% ethanol.

BMI Laboratory Analysis

All BMI samples were delivered to the ABL in Rancho Cordova using Chain of Custody procedures (Harrington 1996). At the ABL, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All detritus was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 2% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. BMIs were then identified to a standard taxonomic level, typically genus level for arthropods and order or class for non-arthropods using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Klemm 1985, Merritt and

Table 1. Years when benthic macroinvertebrates (BMI) samples were collected, number of reaches sampled each year and the latitude and longitude coordinates for each of 21 Russian River tributary streams used to produce the Russian River Index of Biological Integrity (RRIBI).

Stream	**Years Sampled**			**Number of Reaches**			**Lat/Long**
Mill Creek	1995	1996	1997	4	5	4	N38°35'20", W122°52'08"
Felta Creek	1995	1996	1997	3	3	3	N38°34'52", W122°52'56"
Palmer Creek	1995	1996	1997	2	2	2	N38°35'5", W123°56'48"
Angel Creek	1995	1996	1997	1	1	1	N38°36'20", W122°58'45"
Willow Creek	1995	1996	1997	4	4	3	N38°26'25", W123°05'42"
Wallace Creek	1995	1996		2	2		N38°35'55", W122°54'38"
Mark West Creek	1995	1996		4	2		N38°29'30", W122°53'30"
Blue jay Creek			1997			1	N38°32'05", W123°08'03"
Coon Creek			1997			2	N38°40'40", W122°42'44"
East Austin Creek			1997			2	N38°30'36", W123°04'00"
Gray Creek			1997			1	N38°35'21", W123°03'20"
Bearpen Creek			1997			2	N38°34'39", W123°06'06"
Ward Creek			1997			1	N38°32'29", W123°06'39"
Briggs Creek			1997			2	N38°40'28", W122°44'31"
Little Briggs Creek			1997			1	N38°40'43", W122°43'33"
Sulphur Creek			1997			1	N38°37'06", W123°05'29"
Devil Creek			1997			1	N38°35'40", W123°04'19"
Gilliam Creek			1997			1	N38°33'39", W123°03'53"
Bear Creek			1997			1	N38°42'05", W122°44'09"
Thompson Creek			1997			1	N38°34'15", W123°02'06"
Sheephouse Creek			1997			2	N38°26'58", W123°05'22"

Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Data Analysis

A taxonomic list of BMIs identified from the samples was entered into a Microsoft Excel® spreadsheet program. Excel® was then used to calculate and summarize BMI community based metric values. The statistical software package Systat® 8.0 was used to reduce the data set into

Table 2. Bioassessment metrics used to describe characteristics of the benthic macroinvertebrate (BMI) community collected from Russian River tributary streams.

Biological Metrics	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Ephemeroptera Taxa	Number of mayfly taxa (genus or species) .	decrease
Plecoptera Taxa	Number of stonefly taxa (genus or species)	decrease
Trichoptera Taxa	Number of caddisfly taxa (genus or species)	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Modified EPT Index	EPT Index minus the more tolerant Hydropsychids and Baetids	decrease
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) and intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent of organisms in the caddisfly family Baetidae	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Functional Feeding Groups		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease

basic descriptive statistics (means, coefficient of variability, and range of observations), perform Pearson's Correlation analysis and produce graphics.

A description of the biological metrics used to describe characteristics of the BMI community including the response that water quality impairment would have on the metric value is shown in Table 2. Some of the biological metrics are used universally and some are more regional having evolved over the past five years of use in California streams. They have been categorized into the following types (Barbour et al. 1997):

Richness Measures - These metrics reflect the diversity of the aquatic assemblage where increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat and food sources are adequate to support survival and propagation of a variety of species.

Composition Measures - These metrics reflect the relative contribution of the population of individual taxa to the total fauna. Choice of a relevant taxon is based on knowledge of the individual taxa and their associated ecological patterns and environmental requirements such as those that are environmentally sensitive or a nuisance species.

Tolerance/intolerance Measures - These metrics reflect the relative sensitivity of the community to aquatic perturbations. The taxa used are usually pollution tolerant and intolerant, but are generally nonspecific to the type of stressors. Percent Hydropsychidae and Baetidae are regional metrics that have evolved to be particularly useful in California. The metric values usually increase as the effects of pollution in the form of organics and sedimentation increases.

Functional Feeding Groups - These metrics provide information on the balance of feeding strategies in the aquatic assemblage. The functional feeding group composition is a surrogate for complex processes of trophic interaction, production and food source availability. An imbalance of the functional feeding groups reflects unstable food dynamics and indicates a stressed condition.

Site Classification

Classification of BMI sampling locations was determined by examining similarities or differences in the mean biological metric values, for each stream, reaches within streams, stream order, and channel type. Differences in the data was examined by comparing the stream and reach mean biological metic values.

Index Period for Sampling BMIs

The index period for sampling BMIs was determined by examining seasonal and annual differences in the biological metric values (Table 2) and the BMI taxonomic composition at the 7 streams which were sampled in fall 1995 and spring 1996 (Table 1) and the 5 streams which were sampled in fall 1995 and spring 1996 and 1997. Differences in the data was examined by comparing the stream and reach mean biological metric values.

Appropriate Biological Metrics

Table 2 lists the biological metrics most commonly used in California and recommended by Barbour et al. (1997) and Karr and Chu (1999). Biological metrics were chosen to be appropriate for use in determining the RRIBI by first choosing those having the lowest variability as measured by the CV and then by eliminating redundant metrics as much as possible. Redundancy was determined by performing bivariate Pearson's Correlation analysis with similar metrics.

Russian River Index of Biological Integrity (RRIBI)

The RRIBI was produced using a Visual Distribution scoring criteria. The scoring criteria was determined by first producing a histogram of the distribution of biological metric values, visually determining breaks in the distribution, and then for those metrics where values decrease with response to water quality impairment, assigning a score of 5 to the upper, 3 to the middle and 1 to lower values. For those metrics where values increase with response to water quality impairment a score of 5 was assigned to the lower, 3 to the middle and 1 to the upper values.

Results

A taxonomic list of all BMIs identified from the samples collected in the mainstem Russian River and the 21 tributary streams is presented in Appendix 1. The biological metric values are presented by replicate sample and by reach mean and coefficient of variation in Appendix 2. All Appendices are contained in a separate document.

Site Classification

Initial examination of the mean biological metric values for all stream reaches showed that the one reach on the mainstem Russian River was notably different from the other reaches (Table 3). All the biological metric values for the mainstem Russian River reach were consistently indicative of more impaired water quality. Further examination of the data set (minus the mainstem Russian River reach) showed that the mean biological metric values for the D stream reaches (Table 4) and the fourth order stream reaches (Table 5) were notable different from other reaches. Again, all the biological metric values were consistently indicative of more impaired water quality. The D Reach of Willow Creek and the D Reach of Markwest Creek, both fourth order tributary stream reaches, showed consistently different mean biological metric values compared to the other stream reaches (Table 3). There was no notable difference between any of the biological metrics values for stream reaches with different channel types (Table 6).

Index Period for Sampling BMIs

There was a noticeable seasonal difference in the BMI community (Table 7). The percent composition of grazers and shredders were higher in fall than in spring. Conversely, the percent composition of collectors was lower in the fall and higher in the spring. Additionally, Hydropsychids were more abundant in the fall than in the spring. However, these seasonal differences only had a slight influence on the other mean biological metric values. Richness measures were indicative of poorer conditions in the fall than in the spring and composition and tolerance/intolerance measures were indicative of better conditions. There were no notable annual differences between spring 1996 and spring 1997 since both years had similar mean biological metric values (Table 7).

Table 3. Mean biological metric values (coefficient of variation) for benthic macro invertebrates (BMI) samples collected from Willow Creek, Reach D, Markwest Creek, Reach D, the mainstem Russian River and all other tributary streams during fall 1995 and spring 1996 and 1997.

Biological Metrics	**Willow Creek, Reach D**	**Markwest Creek, Reach D**	**Mainstem Russian River**	**All other Streams**
Number of Samples	**8**	**6**	**3**	**191**
Richness Measures				
Taxa Richness	21 (14)	24 (20)	19(5)	32 (20)
EPT Taxa	10 (31)	10 (23)	6 (10)	15 (25)
Mayfly Taxa	4 (47)	4 (28)	3 (22)	6 (33)
Stonefly Taxa	4 (53)	2 (37)	0 (n/a)	4 (36)
Caddisfly Taxa	2 (52)	4 (48)	3 (0)	5 (44)
Composition Measures				
EPT Index	52 (32)	53 (15)	41 (15)	52 (30)
Modified EPT Index	34 (51)	22 (48)	2 (39)	36 (39)
Percent Hydropsychidae	0 (n/a)	6 (99)	26 (25)	1 (99)
Percent Baetidae	18 (89)	25 (55)	13 (26)	14 (93)
Shannon Diversity	2.3 (6)	2.1 (14)	2.2 (0)	2.6 (14)
Tolerance/Intolerance Measures				
Tolerance Value	3.8 (16)	4.4 (5)	4.6 (1)	3.7 (18)
% Intolerant	30 (47)	6 (96)	0 (n/a)	31 (45)
% Tolerant	<1 (99)	1 (89)	1 (59)	<1 (99)
% Dominant Taxa	29 (32)	32 (18)	27 (5)	25 (44)
Functional Feeding Groups				
% Collectors	42 (54)	57 (32)	19 (22)	41 (51)
% Filterers	8 (64)	22 (52)	30 (23)	11 (99)
% Grazers	13 (51)	12 (8)	31 (10)	16 (48)
% Predators	25 (39)	8 (63)	20 (24)	23 (42)
% Shredders	12 (99)	1 (99)	0 (n/a)	9 (99)

Table 4. Mean biological metric values and (coefficients of variation) for benthic macroinvertebrate (BMI) samples collected from 21 Russian River tributary streams during fall 1995 and spring 1996 and 1997. All samples were pooled and partitioned by stream reach from the uppermost (A) to the lowest (E).

Biological Metrics	**Stream Reaches**				
	A	**B**	**C**	**D**	**E**
Number of Samples	93	53	27	23	9
Richness Measures					
Taxa Richness	33 (19)	31 (19)	30 (21)	24 (18)	28 (7)
EPT Taxa	16 (24)	15 (26)	15 (28)	12 (31)	15 (16)
Mayfly Taxa	6 (31)	6 (35)	6 (33)	5 (40)	6 (47)
Stonefly Taxa	4 (41)	4 (31)	4 (31)	3 (58)	4 (26)
Caddisfly Taxa	5 (38)	5 (52)	4 (54)	4 (55)	5 (16)
Composition Measures					
EPT Index	52 (29)	51 (31)	51 (34)	54 (28)	59 (22)
Modified EPT Index	35 (38)	37 (39)	36 (35)	30 (53)	48 28()
% Hydrophyschidae	1 (99)	<1 (99)	1.5 (99)	4 (99)	2 (99)
% Baetidae	16 (95)	13 (91)	13 (99)	20 (65)	9 (69)
Shannon Diversity	2.7 (14)	2.7 (10)	2.6 (16)	2.2 (14)	2.4 (6)
Tolerance/Intolerance Measures					
Tolerance Value	3.7 (18)	3.7 (18)	3.7 (18)	3.8 (18)	3.2 (20)
% Intolerant	28 (45)	32 (45)	30 (44)	24 (70)	44 (38)
% Tolerant	1 (99)	<1 (99)	1 (99)	<1 (99)	1.5 (99)
% Dominant Taxa	25 (48)	24 (34)	25 (50)	31 (37)	28 (20)
Functional Feeding Groups					
% Collectors	43 (48)	41 (44)	39 (47)	41(63)	27 (81)
% Filterers	10 (99)	10 (85)	13 (81)	20 (85)	11 (66)
% Grazers	16 (49)	15 (46)	16 (54)	14 (39)	21 (43)
% Predators	22 (44)	25 (36)	24 (38)	19 (64)	32 (40)
% Shredders	9 (96)	9 (96)	8 (99)	6 (99)	9 (99)

Table 5. Mean biological metric values and (coefficients of variation) for benthic macroinvertebrate (BMI) samples collected from 21 Russian River tributary streams during fall 1995 and spring 1996 and 1997. All samples were pooled and partitioned by stream order.

Biological Metrics	**Stream Order**			
	1	**2**	**3**	**4**
Number of Samples	62	80	49	14
Richness Measures				
Taxa Richness	31 (19)	34 (21)	30 (19)	22 (18)
EPT Taxa	15 (25)	16 (25)	15 (26)	10 (27)
Mayfly Taxa	6 (30)	6 (31)	6 (41)	4 (28)
Stonefly Taxa	4 (41)	4 (35)	4 (35)	3 (36)
Caddisfly Taxa	5 (46)	6 (43)	5 (44)	4 (48)
Composition Measures				
EPT Index	50 (34)	53 (28)	52 (30)	52 (25)
Modified EPT Index	32 (39)	38 (39)	38 (36)	29 (55)
% Hydrophyschidae	<1 (99)	1.5 (99)	2 (99)	2.5 (99)
% Baetidae	17 (87)	13 (99)	12 (75)	21 (71)
Shannon Diversity	2.6 (12)	2.7 (14)	2.6 (14)	2.2 (10)
Tolerance/Intolerance Measures				
Tolerance Value	3.9 (16)	3.6 (20)	3.5 (16)	4.1 (14)
% Intolerant	27 (45)	32 (46)	34 (42)	20 (83)
% Tolerant	<1 (99)	1 (99)	<1 (99)	<1 (99)
% Dominant Taxa	26 (42)	24 (47)	26 (45)	30 (26)
Functional Feeding Group				
% Collectors	44 (47)	42 (48)	35 (62)	48 (43)
% Filterers	10 (99)	10 (92)	13 (99)	14 (76)
% Grazers	14 (50)	17 (48)	18 (46)	12 (35)
% Predators	22 (38)	22 (44)	27 (42)	18 (62)
% Shredders	10 (99)	9 (99)	7 (98)	8 (99)

Table 6. Mean biological metric values and coefficients of variation for benthic macroinvertebrate (BMI) samples collected from 21 Russian River tributary streams during fall 1995 and spring 1996 and 1997. All samples were pooled and partitioned by channel type using Rosgen's designations.

Biological Metrics	Channel Type			
	B	C	F	G
Number of Samples	74	5	117	9
Richness Measures				
Taxa Richness	31 (21)	30 (13)	31 (22)	30 (13)
EPT Taxa	15 (24)	14 (17)	15 (29)	14 (26)
Mayfly Taxa	6 (33)	5 (20)	6 (35)	7 (43)
Stonefly Taxa	4 (37)	4 (25)	5 (47)	3 (35)
Caddisfly Taxa	5 (41)	5 (35)	5 (47)	3 (35)
Composition Measures				
EPT Index	51 (32)	51 (28)	53 (28)	46 (43)
Modified EPT Index	33 (38)	26 (57)	38 (40)	33 (30)
% Hydrophyschidae	2 (99)	1.5 (84)	1 (99)	<1 (99)
% Baetidae	16 (88)	24 (67)	14 (95)	13 (89)
Shannon Diversity	2.6 (16)	2.5 (11)	2.6 (13)	2.6 (16)
Tolerance/Intolerance Measures				
Tolerance Value	3.7 (17)	4.0 (17)	3.7 (19)	3.6 (11)
% Intolerant	28 (45)	24 (67)	31(50)	31 (32)
% Tolerant	1 (99)	< (99)	1 (99)	0 (n/a)
% Dominant Taxa	25 (47)	28 (28)	26 (40)	25 (62)
Functional Feeding Groups				
% Collectors	41 (54)	46 (38)	41 (48)	38 (52)
% Filterers	11 (99)	14 (56)	11 (88)	9 (83)
% Grazers	17 (45)	17 (32)	15 (49)	23 (52)
% Predators	24 (42)	16 (31)	23 (47)	24 (30)
% Shredders	7 (85)	7 (86)	10 (99)	6 (86)

Table 7. Mean biological metric values and (coefficients of variation) for benthic macroinvertebrate (BMI) samples collected from 21 Russian River tributary streams during fall 1995 and spring 1996 and 1997.

Biological Metrics	**Fall 1995**	**Spring 1996**	**Spring 1997**	**All Years Combined**
Number of Samples	51	46	94	191
Richness Measures				
Taxa Richness	29 (17)	33 (23)	32 (18)	32 (20)
EPT Taxa	14 (21)	16 (30)	16 (23)	15 (25)
Mayfly Taxa	5 (30)	6 (30)	7 (33)	6 (33)
Stonefly Taxa	5 (36)	4 (41)	4 (32)	4 (36)
Caddisfly Taxa	4 (36)	6 (48)	5 (42)	5 (44)
Composition Measures				
EPT Index	47 (30)	56 (24)	52 (32)	52 (30)
Modified EPT Index	39 (32)	33 (36)	37 (42)	36 (39)
Percent Hydropsychidae	4 (99)	<1 (99)	<1 (99)	1 (99)
Percent Baetidae	5 (99)	23 (62)	15 (83)	14 (93)
Shannon Diversity	2.7 (13)	2.6 (15)	2.6 (14)	2.6 (14)
Tolerance/Intolerance Measures				
Tolerance Value	3.7 (19)	3.7 (15)	3.7 (19)	3.7 (18)
% Intolerant	33 (42)	30 (40)	30 (49)	31 (45)
% Tolerant	1.5 (99)	<1 (99)	<1 (99)	<1 (99)
% Dominant Taxa	21 (45)	27 (41)	27 (44)	25 (44)
Functional Feeding Groups				
% Collectors	23 (52)	42 (31)	46 (46)	41 (51)
% Filterers	15 (71)	14 (88)	7 (99)	11 (99)
% Grazers	26 (51)	15 (35)	15 (51)	16 (48)
% Predators	22 (45)	23 (43)	24 (41)	23 (42)
% Shredders	14 (63)	5 (93)	7 (99)	9 (99)

Appropriate Biological Metrics

The set of data from all stream reaches except those in the mainstem Russian River and in fourth order tributary streams was used to determine appropriate biological metrics (Table 7). Six metrics were chosen among those used for richness, composition and tolerance/intolerance measures. Taxa Richness and EPT Taxa were chosen because they were the most consistent (CV's = 20% and 25%, respectively) measures of richness. Mayfly, Stonefly and Caddisfly Taxa were eliminated because they correlated fairly well with EPT Taxa (r^2 = 0.69, 0.51 and 0.76 for Mayfly, Stonefly and Caddisfly Taxa, receptively) and had higher CV values (33% to 44%).

Shannon Diversity was chosen because it was the most consistent (CV = 14%) measure of species composition. Although it was a consistent (CV = 30%) measure, EPT Index was eliminated because its values were inflated by the high abundance of the more tolerant Hydropsychid caddisflies and Baetid mayflies. The Modified EPT Index was chosen since its values did not include these two taxa and better reflected the composition of the more sensitive EPT taxa. The direct measure of Percent Hydropsychidae and Baetidae were eliminated because of their very high CV's (> 93%).

Tolerance Value was chosen because it was the most consistent (CV = 18%) measure of tolerance/intolerance. Percent Tolerant was eliminated because there were very few (<1 %) of these organisms collected in the samples. Percent Intolerant was eliminated because it correlated strongly with Tolerance Value (0.84) and had a higher CV value (45%). Although % Dominant Taxa had a higher CV value (44%) and was highly correlated (r^2 = 0.90) with Shannon Diversity, it was chosen to reinforce the Shannon Diversity metric which is not commonly used to develop IBIs.

Russian River Index of Biological Integrity (RRIBI)

The Visual Distribution Score was derived from the histograms of the biological metric values for the 6 chosen metrics (Figure 2). All BMI samples except those from the mainstem Russian River and the fourth order tributary streams were compiled to produce the histograms. The scoring criteria for the Visual Distribution Score are shown in Table 8.

Discussion

Site Classification

The 21 Russian River tributary streams were selected for their high quality salmonid fisheries habitat. Although these streams were potentially affected by various land-use practices in their watersheds, they represented some of the best aquatic resources available in the Russian River drainage. Only the one reach on the mainstem Russian River and the lowermost reaches on two of the tributary streams (Willow and Mark West Creeks) had notably different biological metric values. The biological metric values for these reaches were consistently indicative of more impaired water quality which may be a result of cumulative impacts affecting conditions in the

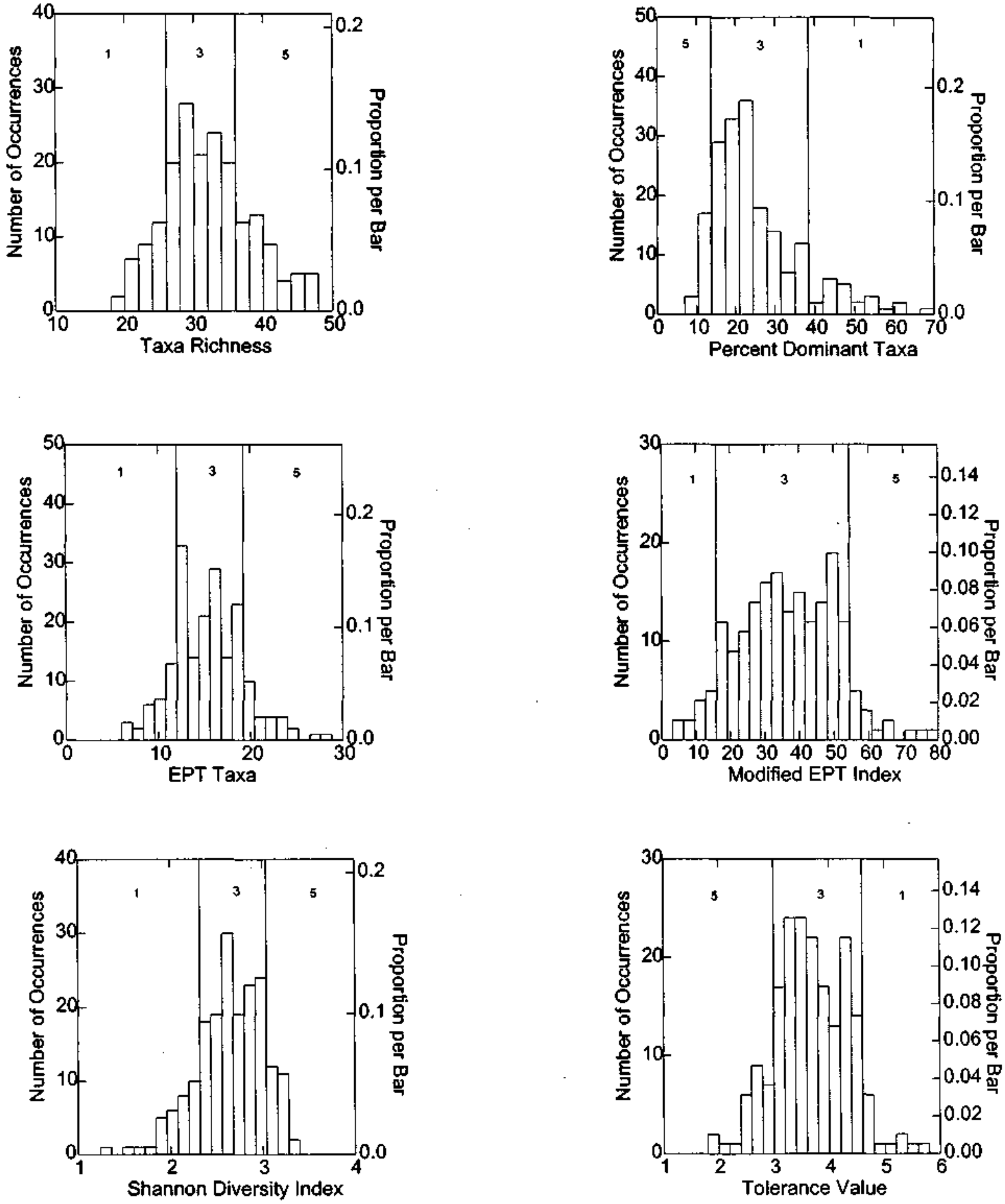

Figure 2. IBI scoring criteria based on the distribution of biological metric values for all benthic macro invertebrate (BMI) communities collected in 1995 through 1997 from 21 Russian River tributary streams.

Table 8. Scoring criteria based on visual examination of the distribution of values for six biological metrics used to describe benthic macroinvertebrate (BMI) samples collected from 21 Russian River tributary streams during fall 1995 and spring 1996 and 1997.

Biological Metric	**Visual Distribution Score**		
	5	**3**	**1**
Taxa Richness	≥ 36	35 - 26	< 26
EPT Taxa	≥ 19	18 - 12	< 12
Modified EPT Index	≥ 54	53 - 17	< 17
Shannon Diversity	≥ 3.0	2.9 - 2.3	< 2.3
Tolerance Value	≤ 3.0	3.1 - 4.6	> 4.6
% Dominant Taxa	≤ 14	15 - 39	> 39

lower watershed or simply indicative of fourth order and larger streams. Regardless, these reaches clearly belong to a different class of stream reach than the remaining first to third order reaches.

Index Period for Sampling BMIs

Although seasonal sampling events are ideal for documenting trends in biological condition and capturing the effects of unanticipated pollution events (Gibson 1996), the costs can be prohibitive for watershed or regional monitoring programs. Sampling BMIs once a year or during an index period can adequately characterize biological condition as long as the sampling event occurs at the same time each year. To facilitate taxonomic identification and collection of a balanced indigenous community, BMIs should be collected in the spring or the fall just prior to their emergence from larvae to adult (Gibson 1996). Other factors, such as adequate or safe flows within particular streams can also effect the selection of index periods.

There was a noticeable seasonal difference in the BMI community. As would be expected, BMIs which function as shredders were more abundant in the fall when there was more leaf litter in the stream, and grazers were also more abundant in the fall when periphyton growing on the stream substrate was more plentiful. Additionally, two important groups of BMIs showed strong seasonal abundance trends. Hydropsychids were common in the fall samples and rare in the spring where Baetids were quite abundant in the spring, but only common in the fall.

Regardless of this seasonal difference in community structure, there was only a slight difference in the mean biological metric values. Richness measures were indicative of slightly poorer conditions and composition and tolerance/intolerance measures indicative of slightly better conditions in the fall than in the spring. Furthermore, there were no notable annual differences between spring 1996 and spring 1997 since both years had similar mean biological metric values.

Appropriate Biological Metrics

The set of core biological metrics used to derive the IBI were the ones most commonly used in California and recommended by Barbour et al. (1997) and Karr and Chu (1999). Barbour et al. (1997) suggests that appropriate metrics are regionally based where Karr and Chu (1999) believe there are eight universal metrics which are appropriate for all bioassessment programs. Four of the six metrics (Taxa Richness, EPT Taxa, Tolerance Value and % Dominant Taxa) chosen for the RRIBI are fairly universal. Shannon Diversity is not as common because of the high rate of redundancy with richness measures and % Dominant Taxa. It was chosen because of the consistency (CV = 18) of values and to supplement % Dominant Taxa values which were more variable (CV = 44).

The sixth biological metric chosen for the RRIBI, Modified EPT Index, was regionally derived. The unmodified EPT Index which is the percent composition of the usually pollution sensitive mayflies (Order Ephemeroptera), stoneflies (Order Plecoptera) and caddisflies (Order Trichoptera) did not follow expected direction in response to water quality impairment. All stream reaches, including the mainstem Russian River reach and the fourth order stream reaches had exceptionally high values. Two EPT organisms, baetid mayflies and hydropsychid caddisflies, which are moderately pollution tolerant, made up close to one-third of all EPT organisms. Modifying the EPT Index by subtracting the contribution of these two organisms, produced a metric that responded as expected.

Russian River Index of Biological Integrity (RRIBI)

The purpose of the RRIBI is to integrate the information the six chosen biological metrics provide about the sampled stream reach. Barbour et al. (1997) describes two ways to determine scoring criteria for an IBI; one is based on using data from reference conditions and the other is from data representing a gradient of conditions. This data set did not represent a gradient of response to water quality impairment and though the streams were chosen from the best possible tributary streams in the Russian River drainage, they did had some level of impairment.

An intuitive approach which produced conservative scoring criteria was used to produce the RRIBI. A Visual Distribution Score was derived by producing a histograms of the values for each of the 6 chosen biological metrics and visually determining breaks in the distribution of those values. According to Karr and Chu (1999), natural shift or breaks in the distribution of biological metric values should be used to determine scoring criteria because these points can reflect biological response. In addition to being more intuitive, this approach for determining scoring criteria was probably more appropriate given that the streams the index was based on could have been moderately impaired and not actually representative of pristine reference conditions.

Recommendations

1. Although there was no indication of strong seasonal variability in the BMI communities, we recommend that the index period for the Russian River tributary streams be in the spring. However, samples collected during other times of the year could probably be adequately assessed using the RRIBI.

2. We recommend that the RRIBI be considered preliminary and that it be tested for its effectiveness in assessing biological integrity of first to third order tributary streams in the Russian River watershed.

3. The RRIBI is based on six biological metrics. We recommend that additional metrics be tested on future data sets to improve the effectiveness of the RRIBI in measuring biological integrity of Russian River tributary streams. Sampling sites reflecting a stronger gradient of water quality impairment would be necessary to test for appropriate biological metrics.

4. We recommend that additional Russian River tributary streams and the mainstem Russian River be sampled to develop IBI scoring criteria for larger than third order streams.

5. We recommend that the RRIBI be tested in other central coast California streams to test its usefulness outside the Russian River watershed.

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