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*Report*

# Misuse of Checklist Assessments in Endangered Species Recovery Efforts

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ABSTRACT. Natural resource agencies worldwide must develop species recovery plans that specify threats, propose targets required for recovery, and evaluate the extent to which habitat alteration and restoration may influence species decline and recovery. To evaluate the impacts of proposed habitat alterations on species of conservation concern, standardized protocols may be adopted even when supporting data are scarce. For example, a habitat matrix was developed by the National Marine Fisheries Service (NMFS) to guide consultations under the *Endangered Species Act* for actions that may affect the functioning of the freshwater habitat used by several federally listed salmonid species. The habitat matrix has also been advocated as a tool for recovery planning by agencies apart from the NMFS, who could use it to define the habitat conditions assumed to be necessary for salmonid population viability and hence recovery. This use of the habitat matrix in a recovery context has not been evaluated, and, despite its widespread use as a regulatory tool, the empirical relationships between many of the habitat matrix variables and salmonid populations remain unexplored. By amassing data on habitat assessments and trends in fish abundance, we empirically evaluate the relationship between habitat matrix scores and salmonid population metrics. We found that abundance trends for populations of three species of threatened and endangered salmonids (chinook, coho, and steelhead) were unrelated to these habitat matrix assessments. This study reveals the danger of assuming quantitative relationships between habitat and organism and cautions against co-opting protocols from the regulatory realm for recovery planning for endangered species.

## INTRODUCTION

The volume of species listed under the U.S. *Endangered Species Act* (ESA) since its inception in 1973 is impressive: as of May 2002, 1070 animal species and 746 plant species were listed as threatened or endangered (http://ecos.fws.gov/). The agencies charged with administering the ESA, particularly the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, are thus faced with a huge regulatory challenge in ensuring compliance with the act's requirements. Although one of the major tasks associated with a listing is to develop recovery plans, almost half of the 1816 species currently listed do not have a recovery plan ($N$ = 835 species with no plan); see http://endangered.fws.gov/recovery/recplans/index.htm). In addition to U.S. federal efforts to conserve species, state agencies and NGOs have also developed lists of threatened species, risk-ranking protocols, and plans for coordinating the recovery of imperiled species, e.g., http://www.evergladesplan.org, http://www.natureserve.org/explorer.

Once a species has been deemed to be of conservation concern, the two main challenges facing conservation and species management communities in developing recovery plans are (1) to design the biologically defensible, clearly articulated, and measurable species targets required for recovery and (2) to specify what level of effort in abating threats or restoring habitats is needed to allow the species to recover. For the first of these challenges, the fundamental biological question that must be addressed is: how many individuals or populations are needed so that the species can be delisted? Progress toward addressing this question in practice is mixed, and discussions of the analytical approaches used in goal setting and their inadequacies in recovery plans have recently been well reviewed (Tear et al. 1993, 1995, Boersma et al. 2001). The pressure is thus intense for simple, standardized tools to help agencies develop recovery plans. In this paper, we address the second main challenge: evaluating attempts to determine what actions are necessary for species recovery.

Natural resource managers and conservation planners

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must make decisions about actions affecting species or land use, often with little information on which to base them and enormous pressure to act quickly. Furthermore, decision makers must be able to show clearly that the bases for their conclusions are consistent across decisions. To more effectively make decisions about what threats to abate or areas to restore for species recovery, local and federal agencies often adopt standardized protocols. Implementation of standardized protocols for making these decisions invariably involves using information that serves as a proxy for what managers really want to know (e.g., International Union for the Conservation of Nature 1994, Burgman et al. 2001). The adequacy of such proxies and the thresholds that guide protocol results can be seriously compromised if these protocols are used in a way that differs from the original design. Here, we explore approaches to endangered-species recovery efforts as an example of some of the difficulties associated with answering the question of what actions are allowable or advisable under the ESA. In particular, we explore the advisability of taking a standardized decision-making tool developed for regulatory purposes and using it in a recovery context for threatened and endangered Pacific salmonids.

## THE NMFS CONSULTATION PROCESS FOR LISTED PACIFIC SALMONIDS

Because the number of Pacific salmonid species listed under the *Endangered Species Act* (ESA) has increased over the past decade (Levin and Schiewe 2001), the National Marine Fisheries Service (NMFS) must make hundreds of decisions each year for listed species with regard to the likely impact of a wide variety of human activities. To be as fair as possible and not capricious in spite of great scientific uncertainty, the NMFS developed a decision support tool for evaluating the advisability of actions that could affect the habitat of federally listed salmon species. Agencies whose actions may affect listed fish directly or indirectly through negative impacts on habitat condition are required to consult with the NMFS under Section 7 of the ESA prior to project initiation. These agencies also need guidance as to how to consistently conduct the biological assessments required as part of the Section 7 consultation process.

The NMFS adopted the concept of properly functioning conditions (PFC) to help guide decisions required for their rapidly increasing number of consultations (National Marine Fisheries Service 1996, 1999). PFC were intended to serve as a proxy for describing salmonid population health by describing the habitat conditions and implied processes that are thought to be necessary to support self-sustaining populations. The indicators of PFC that constitute the habitat component of a species' biological requirements are represented by a "matrix of pathways and indicators" (National Marine Fisheries Service 1996). This habitat matrix is often used by the NMFS during consultations under the ESA for actions that may affect freshwater habitat used by listed salmonids. The habitat matrix consists of six pathways describing key processes that include water quality, habitat access, habitat elements, channel condition and dynamics, flow/hydrology, and watershed conditions. These represent the baseline conditions against which the potential effect of proposed actions will be measured. The pathways and indicators included in the habitat matrix are based on scientific studies that have identified links between habitat elements and ecosystem functions that are believed to be important for healthy salmonid populations (e.g., National Marine Fisheries Service 1996, 1999, Bilby and Bisson 1998, Nickelson and Lawson 1998).

Applications of the habitat matrix in Oregon, Washington, and Idaho number well into the hundreds from the period 1995 to 2000. Typically, such consultations involve actions that potentially affect habitat at a relatively small geographic scale relative to the spatial extent of salmon populations. Because many factors outside of freshwater habitat condition affect salmonid abundance and productivity, consultation decisions at the site scale are based on the potential of proposed actions to jeopardize the continued existence of the species or the destruction or adverse modification of critical habitat, rather than on fish population responses. Implicit in such an approach is the assumption that the combined effects of all management decisions, e.g., actions allowed in freshwater and estuarine habitats, hydropower operations, harvest and hatchery management, will adequately protect salmonid populations. Viewed in this way, the application of the habitat matrix at this smaller scale is designed to address only one, i.e., freshwater habitat, of the many threats affecting salmonid populations throughout the life cycle of individuals.

### Using the habitat matrix in recovery planning

Recently, other federal, state, tribal, and local entities have proposed using the habitat matrix in the arena of recovery planning for federally listed salmonids in situations in which achieving the habitat conditions specified in the matrix is assumed to be necessary and sufficient for salmon population health or viability. Some natural resource agencies are advising watershed planning groups that watershed-level recovery efforts are sufficient so long as their individual habitat actions, based on the application of the habitat matrix, are determined to maintain or not significantly degrade the habitat conditions on their land. Elements of the habitat matrix may be adopted as preliminary performance standards for monitoring programs throughout the Columbia River basin (Hillman and Giorgi 2002). The habitat matrix has also been used to justify the continuation of hatchery practices in target watersheds by characterizing the watersheds with the most degraded habitat as at lower risk from the potentially deleterious effects of hatchery programs; the rationale in this case is that such watersheds have risk tolerance profiles that justify preserving or enhancing artificial propagation (Washington Department of Fish and Wildlife 2001). In all of these cases, the underlying assumption is that the relationships between a select number of environmental indicators and fish population responses are both captured by the habitat matrix and known with confidence.

Unfortunately, there has been no scientific test of the application of the habitat matrix in the context of recovery planning. Although the links between the habitat characteristics included in the matrix and ecosystem functioning are well founded in the literature (National Marine Fisheries Service 1996, National Research Council 1996), empirical links between the collection of habitat conditions described by the matrix and fish population dynamic responses, e.g., abundance and productivity measures important for recovery planning, have not been documented. Without an estimate of the empirical relationship between the habitat conditions categorized in the habitat matrix and salmonid abundance or productivity, it is impossible to conclude whether particular actions are sufficient for, or consistent with, population recovery.

The official application of the habitat matrix as a decision support tool to process consistent NMFS consultations generated by ESA listings of salmon is not the focus of this study. Rather, we focus on the assumptions behind the unofficial application of the habitat matrix as a tool, a use for which it was not designed. Our motivation for this study stems from the potential damage to recovery efforts that could result from the misuse of this regulatory tool. Because the pathways and indicators include habitat characteristics that are thought to influence ecosystem functioning for salmonids, a logical first question is whether the scores recorded in the habitat matrix predict fish numbers. In this study, we ask: What is the relationship between the habitat conditions estimated from the application of the habitat matrix and salmonid abundance? This is a useful question to ask in a management context, but especially so if various public and private sectors hope to rely on the proxy indicators in the habitat matrix to guide recovery efforts for salmon.

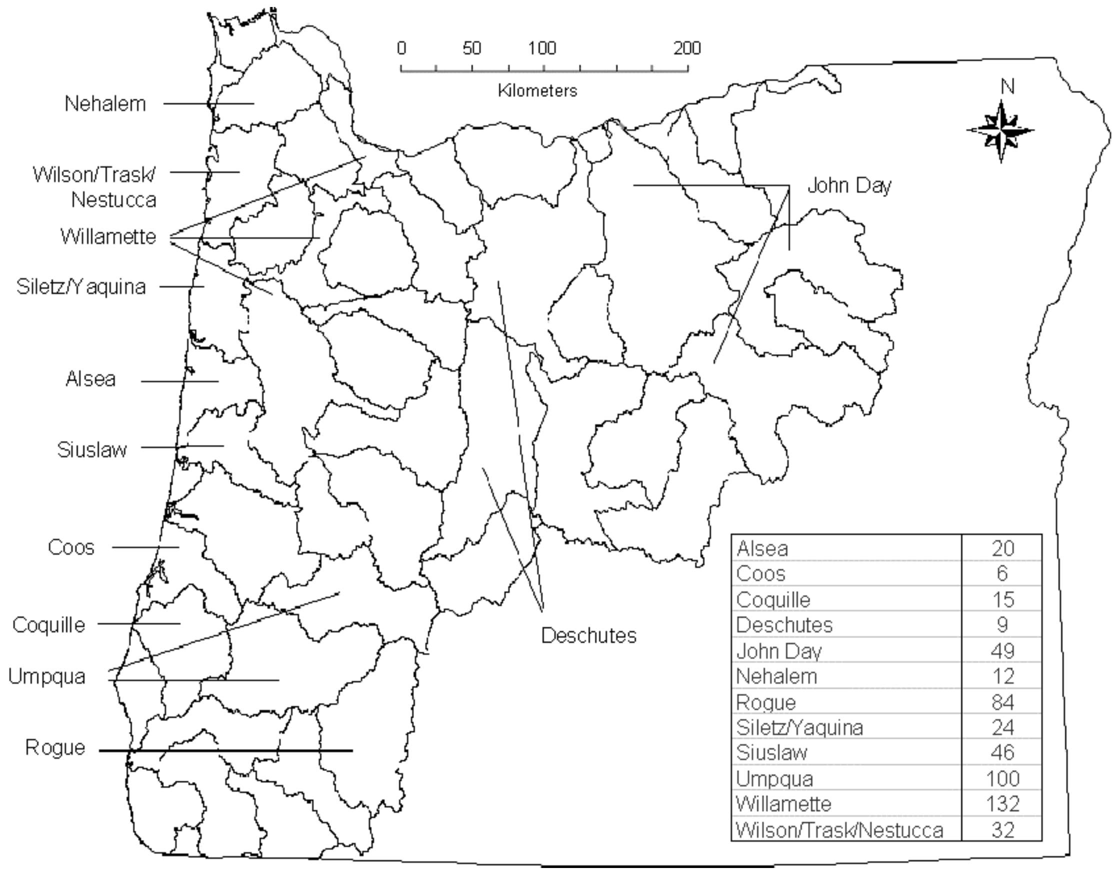
## METHODS

### Habitat quality index

To explore the link between salmonid population responses and the habitat characteristics defined in the matrix, we identified sites for which habitat assessments have been conducted using the matrix. We compiled 734 habitat matrices from 226 consultations for projects in Oregon carried out under Section 7 of the *Endangered Species Act* (ESA) from 1996 to 2001. We reviewed informal and formal consultations from watersheds along the Oregon coast and to a lesser extent in the Columbia River basin (Fig. 1). These consultations with the National Marine Fisheries Service (NMFS) were undertaken by various entities, including the U.S. Forest Service, the Bureau of Land Management, the Bureau of Reclamation, the Army Corps of Engineers, the Oregon Department of Transportation, and Oregon municipalities and counties. The consultations included projects such as timber sales, stream restoration, dock and ramp repairs, bridge and road repairs and replacement, water system improvements, and dam projects.

The NMFS habitat matrix consists of a checklist of habitat indicators, each of which is qualitatively evaluated in the Environmental Baseline section as "properly functioning," "at risk," or "not properly functioning" (Fig. 2). Documentation supporting this matrix (National Marine Fisheries Service 1996, 1999) defines guidelines for evaluating and classifying the indicators, although site-specific interpretations are permissible. Although habitat indicators in the baseline assessment may entail instantaneous measurements, they have been selected to detect the health of underlying processes. The indicators thus represent an integrated assessment of habitat condition over time, including present and past impacts of activities in the action area, and are assumed to be not just static environmental characteristics (National Marine Fisheries Service 1999). The anticipated impact of the action is evaluated in the section on the effects of the action according to whether it is likely to "restore," "maintain," or "degrade" current habitat conditions. Our analyses used assessments from the environmental baseline section; we are thus not evaluating judgments about the presumed effects of habitat actions on any fish population metrics.

**Fig. 1.** Map of the State of Oregon showing watersheds within which we examined habitat matrix baseline assessments and the number of consultations in each watershed.




We gave quantitative scores to the categorical assessments in the matrices by assigning a numeric value to each of the indicators in the matrix. The "not properly functioning" category was assigned a value of 0, "at risk" was assigned a value of 1, and "properly functioning" was assigned a value of 2. Because no a priori weighting had been established for the indicators in the habitat matrix, we used equal weighting of the values as the default for our analyses by summing across all 18 categories evaluated in each matrix.

In some of the evaluations we reviewed, only a subset of the 18 indicators was scored, so that the potential total score could be less than the highest score of 36. To standardize scores among matrices that contained evaluations of varying subsets of indicators, we generated a composite habitat matrix index by dividing the summed score by the total score possible for the matrix elements used in each assessment. The habitat matrix index thus ranged from 0.0, i.e., all indicators not properly functioning, to 1.0, i.e., all assessed indicators properly functioning. We also decomposed the total score into an index for each pathway, i.e., water quality, habitat access, habitat elements, channel condition and dynamics, flow/hydrology, and watershed conditions, by dividing the summed score within each pathway by the total score possible for each pathway. Composite and index scores were generated for these analyses alone and were not used in the consultation process.

**Fig. 2.** The National Marine Fisheries Service matrix of pathways and indicators used in federal consultations under the U.S. *Endangered Species Act.*

| Pathways | Environmental baseline | | | Effects of the action(s) | | |
|---|---|---|---|---|---|---|
| Indicators | Properly functioning | At risk | Not properly functioning | Restore | Maintain | Degrade |
| Water quality | | | | | | |
| Temperature | | | | | | |
| Sediment | | | | | | |
| Chemical contamination/nutrients | | | | | | |
| Habitat access | | | | | | |
| Physical barriers | | | | | | |
| Habitat elements | | | | | | |
| Substrate | | | | | | |
| Large woody debris | | | | | | |
| Pool frequency | | | | | | |
| Pool quality | | | | | | |
| Off-channel habitat | | | | | | |
| Refugia | | | | | | |
| Channel condition and dynamics | | | | | | |
| Width/depth ratio | | | | | | |
| Streambank condition | | | | | | |
| Floodplain connectivity | | | | | | |
| Flow/hydrology | | | | | | |
| Peak/base flows | | | | | | |
| Drainage network increase | | | | | | |
| Watershed conditions | | | | | | |
| Road density/location | | | | | | |
| Disturbance history | | | | | | |
| Riparian reserves | | | | | | |

## Salmonid abundance

Salmonid abundance data were obtained from the NMFS, the Oregon Department of Fish and Wildlife, Streamnet (www.streamnet.org), and other federal, state, and tribal data sources. We examined species-specific responses to habit matrix score using abundance data amassed for populations of three species of threatened or endangered salmonids: coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*), and steelhead (*O. mykiss*). Abundance data represent counts of naturally spawning fish; some counts likely contain an unknown number of hatchery-origin fish. Further, we analyzed the relationship between matrix index scores and salmonid abundance for different life-history stages to examine whether differences in the freshwater residence times of specific life stages affected the relationship between habitat characteristics and abundance trends. Juvenile salmonids rear in freshwater for several months to years before migrating to the sea, depending on the species (Groot and Margolis 1991). Adults return from the ocean to spawn in freshwater streams after 1-5 yr at sea; precocious males that spend only a year at sea before returning to spawn are referred to as "jacks." Adult and subadult/jack abundance estimates were obtained from index reaches of streams, redd counts, and counting facilities at dams and weirs; index reach and redd counts were standardized to per kilometer estimates. Juvenile estimates were obtained from counting facilities at dams, outmigrant traps, and seine sampling.

Because abundance estimates were made using a variety of methods, we used trends in abundance as our metric of fish population response; this is a standard metric for salmonid population status assessments. Trends in abundance were calculated as the slope of a least-squares regression of the natural logarithm of abundance against year. We summarized the results as an average percent annual change in salmonid abundance as a fraction of abundance per year. The percent annual change is thus a direct estimate of the mean instantaneous rate of population change. We calculated both long-term (> 10 yr) and short-term trends (the most recent 7–10 yr or 3-10 yr for juveniles). Because abundance trends were to be paired with habitat matrix scores, the last year of data included in the trend was the year in which the corresponding habitat matrix was completed.

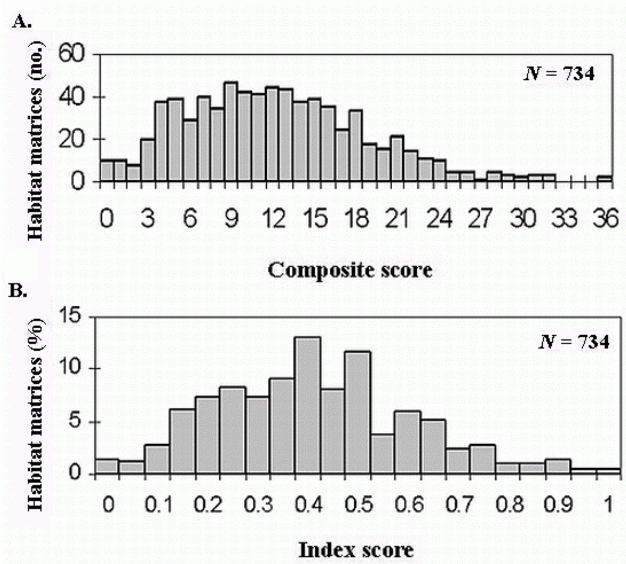
## Associating salmonid and habitat data

We established a set of rules to guide the pairing of habitat matrices with salmonid abundance data. Abundance data were only matched to habitat matrix scores when both occurred within the same watershed. Where possible, we matched abundance data and habitat matrix scores occurring at similar locations and geographic scales. In some cases, matches of abundance data and habitat matrix scores at the same spatial scale were not possible. To distinguish these different scales of matching, we divided our analyses into two sets: "scale matches," which used abundance data that were collected from a smaller area than that at which the habitat was assessed, and "exact matches," where the scale of habitat assessment and abundance data coincided. In our analyses, we did not use cases in which abundance data existed for a larger scale than the one at which the habitat was assessed. For cases in which multiple habitat matrices were completed at a site, the habitat matrix filled out at the earliest date was chosen to minimize the confounding effects of successive actions that may have influenced subsequent assessments. When multiple habitat matrices were completed at a site in the same year, a mean habitat matrix score was used. In one case, separate habitat matrices completed for upper and lower reaches of the stream were averaged and matched with abundance data for the entire stream. There were exact matches of abundance data with 55 habitat matrices ($N$ = 27 adult, $N$ = 14 subadult/jack, and $N$ = 14 juvenile trends). There were scale matches of abundance data for 136 habitat matrices ($N$ = 61 adult, $N$ = 59 jack/subadult, and $N$ = 16 juvenile trends).

## Statistical analyses

Because of differences in freshwater residence time among life-history stages, species, and sampling methods, we conducted our analyses separately by species and then by life-history stage. We used linear regression to examine the relationship between habitat conditions as defined by the matrix and trends in salmonid abundance. This analysis allowed us to determine whether the habitat matrix index or particular pathways in the habitat matrix were good predictors of trends in fish abundance. Response data are presented throughout as mean annual percent change in abundance or density ± 1 SE. All regression analyses were performed using SYSTAT version 10.0 (SysStat Software 2000).

**Fig. 3.** Distribution of composite habitat matrix composite (A) and index (B) scores.

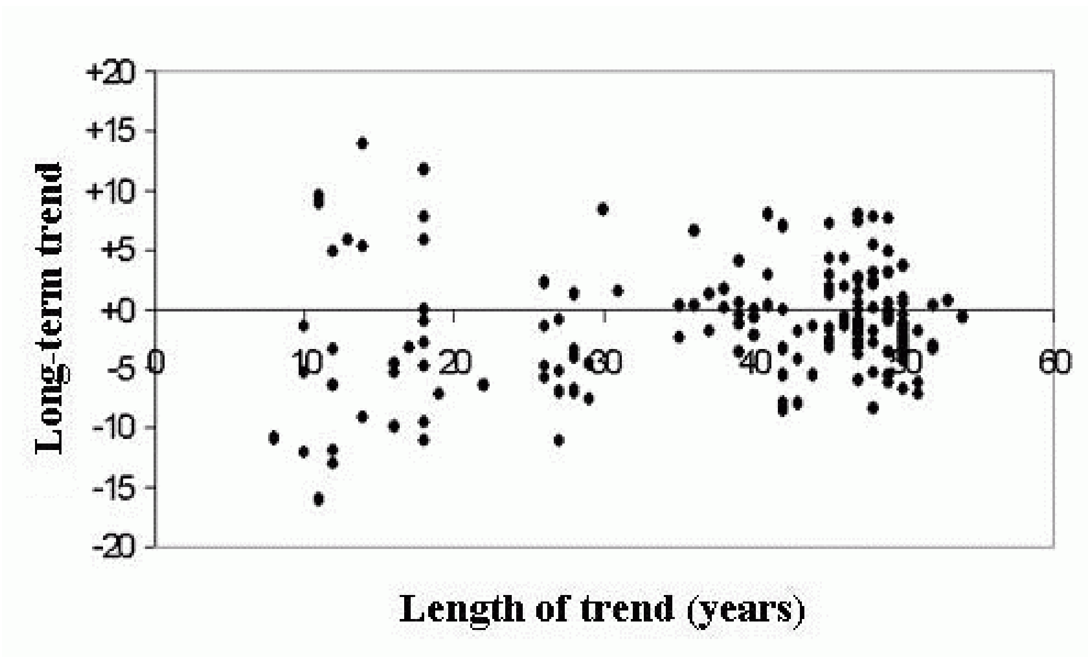



## RESULTS

### Input data from habitat assessments and salmonid population trends

Habitat assessments were strongly skewed toward poor conditions (Fig. 3), as might be expected when dealing with managed and/or degraded landscapes. Although habitat matrix index scores varied from 0.0, i.e., "not properly functioning" for every indicator scored, to 1.0, i.e., "properly functioning" for every indicator scored, the median index score was 0.38. Trends in salmonid abundance were calculated from data spanning three (for juveniles) to 50 yr. Abundance trends were largely negative (210 of 367 trends), which might also be expected when dealing with threatened and endangered species. The sign of the long-term trends in abundance was unrelated to the number of years over which the trends were calculated (slope = 0.05, $r^2 = 0.02$, $P = 0.07$; Fig. 4).

**Fig. 4.** Relationship between the length of the long-term trends in salmon abundance and the positive or negative direction of the trend.




### Habitat quality and trends in salmonid abundance

Habitat quality as evaluated using the habitat matrix was a poor predictor of abundance and population trends for all the species and life stages examined (Table 1). For the exact-match subset of analyses, the highest $r^2$ value was 0.30, and in a few instances, negative slope values showed that more positive population trends were associated with poorer habitat evaluations. The habitat matrix index was a poor predictor of long-term and short-term trends in adult abundance (Fig. 5), as well as long-term and short-term trends in subadult/jack and juvenile abundance (Table 1) for all species combined. The scale-match subset of data, despite larger sample sizes and a wide range of values for both salmonids and habitat data, had a maximum $r^2$ value of 0.25 for long-term trend in coho subadult/jack abundance (Table 1). There were several instances of negative slope values, meaning that salmonid abundance trends were most positive where the habitat had the lowest scores, such as for short-term trends in chinook adult (Fig. 6) and coho subadult/jack abundance (Table 1). Similarly, regressions of residuals of the last year of each salmonid time series on exact-matched or scale-matched habitat matrix index scores (Table 2) showed little or no relationship between this index of deviation of the last year of data from the long-term trend in abundance and the habitat matrix index scores.

**Fig. 5.** Regression of long-term (A) and short-term (B) trends in abundance (± SE) of adult salmon on exact-matched habitat-matrix index scores for coho, chinook, and steelhead combined.

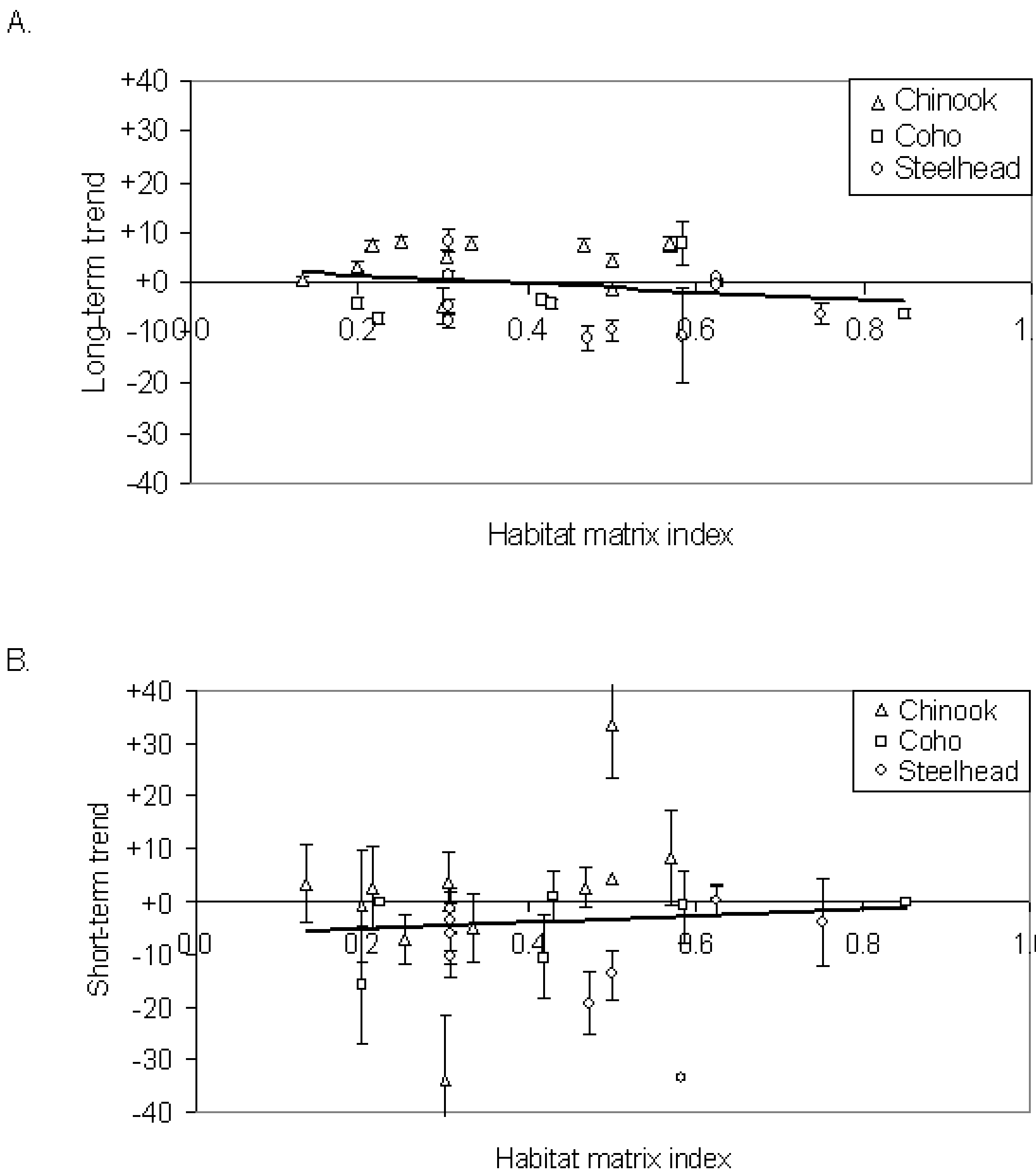
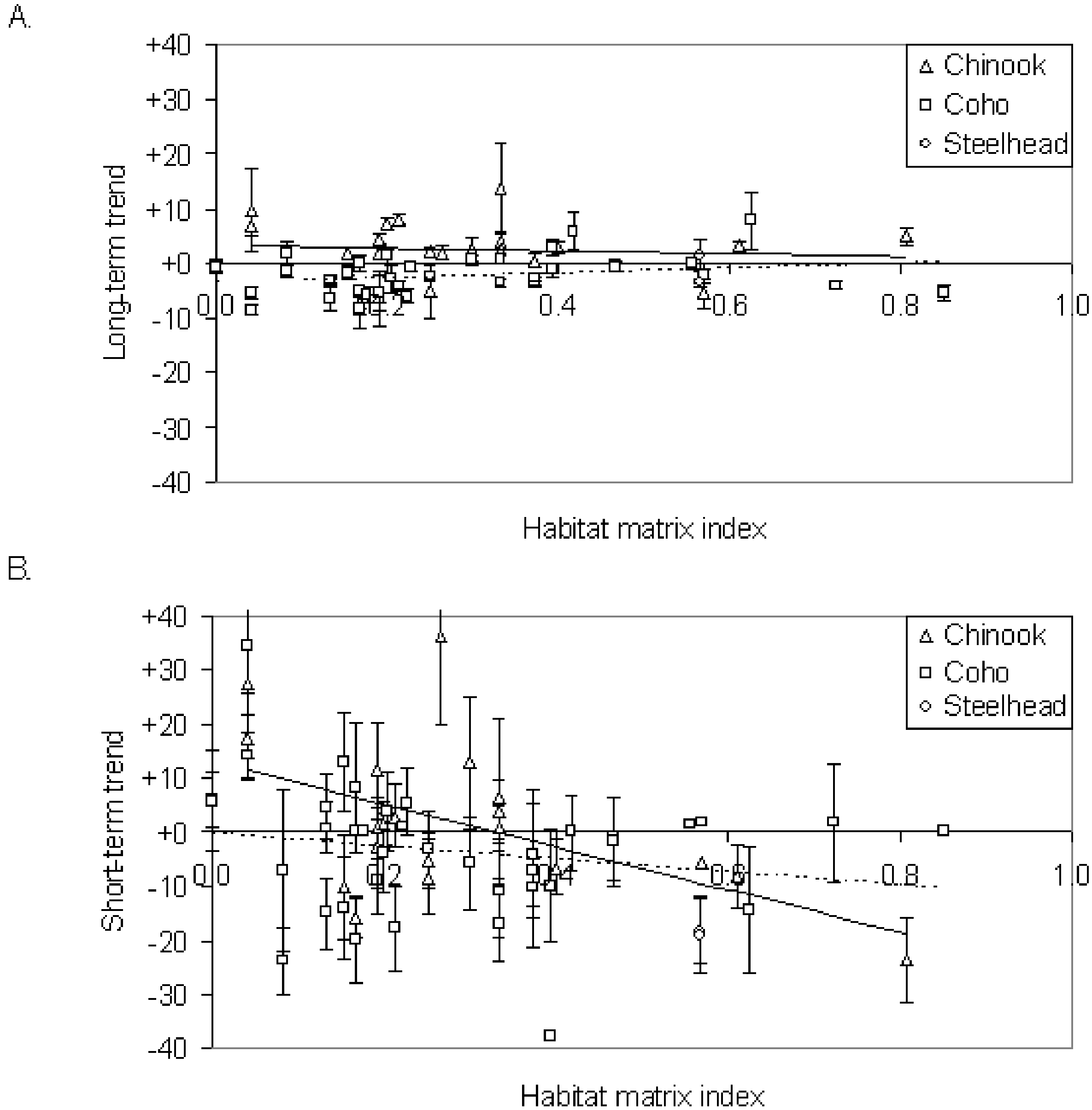


**Fig. 6.** Regression of long-term (A) and short-term (B) trends in abundance (± SE) of adult salmon on "scale-matched" habitat matrix index scores for chinook (solid line) and coho (dashed line).




Decomposing the habitat assessments into the six different pathways of habitat indicators did not reveal strong relationships. The pathways varied in their explanatory power, but the associations of abundance trends with index scores for the six pathways were as poor as the composite habitat scores (Table 3). The strongest positive associations of salmonid population trends with pathways were those of short-term trends in juvenile abundance with watershed conditions and water quality; the strongest negative association of salmonid population trends with pathways was that of long-term trends in adult abundance with habitat elements (see Table 3).

## DISCUSSION

The National Marine Fisheries Service (NMFS) habitat matrix protocol, which is one of the most widely embraced decision-support tools for salmon management, yielded habitat ratings that bore little relationship to salmon population trends. What then are the implications of our results for the use of a habitat condition matrix in salmon recovery? The observation that streams can score high in terms of habitat quality yet have declining abundance trends indicates that, although "properly functioning conditions" may fairly represent the underlying freshwater habitat, it may be a poor idea to rely on categorical determinations of habitat indicators as an assurance that salmon recovery goals have been met. Thus, relying on categorical, and often qualitative, assessments of a suite of habitat variables is no substitute for assessments of the biological resource.

**Table 1.** Regression analyses of long-term (> 10 yr) and short-term (7–10 yr or 3–10 yr for juveniles) trends in adult, subadult/jack, and juvenile salmonid abundance and exact and scale matches of composite habitat matrix index scores ($\beta$ = regression coefficient, $N$ = number of trends, $r^2$ = coefficient of determination, and $P$ = regression significance level).

| | | Exact matches | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Short-term | | | | Long-term | | | |
| Life stage | Species | $\beta$ | $N$ | $r^2$ | $P$ | $\beta$ | $N$ | $r^2$ | $P$ |
| Adult | All | 5.9 | 27 | 0.007 | 0.7 | -8.0 | 27 | 0.05 | 0.3 |
| Subadult/ jack | All | 24.4 | 14 | 0.06 | 0.4 | 2.8 | 14 | 0.02 | 0.6 |
| Juvenile | All | 0.004 | 14 | 0.07 | 0.4 | -0.03 | 6 | 0.28 | 0.3 |
| | | Scale matches | | | | | | | |
| | | Short-term | | | | Long-term | | | |
| Life stage | Species | $\beta$ | $N$ | $r^2$ | $P$ | $\beta$ | $N$ | $r^2$ | $P$ |
| Adult | Coho | -11.5 | 38 | 0.04 | 0.3 | 4.3 | 38 | 0.06 | 0.1 |
| | Chinook | -39.5 | 21 | 0.26 | 0.02 | -2.5 | 21 | 0.007 | 0.7 |
| Subadult/ jack | Coho | -23.4 | 35 | 0.12 | 0.04 | 8.7 | 35 | 0.25 | 0.002 |
| | Chinook | -10.6 | 24 | 0.02 | 0.6 | 3.2 | 24 | 0.005 | 0.7 |
| Juvenile | All | -0.004 | 16 | 0.19 | 0.1 | 0.03 | 10 | 0.19 | 0.2 |

**Table 2.** Regression analyses of the last year's residual from long-term (> 10 yr) trends in adult, subadult/jack, and juvenile salmonid abundance and exact and scale matches of composite habitat matrix index scores ($\beta$ = regression coefficient, $N$ = number of trends, $r^2$ = coefficient of determination, and $P$ = regression significance level).

| | | Exact matches | | | |
|---|---|---|---|---|---|
| Life stage | Species | $\beta$ | $N$ | $r^2$ | $P$ |
| Adult | All | 0.9 | 27 | 0.07 | 0.2 |
| Subadult/jack | All | 0.09 | 14 | 0.0004 | 0.9 |
| Juvenile | All | 0.12 | 6 | 0.002 | 0.9 |
| | | Scale matches | | | |
| Life stage | Species | $\beta$ | $N$ | $r^2$ | $P$ |
| Adult | Coho | -0.5 | 38 | 0.02 | 0.4 |
| | Chinook | -2.2 | 21 | 0.32 | 0.001 |
| Subadult/jack | Coho | -0.7 | 35 | 0.05 | 0.3 |
| | Chinook | 0.6 | 24 | 0.02 | 0.6 |
| Juvenile | All | -1.5 | 10 | 0.19 | 0.09 |

**Table 3.** Regression analyses of long-term and short-term trends in salmon populations and the six major pathways for exact-matched habitat matrix index scores, reported separately for adults ($N$ = 27), subadults/jacks ($N$ = 14), and juveniles ($N$ = 14). Scores for Flow/hydrology were too rare in the consultations reviewed to analyze as a separate pathway and are not included in this table ($\beta$ = regression coefficient, $N$ = number of trends, $r^2$ = coefficient of determination, and $P$ = regression significance level).

| | | Long-term trends | | | Short-term trends | | |
|---|---|---|---|---|---|---|---|
| Life stage | Pathway | $\beta$ | $r^2$ | $P$ | $\beta$ | $r^2$ | $P$ |
| Adult | Water quality | 0.3 | 0.0001 | 0.9 | 11.6 | 0.05 | 0.3 |
| | Habitat access | -2.2 | 0.02 | 0.5 | -0.2 | 0.0003 | 0.9 |
| | Habitat elements | -9.8 | 0.13 | 0.06 | -3.5 | 0.004 | 0.7 |
| | Channel condition and dynamics | 2.2 | 0.01 | 0.7 | -1.6 | 0.001 | 0.9 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Watershed conditions | 0.6 | 0.0003 | 0.7 | 8.9 | 0.02 | 0.5 |
| Subadult/ jack | Water quality | 2.0 | 0.03 | 0.5 | 0.5 | 0.0008 | 0.9 |
| | Habitat access | 3.2 | 0.21 | 0.1 | -1.5 | 0.002 | 0.9 |
| | Habitat elements | -5.5 | 0.07 | 0.4 | 30.1 | 0.09 | 0.3 |
| | Channel condition and dynamics | 2.0 | 0.04 | 0.5 | 18.5 | 0.12 | 0.2 |
| | Watershed conditions | 1.7 | 0.006 | 0.8 | 8.9 | 0.006 | 0.8 |
| Juvenile | Water quality | ... | ... | ... | 7.0 | 0.19 | 0.09 |
| | Habitat access | ... | ... | ... | 4.6 | 0.13 | 0.1 |
| | Habitat elements | ... | ... | ... | 4.0 | 0.07 | 0.3 |
| | Channel condition and dynamics | ... | ... | ... | 7.0 | 0.09 | 0.3 |
| | Watershed conditions | ... | ... | ... | 7.4 | 0.31 | 0.04 |

Because high matrix scores are not associated with increasing populations of salmonids at any life stage in our analyses, the achievement of high matrix scores, e.g., in the context of a monitoring plan, should not be interpreted as indicating recovery. This result should not be surprising to biologists; implicit in the habitat matrix design is that, all else being equal, healthier freshwater habitat will encourage greater salmonid numbers. However, all else is probably not equal, and there are many reasons why there may not be a positive relationship between higher-quality freshwater habitat and greater salmonid numbers (Lee et al. 1997). Improving freshwater habitat removes one obstacle to recovery but cannot guarantee recovery because of other factors also known to affect salmonid numbers. The quality and quantity of estuarine habitats, ocean conditions, hydropower operations, hatchery management, and harvest practices may confound the ability to detect the effects of freshwater habitat conditions on salmonid population status. As examples, harvest rates downstream of spawning grounds and/or the influx of hatchery-origin fish on the spawning grounds could influence abundance estimates of natural-origin spawners.

Applying the habitat matrix in recovery planning without considering the life-cycle context within which habitat conditions exist is dangerous, because important sources of mortality could be completely overlooked. Salmon recovery efforts require an evaluation of the potential contributions of reducing all threats to the status of fish populations, not just habitat conditions, and threats that occur throughout all life stages, not just in freshwater. Standardized checklist tools for assessing risk from habitat quantity and quality can be useful, as long as assessments of risk from other sources are not neglected in deciding which actions are sufficient for salmon recovery. The proposed and ongoing uses of this habitat matrix in recovery contexts do not incorporate assessments of other major risk factors.

It is important to emphasize that the absence of correlations between habitat matrix scores and population performance says nothing about the impact of habitat on salmonid ecology or population dynamics. The inclusion of the individual elements in the habitat matrix is well founded; although the matrix excludes other habitat factors potentially affecting salmon, e.g., stream gradient, the effect of the indicators on ecosystem function is well established (National Marine Fisheries Service 1996, National Research Council 1996). The lack of association between habitat scores and trends in fish abundance may be the result of habitat characterizations that are often not measured data. Rather, they are an idiosyncratic collection of measurements and opinions based on a disparate range of inputs, primarily the "expert opinions" of a wide variety of fishery biologists or consultants. Moreover, whereas it may be quite appropriate to use proxy indicators to assess how projects may degrade habitat and thus endanger the fish present in the system, it is likely quite inappropriate to predict that an assessment of adequate habitat using those same indicators will lead that same fish population to recovery.

## SPECULATION

Matching the spatial and temporal scales of the data was challenging. Although matrix scores are supposed to be an integrated temporal assessment of habitat conditions, they may be relatively static depending upon the rate at which salmon respond to habitat change, whereas trends in salmonid abundance are integrated over several decades. It may be that, if we had explored different metrics of salmon population status, e.g., density or capacity, we would have detected a stronger relationship between habitat matrix assessments and fish metrics. More complex analyses might also better explore the synergistic relationships that exist among the habitat matrix indicators. Such analyses might be interesting to try if the data were available, but they were not the aim of our enquiry. Rather, we were interested in testing a key assumption of applications of the habitat matrix in recovery planning: Is a key indicator of salmon population status, trend in abundance, related in any way to habitat condition as indicated by assessments with the matrix?

We expect that analyses of many commonly used assessment methods would similarly uncover weak relationships between the ways in which habitat was scored and the success of the species that use that habitat. In planning for the recovery of listed salmonids, managers need to more frequently demand concrete evidence that improved habitat conditions do in fact improve the status of the fish that are the target of recovery efforts, and remember that such improvements are likely to be only part of the actions needed to address threats throughout the life cycle of salmon.

*Responses to this article can be read online at:*
*http://www.consecol.org/vol7/iss2/art12/responses/index.html*

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## LITERATURE CITED

**Bilby, R. E., and P. A. Bisson.** 1998. Function and distribution of large woody debris. Pages 324-346 *in* R. J. Naiman and R. E. Bilby, editors. *River ecology and management: lessons from the Pacific Coastal Ecoregion.* Springer, New York, New York, USA.

**Boersma, P. D, P. Kareiva, W. F. Fagan, J. A. Clark, and J. M. Hoekstra.** 2001. How good are endangered species recovery plans? *BioScience* **51**:643-649.

**Burgman, M. A., H. P. Possingham, A. J. J. Lynch, D. A. Keith, M. A. McCarthy, S. D. Hopper, W. L. Drury, J. A. Passioura, and R. J. DeVries.** 2001. A method for setting the size of plant conservation target areas. *Conservation Biology* **15**:603-616.

**Groot, C., and L. Margolis.** 1991. *Pacific salmon life histories.* University of British Columbia Press, Vancouver, British Columbia, Canada.

**Hillman, T. W., and A. E. Giorgi.** 2002. *Monitoring protocols: effectiveness monitoring of physical/environmental indicators in tributary habitats.* Draft report prepared for Bonneville Power Authority. BioAnalysts, Inc., Boise, Idaho, USA.

**International Union for the Conservation of Nature.** 1994. *IUCN red list categories.* IUCN, Gland, Switzerland.

**Lee, D. C., J. R. Sedell, B. E. Reiman, R. F. Thurow, and J. E. Williams.** 1997. Broadscale assessment of aquatic species and habitats. Pages 1058-1496 *in* T. M. Quigley and S. J. Arbelbide, editors. *An assessment of ecosystem* *components in the interior Columbia Basin and portions of the Klamath and Great Basins.* U.S. Forest Service General Technical Report PNW-GTR-405.

**Levin, P. S., and M. Schiewe.** 2001. Preserving salmon biodiversity. *American Scientist* **89**:220-227.

**National Marine Fisheries Service.** 1996. *Making ESA determinations of effect for individual or grouped actions at the watershed scale.* National Marine Fisheries Service, Portland, Oregon, USA.

**National Marine Fisheries Service.** 1999. *The habitat approach: implementation of Section 7 of the* Endangered Species Act *for actions affecting the habitat of Pacific anadromous salmonids.* National Marine Fisheries Service, Portland, Oregon, USA.

**National Research Council.** 1996. *Upstream: salmon and society in the Pacific Northwest.* National Academy Press, Washington, D.C., USA.

**Nickelson, T. E., and P. Lawson.** 1998. Population viability of coho salmon, *Oncorhynchus kisutch,* in Oregon coastal basins: application of a habitat-based life-cycle model. *Canadian Journal of Fisheries and Aquatic Sciences* **55**:2383-2392.

**Office of Technology Assessment.** 1993. *Harmful non-indigenous species in the United States.* OTA-F-565. U.S. Government Printing Office, Washington, D.C., USA.

**Systat Software.** 2000. *SYSTAT.* Volume 10. SPSS, Chicago, Illinois, USA.

**Tear, T. H., J. M. Scott, P. H. Hayward, and B. Griffith.** 1993. Status and prospects for success of the *Endangered Species Act*: a look at recovery plans. *Science* **262**:976-977.

**Tear, T. H., J. M. Scott, P. H. Hayward, and B. Griffith.** 1995. Recovery plans and the *Endangered Species Act*: are criticisms supported by data? *Conservation Biology* **9**:182-195.

**Washington Department of Fish and Wildlife.** 2001. *Benefit-risk assessment procedure (BRAP v5.0) for Washington Department of Fish and Wildlife artificial propagation programs: overview for co-manager technical review.* Washington Department of Fish and Wildlife, Olympia, Washington, USA.