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FINAL TECHNICAL REPORT #1:
CONDITION ASSESSMENT OF COASTAL STREAMS IN SOUTHERN AND CENTRAL CALIFORNIA

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FINAL TECHNICAL REPORT #1: CONDITION ASSESSMENT OF COASTAL STREAMS IN SOUTHERN AND CENTRAL CALIFORNIA

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Report to the California Environmental Protection Agency
and the State Water Resources Control Board

prepared by the
Aquatic Bioassessment Laboratory

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Introduction

Historical assessments of stream condition have usually focused on describing the chemical quality of streams. As we have made progress in controlling chemical problems it has become obvious that the ultimate concern is actually the health of the plants and animals that inhabit these streams (EPA 2000). Streams in good ecological condition provide habitat for diverse aquatic communities, and provide clean drinking water and recreational opportunities for people. Biological organisms in a stream integrate the many chemical and physical stressors that act on the stream ecosystem, thus stream condition can be determined by assessing appropriate biological indicators, or combinations of these indicators, called indices.

California's Aquatic Bioassessment Lab recently developed a benthic index of biotic integrity (B-IBI) for the central and southern coasts of California (Ode *et. al.* in review). The index is based on benthic macroinvertebrate (BMI) samples collected from 275 sites in this region by the US Forest Service, US EPA and regional Water Quality Control Boards. The index defines the composition of BMI assemblages when human disturbance is absent or minimal (reference conditions), and because it is based on metrics that are responsive to key stressor gradients, it allows detection of potential ecological impairment when BMI samples from test sites are compared to reference conditions. Thus, the B-IBI provides a yardstick for measuring ecological conditions, and allows us to categorize site conditions as either "Good", "Fair" or "Poor" based on BMI assemblages.

We used the B-IBI in conjunction with EMAP's probabilistic sampling design (Herlihy *et. al*. 2000) to conduct a stream condition assessment for central and southern coastal California. EMAP's statistical survey of streams operates in the same manner as public opinion polls used to project winners and losers of political campaigns. A subsample of stream reaches is selected at random to represent the population of streams in a region, just as the subsample of individuals in a public opinion poll is selected to represent the voting population as a whole. Thus, we can estimate what percentage of regional stream miles are in "Good", "Fair" and "Poor" condition, with known amounts of error in the estimate, based on the B-IBI yardstick.

This approach is very different from regional monitoring designs that have been used to date in California. Typically, stream reaches are targeted for sampling because they have known physical or chemical impairments. Whereas such targeted designs, if continued over time, can help evaluate whether best management practices improve stream condition *at a site*, they do not answer the question, "What is the overall condition of streams in the region?"

The purpose of the following report is to:

1) Report on the ecological condition of streams in central and southern coastal California to help meet statewide obligations under the Clean Water Act (305(b)).

2) Provide preliminary examples of how condition assessments can be used to associate environmental stressors with ecological condition and to rank the relative importance of different stressors.

Methods

Site selection

A stratified random sampling design (SRSD) was developed for southern coastal California in 2000 as part of the EMAP Western Pilot. Southern coastal watersheds were considered by EPA to be a special interest area, so a sampling design was developed for that region independently of the larger statewide design. In 2003, a separate SRSD was developed for central coastal California, a region that was underrepresented in EMAP's statewide effort. In both regions, a list of potential sampling sites was generated based on the EPA's 1:100,000 scale "River Reach File Version 3" (RF3). An SRSD was required because a simple random sample would most likely yield a sample population comprised mostly, if not entirely, of first order streams, which are far more frequent in the environment than higher order streams. Thus, each stream segment in the RF3 stream layer was given a probability of selection that was inverse to its percent contribution to the total estimated resource population. First order streams were assigned a relatively low probability of selection, whereas larger order streams (fourth order and higher) were assigned a relatively high probability of selection to ensure that the final stratified random sample would contain sample reaches across all stream orders. An even spatial distribution of sites throughout the region of interest was achieved using a reverse hierarchical order selection process. In this approach, the numeric code for each stream reach is placed randomly on a line, then each code is reversed (e.g. 21 = 12). The reversed codes then are sorted in ascending order and switched back to the original. A random starting point along the line is then selected, and sites are chosen by moving in fixed intervals along the line.

Each potential sampling site was assigned an associated weight equal to the number of stream kilometers represented by that sample reach. For example, first order streams comprise a much greater proportion of total stream kilometers than fourth order streams, so each first order reach received a greater weight than each fourth order reach.

Site evaluation

Once the list of potential sampling reaches was generated for each region, we conducted site reconnaissance to determine each site's target status. A site was considered as target if there was a natural channel present with perennial flow. In the arid southwest, streams that appear on the 1:100,000 RF3 stream layer often are not perennial, and reconnaissance revealed many sites to be non-target. Also, underground pipelines and aqueducts frequently appear as streams on the RF3 stream layer, and these also were considered to be non-target. Some perennial sites were inaccessible due to physical barriers, e.g. they were in a steep, dangerous canyon or required a ten-mile hike, one-way. Finally, many sites were on private land; if landowners denied access, it was impossible to determine their target status, and they were categorized as "status unknown".

Site reconnaissance continued until a pool of 50 target sites was identified and sampled in each region (if possible). During the reconnaissance process, careful records were kept of each site's target status, and if applicable, reasons why sites were eliminated from the target pool.

Estimation

Once site evaluation was completed and target sites were sampled, the statistical program "R" (Version 1.8.1; www.r-project.org), was used to combine the two coastal design files and adjust site weights to reflect their true percent contribution to the target population. For example, suppose that our region of interest initially contained an estimated 10,000 km of first order streams based on the 1:100,000 RF3 stream layer, and that first order streams were divided into 1000 stream segments, each with a weight of 10 (= 10,000/1000). Suppose also that 75% of first order streams proved to be non-perennial in the evaluation process. Because of the random EMAP design, we can extrapolate this result to all first order streams in the region; thus, an estimated 2500 km are actually first order, perennial streams. If, at the end of the reconnaissance/sampling process, we sampled 20 first order sites, then each of those 20 sites has an adjusted weight of 2500/20 = 125, i.e. each sampled first order stream represents 125 km of stream length. Adjusted weights were used in conjunction with B-IBI scores calculated for each site to estimate the percentage of stream miles in "Good", "Fair" and "Poor" ecological condition.

Stressor association

Examples of stressor association were developed by determining whether candidate stressor levels were significantly different between reference and test sites using box plots and the non-parametric Mann-Whitney U test of statistical difference between two distributions. We then plotted cumulative distribution functions of percent stream miles affected by each stressor. For stressors with no published thresholds of impairment, we used statistical properties (percentiles) of the test site distribution to develop preliminary thresholds.

Four physical stream attributes were selected for our examples: relative bed stability, total nitrogen concentration, total phosphorous concentration, and fraction of reach with riparian disturbance. Relative bed stability is a measure of whether a stream has too much or too little sediment (Kaufmann *et. al.* 1999); increasingly negative numbers on a logarithmic scale indicate "fining" of the sediment, i.e. the median particle size is much smaller than the stream can transport at bankfull flow. Increasingly positive numbers indicate "armoring" of the substrate, which is solidification of the channel bottom when the stream is sediment starved. All four of these attributes can be directly or indirectly altered as a result of human activity, and have been known to have harmful effects on stream biota (EPA 2000). All attributes were measured at the time biological samples were taken.

Results

Stream condition

416 sites in central and southern coastal California were evaluated between 2000 and 2003 (Figure 1, Table 1). Initial weights and adjusted weights for each site are listed in Appendix 1. Based on the adjusted (post-evaluation) weights, an estimated 77% of stream length in central and southern California is non-perennial, and was therefore considered non-target in the present study. Sixty-three target sites were sampled in the southern coast region, and 22 target sites were sampled in the central coast region. Five sites had no available riffle habitat, and we were unable to score these sites with the riffle-based SoCal B-IBI. Fewer than the desired 50 sites were sampled in the central coast due to a regionally high frequency of non-perennial streams and landowner denial. However, by combining the two design files from both regions and by using all target-sampled sites in estimation of regional stream condition, the estimation is based on a total of 80 sites.

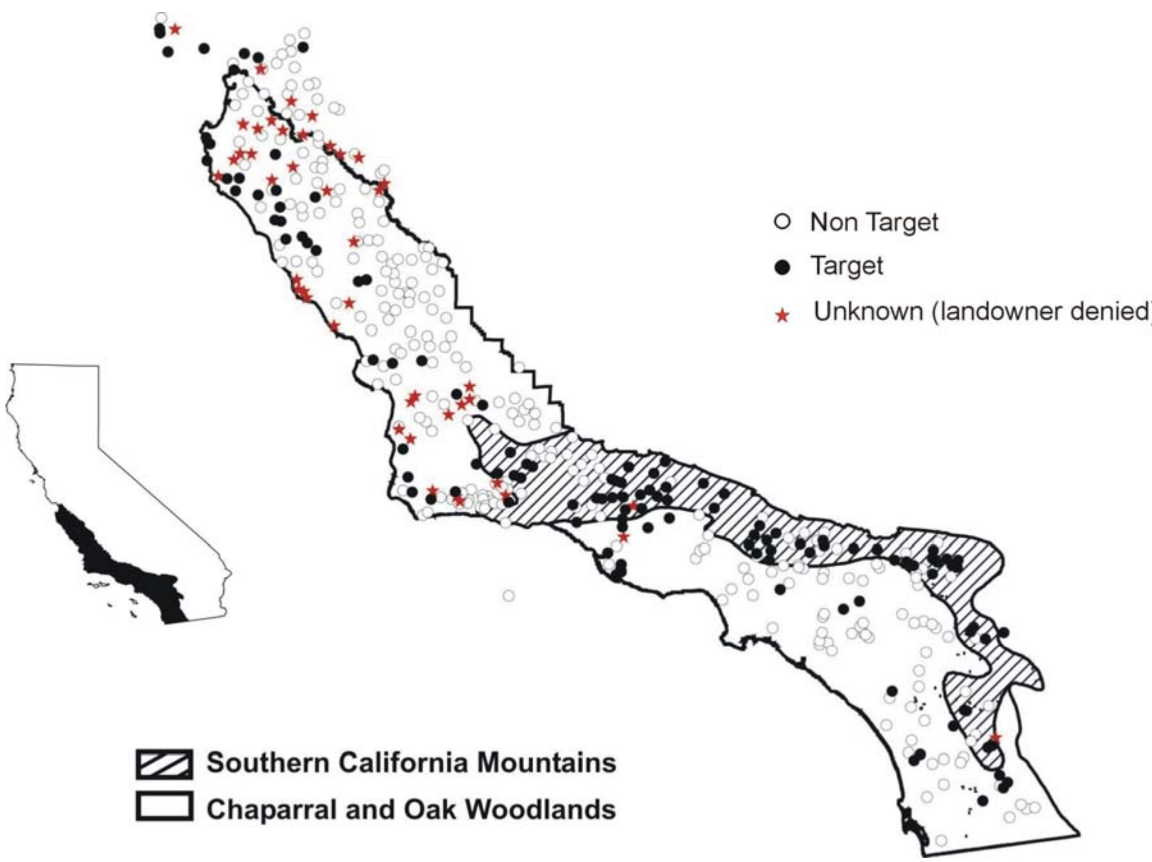

Figure 1. Map of study area with 416 evaluated sites coded by target status. Northern sites are off the map because they occur slightly outside of the region that was sampled for SoCal IBI development.

Table 1. Summary of the estimated stream length (km) in each of six evaluation categories.

Site Status	N Sites	Estimated length (km)	Std Error km	LCB95 km	UCB95 km	Estimated %	Std Error %	LCB95 %	UCB95 %
Landowner Denied	44	2630	497	1655	3605	10	2	6	13
Target, nonwadeable	4	135	52	33	236	1	0	0	1
Non-target	251	20652	1464	17781	23522	77	2	72	81
Target, not used	8	222	70	85	359	1	0	0	1
Physical Barrier	24	933	317	311	1554	3	1	1	6
Target sampled	85	2379	316	1759	2999	9	1	6	11
Total	416	26950	1439	24130	29770	100	0	100	100

Strictly speaking, our estimation of ecological condition in central coastal and southern coastal California streams is based only on the 80 target-sampled sites, which represent an estimated 2199 km of stream length. Results of our estimations could potentially be extrapolated to sites that were physically inaccessible, landowner denied or target-not used, ***if*** one is willing to assume that there is no bias in the spatial distribution or ecological condition of those sites, but we believe this is a management decision. For example, most of the landowner denied sites were concentrated in the central coast region, and most of the physically inaccessible sites were concentrated in wilderness areas where human disturbance is minimal and ecological condition is probably good. Therefore, the following summaries of ecological condition refer only to the sampled population of 80 sites with B-IBI scores.

The estimated number of stream kilometers in each of the five biological condition categories defined in the SoCal B-IBI is shown in Table 2. Cumulative distribution functions are another useful method for depicting what percentage of a resource of interest scores above or below some threshold on an evaluation scale. For example, in the SoCal B-IBI, a score of 59 represented the 25th percentile of reference site scores and was chosen as the ecological threshold between “Fair” and “Good” condition. Thus, if sites with a B-IBI score ≤ 59 are considered biologically impaired, then 58% of stream kilometers in central and southern California are biologically impaired (Fig. 2). By contrast, a score of 37 defines the threshold between “Fair” and “Poor” condition; if that same threshold is used to define impairment, then only 32% of stream miles are impaired.

Table 2. Summary of the estimated stream length (km) in each of the five condition categories defined in the SoCal B-IBI.

Category	N Sites	Estimated length (km)	Std Error km	LCB95 km	UCB95 km	Estimated %	Std Error %	LCB95 %	UCB95 %
No Riffle Sample	5	179	93	0	362	8	4	0	15
Fair	24	480	140	206	755	20	6	9	32
Good	32	742	163	423	1061	31	7	18	45
Poor	12	772	258	266	1278	32	11	11	54
Very Good	8	134	71	0	274	6	3	0	12
Very Poor	4	70	47	0	162	3	2	0	7
Total	85	2378	NA	NA	NA	100	NA	NA	NA

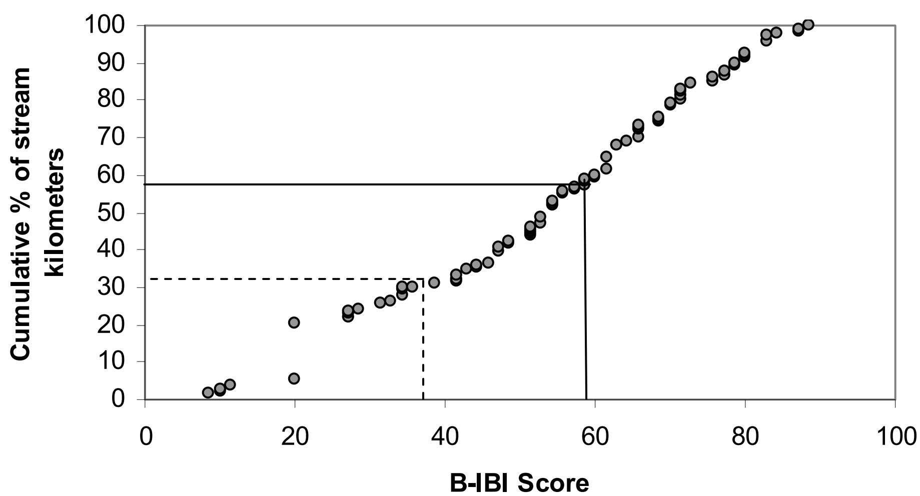

Figure 2. Cumulative distribution function of B-IBI scores for 80 target-sampled sites in central & southern coastal California showing two potential B-IBI impairment thresholds: --- B-IBI =37 (“Poor”); — B-IBI = 59 (“Fair”).

Stressors

In the previous section, the ecological condition of streams in central and southern coastal California was described based on direct measurements of stream biota. Here we present examples of how to identify “potential” stressors affecting ecological condition. The stressors are described as “potential” because we have yet to establish the statistical relationship between these stressors and the biological conditions described above, and because correlation between stressors and biotic condition does not demonstrate cause and effect . This exercise is better thought of as “stressor association” rather than “stressor identification”.

Figures 3-6 show cumulative distribution functions for each of the four potential stressors with site symbols coded according to biological condition. Of the four potential stressors, log relative bed stability (LRBS) had the strongest association with biological condition (Fig. 3). If the 50th percentile of test sites is used to define the threshold for excess sediment in a stream (LRBS = -1.25, Fig. 7), then 40% of stream length in this region is impaired by excess sediment. Most sites with LRBS ≤ -1.25 have impaired biological condition.

If the EPA (2000) guidelines for total nitrogen and total phosphorous concentrations (750 ppb and 100 ppb, respectively) are used as an approximation of objectives for California streams, then approximately 11% of stream length exceeds the recommended nitrogen concentration (Fig. 4), and approximately 10% of stream length exceeds the recommended phosphorous concentration (Fig. 5). However, biotic condition is not always impaired when nitrogen and phosphorous levels are high. For riparian disturbance, if the 50th percentile of test sites is used as the threshold of impairment (= 0.14, not shown) then approximately 43% of stream length is impaired (Fig. 6). Finally, we ranked stressors according to the proportion of stream length impaired by each indicator for all sampled streams and for streams that are in “Fair or “Poor” condition according to the SoCal IBI (Figure 8). These thresholds are meant only to serve as examples, and final thresholds should be set on the basis of regional management goals.

Summary

The statistical survey approach offers an objective view of stream quality across central and southern coastal California. By knowing first how many streams are in poor ecological condition, or are affected by particular stressors, we can begin to make informed decisions about what level of impairment we are willing to accept. It has been our purpose in this report to provide technical guidance in the use of statistical surveys to assess and report on ecological condition of streams, and to associate stressors with ecological condition; it is the responsibility of resource managers to determine exact thresholds of impairment. In addition, estimates of regional stream conditions should ultimately be based on a fully-integrated ecological assessment of multiple communities (BMIs, fish and periphyton); the analyses presented here are one component of EMAP’s survey of multiple biological indicators.

One of the major strengths of the sample survey design is that is can be used and interpreted from various management perspectives or scales. We can use the same approach (first assessing the ecological condition, then identifying the major stressors) to look at different geographic areas within a region such as ecoregions, large watersheds or states. Ecoregional differences play a major role in determining which streams have been

affected by, or are susceptible to, different stressors. Central and southern coastal California is divided into two Omernik Level III ecoregions: chaparral/ oak woodland and southern California mountains (Omernik 1987). Management practices within an ecoregion typically are applicable for many streams with similar problems because stream characteristics within the region are similar. However, some problems are more extensive in some ecoregions than others.

One of the major limitations of the design, at least in the present analyses, was the high percentage of sites where we were denied access by landowners. This problem was encountered far more frequently in the central coast than in the southern coast, thus may not be symptomatic of statistical survey designs in general. However, an implicit assumption of estimates based on a sample survey design is that the sampled population provides an unbiased estimate of stream condition. In the central coast, if streams where access was denied are concentrated on agricultural land where ecological condition is more likely impaired, then we may have underestimated the number of streams in poor ecological condition. Nonetheless, our analyses provide the first statistically defensible estimates of stream condition for a large region of California, and when used to complement existing monitoring networks, the statistical survey approach provides a tiered perspective for determining where the high-priority environmental problems are and how to target management efforts.

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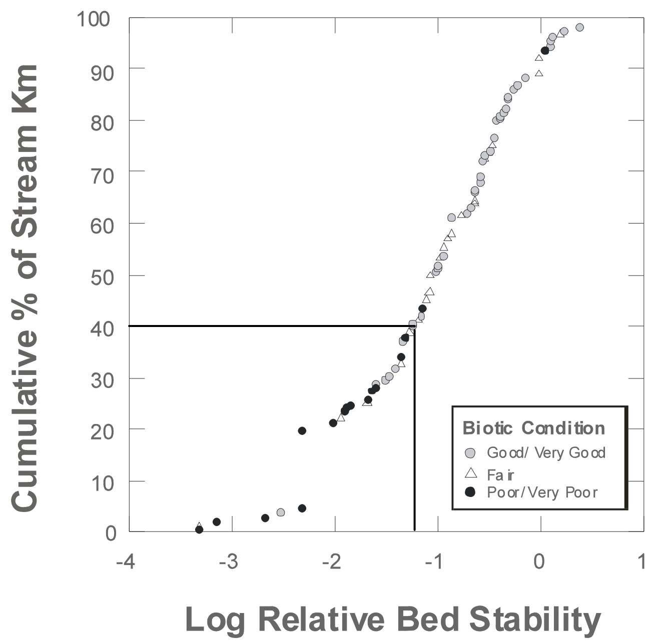

Figure 3. Cumulative distribution function of relative bed stability for 80 target-sampled sites in central & southern coastal California; 40% of stream km are impaired at LRBS threshold of -1.25.

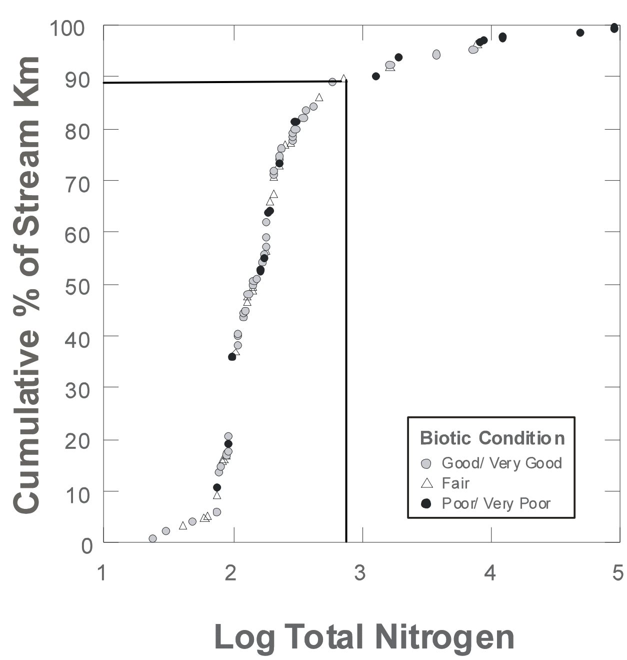

Figure 4. Cumulative distribution function of total nitrogen concentration for 80 target-sampled sites in central & southern coastal California; 11% of stream km are impaired at nitrogen threshold of 750 ppb (log = 2.87).

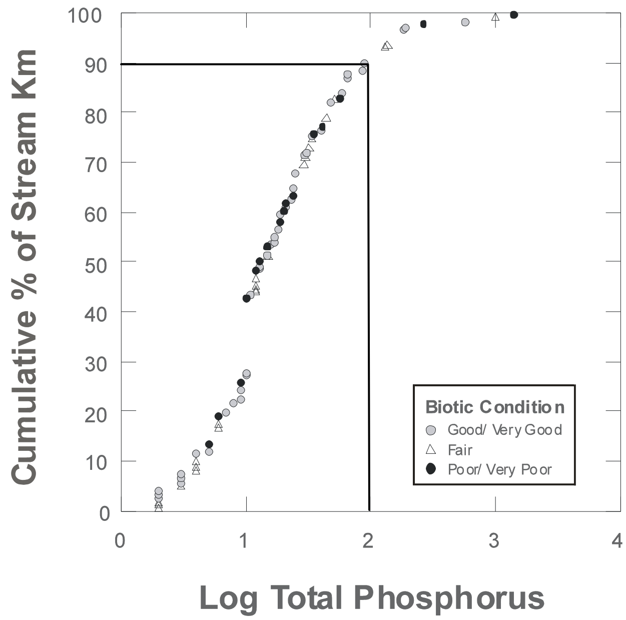

Figure 5. Cumulative distribution function of total phosphorous concentration for 80 target-sampled sites in central & southern coastal California; 10% of stream km are impaired at phosphorous threshold of 100 ppb (log = 2).

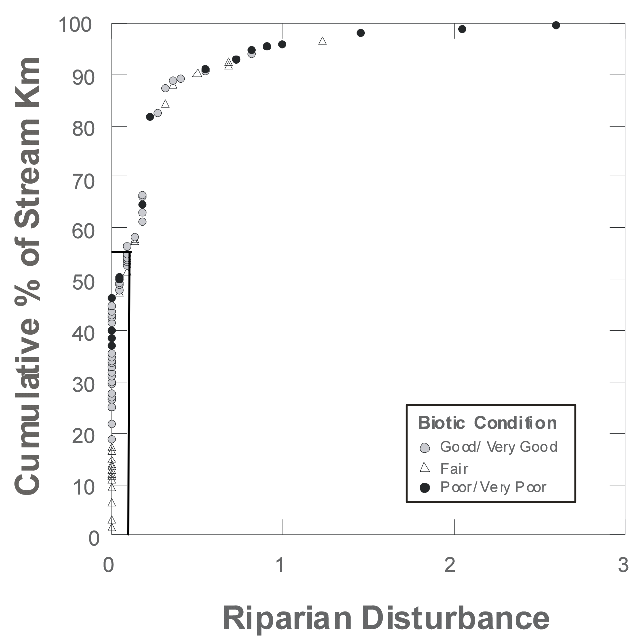

Figure 6. Cumulative distribution function of riparian disturbance for 80 target-sampled sites in central & southern coastal California; 43% of stream km are impaired at disturbance threshold of 0.14.

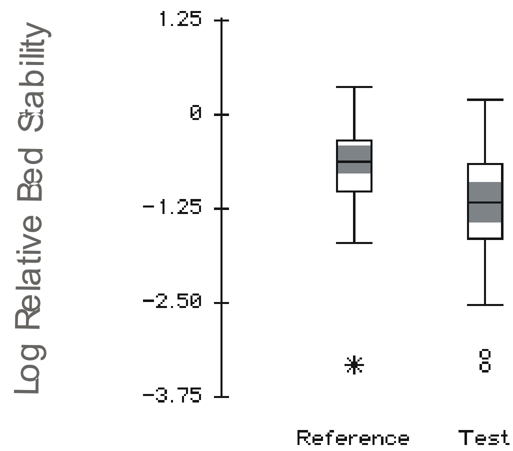

Figure 7. Box plots of log relative bed stability in reference sites vs. test sites; p = 0.0025 (Mann-Whitney U).

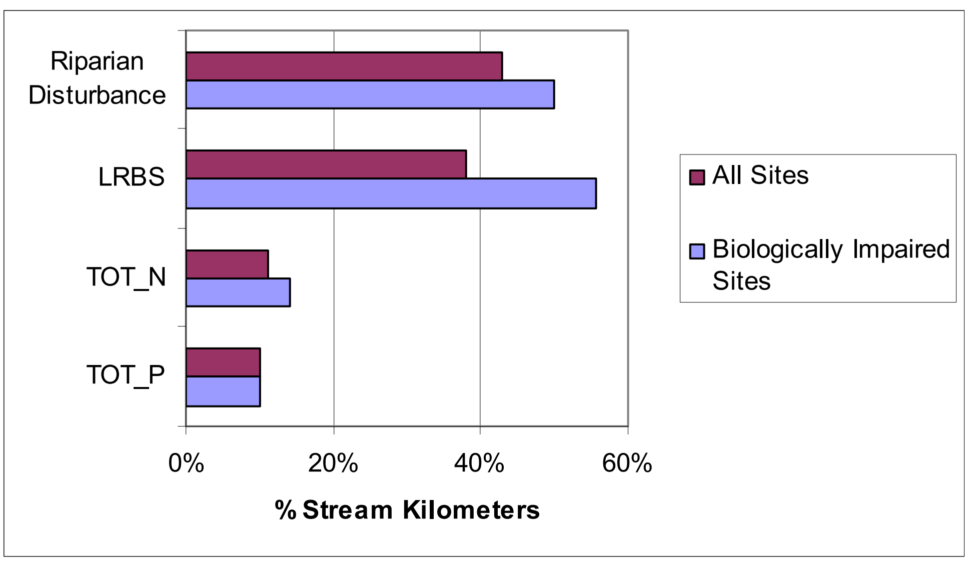

Figure 8. Overall ranking of 4 stressors influencing the condition of central and southern coastal California streams.