Intensively Monitored Watersheds in Context[1]

PNAMP IMW Subcommittee

In general, the implementation of region-wide watershed recovery actions are intended to increase pre-spawning survival of adults, increase the survival of juveniles (e.g., egg-smolt), and/or expand the geographic distribution of target populations. In all cases, the ultimate performance measure is survival (or productivity) and/or distribution of the "population." That is, successful restoration or improvements should translate into survival and distribution benefits at the scale of populations, not just at the scale of the implemented actions. Monitoring should therefore be sensitive to responses not only at small spatial scales (e.g., reach or small watershed), but also at the scale of populations. This burden is not easily resolved under traditional monitoring programs, because most programs have lacked critical elements of experimental design (replication, randomization, independence, and controls/references), have collected data at the wrong spatial or temporal scales, or lacked sufficient institutional controls to maintain the integrity of the monitoring design over a time period sufficient to generate reliable results. Nevertheless, existing monitoring programs can be tweaked, or new ones can be developed, that should provide information necessary to detect changes at the appropriate spatial and temporal scales.

<u>Effectiveness Monitoring Precepts</u>

In general, lessons from past monitoring activities of habitat actions in watersheds include:

(1) Status and trend monitoring of population and habitat conditions is needed to establish baseline conditions and to develop a reference for large-scale, long-term patterns that may confound population-scale analyses of habitat restoration effects.

(2) Population-level responses to habitat actions can only be detected at the appropriate spatial and temporal scales. Measurements of the effects of restoration actions may occur at multiple spatial and temporal scales, but monitoring programs must be designed to evaluate responses at population scales, or at least the scale of major life-history components, and over multiple years or generations.

(3) Individual habitat actions generally do not directly impact population processes. Their direct effect is to modify physical or biological habitat condition. Therefore, responses of individual habitat actions are most easily detected at the scale of the action (i.e., reach or habitat unit scale).

(4) The mechanism(s) by which a given action generates a response at the population scale is usually unknown and may differ across populations.

Given these precepts, one should be able to develop valid approaches to monitoring the effects of actions.

<u>Ideal Effectiveness Monitoring Approaches</u>

In general, the basic Before-After, Control-Impact (BACI) experimental design provides a foundation for monitoring the effects of actions on population productivity and distribution. The

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validity of the basic BACI design can be extended by including sampling at multiple Control and Impact locations on multiple occasions during the Before and After periods (MBACI). Better yet, the certainty of inferences may be further improved by establishing several pairs of Control and Impact locations that are sampled on multiple occasions during the Before and After periods (MBACI(P)). The intent of these designs is to reduce the likelihood of alternative explanations for differences seen in treatment and control locations. These designs, if implemented correctly, include the four essential ingredients of an ideal design: randomization, replication, controls, and independence.

Problems with Ideal Approaches

In practice, the “ideal” design is rarely, if ever, feasible at population scales because of losses of control and/or treatment areas, spatial arrangements of populations, lack of randomization, lack of independence, the nature of variables measured, and institutional and economic arrangements. BACI-type designs require institutional controls over the time and place of implementation of treatments and the selection and preservation of control areas. This is rarely feasible at the scale of populations. In reality, controlling social, economic, and political arrangements at the scale of populations is very difficult and the lack of experimental control often results in treatments being implemented at different times and intensities, and control areas being treated (loss of independence). Maintaining control populations for comparison with treated populations for long periods of time is very difficult institutionally.

In addition, some performance measures, such as fish abundance, biomass, and productivity are quite variable in space and time. Variability in fish metrics may result from different seeding levels (recruitment) and density-dependent factors that can be independent of habitat conditions. Large variability in fish metrics makes it difficult to assess effects of habitat actions on population productivity.

Given the problems associated with implementing BACI-type designs at the scale of populations, complementary alternative approaches are needed. Although these alternatives do not provide the level of certainty of inference that attends MBACI or MBACI(P) designs, the alternatives may demonstrate causation at the population scale if implemented correctly.

Effectiveness Monitoring Approaches

There are two general types of approaches that can be implemented to assess action ‘treatment effects’ on population productivity and distribution – intensively monitored watershed approaches and levels-of-evidence approaches.

Intensively Monitored Watershed (IMW) Approaches

There are at least two IMW approaches that differ depending on the number of types of habitat actions implemented.

(1) ***Intensively Monitored Watershed (Single Habitat Action Type)***—This IMW involves the implementation of a single action type in a population-scale area. The treated area is matched with a control population-scale area. Effects of a specific action type are assessed through monitoring population productivity in a treatment-control or intervention-analysis context.

(2) ***Intensively Monitored Watersheds (Multiple Habitat Action Types)***—This IMW involves the implementation of multiple action types in a population-scale area. The

treated area is matched with a control population-scale area. Cumulative effects of the actions are assessed through monitoring population productivity in a treatment-control or intervention-analysis context. This approach cannot by itself separate the effects of individual action types on population productivity.

Both IMW approaches provide inferences at the population scale; however, only the IMW (single habitat action type) can assess the effects of specific action types on population productivity. The lack of spatial replication and randomization limits the certainty of inferences of IMWs. In addition, they require long-term institutional controls, which means that relatively few of these can be implemented successfully.

Levels-of-Evidence Approaches

The levels-of-evidence approaches consist of at least three interdependent approaches to monitoring actions to determine biological benefit:

(1) ***Watershed-scale Monitoring***—This approach is similar to IMWs, but is implemented at a sub-population scale (a watershed scale smaller than the geographic area of the population). As with IMWs, this approach may include control-treatments in multiple habitat action types or single action types. Because watershed-scale monitoring does not directly measure the effects of actions at the population scale, status/trend monitoring should be used to assess possible changes at the scale of the population.

(2) ***Project-based Monitoring***—Project-based monitoring includes measuring physical and biological effects of individual actions at a reach or habitat unit scale. Because this type of monitoring does not directly measure the effects of actions on the population, complementary status/trend monitoring is needed to assess possible changes at the scale of the population. Effects of individual actions or classes of actions can be assessed through extrapolation of action influence and modeled connection of habitat condition to population processes.

(3) ***Status/Trend Monitoring***—Status/trend monitoring of population productivity and habitat condition is a long-term effort (decades) that can assess effects of actions through correlation of productivity change to habitat condition and action reporting. Status/trend monitoring provides higher certainty of inference if before-after data are collected at the population scale and physical and biological effects are measured at the reach or habitat unit scale.

These approaches are not mutually exclusive, and as shown in Table 4, lie along a gradient of inferential certainty from relatively strong to relatively weak. IMWs provide more inferential certainty at the population scale than do levels-of-evidence approaches, to the extent that IMWs are design-based at the population scale. That is, inferences from IMWs are based on the design rather than model assumptions. However, the lack of randomization and replication of IMWs may not allow their results to be easily generalized to other populations.

Comparison of approaches to determine population-scale biological effect of restoration and protection actions.

Monitoring Approach	Scale		Type of Inference		Certainty of Cause-and-Effect at Population Scale	Identify Mechanism (Action specific)	Sensitivity to Institutional Control	Notes
	Spatial	Temporal	Design Based (Test/Control)	Model Based (Correlational)				
IMW (one or more action type)	Watershed-Population	Short	Yes at all scales	No	High	Yes at all scales	High	Difficult to implement, rare opportunities
Level of evidence: Watershed scale	Watershed-sub-population (scaled to population indirectly using status/trend)	Short-Moderate	Yes at all scales	No	High	Yes at small scale. No at population scale.	High	Confounded with multiple treatments, rare opportunities
Level of evidence: Action-based (Reach or site scale)	Small (but scaled to population indirectly using status/trend)	Long (decades)	Yes at small scale. No at population scale.	No at small scale. Yes at population scale.	Low-Moderate	Yes at small scale. No at population scale.	Medium at small scale. Low at population scale.	Relatively inexpensive, and does not provide population level answers
Level of evidence: Status/Trend	Large (population, MPG, ESU)	Long (decades)	No	Yes	Low-Moderate	No	Low	Confounded by lack of controls, replicates, and multiple treatments

The three levels-of-evidence approaches rely on correlative data to try and make a case for causal inference. Correlation is used to rule out alternative hypotheses (note-as much if not more is known by disproving plausible alternatives than by showing that data are consistent with an hypothesis). Although the levels-of-evidence approaches may allow robust inferences at small spatial scales (scales smaller than the population), inferences at the population scale are usually inferred from correlation. The following criteria are often used to demonstrate causation from levels-of-evidence approaches:

- *Strength of Association*—Measures the size of the change in performance measures associated with the incidence of treatments. In some respects, this is similar to gradient analysis. One can compare the percentage difference in average value of performance measures at locations that received treatments to those that did not.

- *Consistency of Association*—An association between performance measures and the treatment that is observed many times provides higher confidence than if no such consistency is observed.

- *Specificity of Association*—The association is only seen in the presence of the treatment (i.e., an observed change in the performance measures occurs after the onset of the treatment).

- *Temporality*—If the treatment causes some change, then the change must follow the onset of the treatment. Temporality is a particularly useful criterion, because it has the potential to discard explanations – either the treatment explanation or alternative ones.

- *Biological or Ecological Gradient*—If one can observe a distinct increase in the magnitude of effect with increasing intensity of the treatment, then there is further evidence of causality.

Summary

Given the uncertainty of maintaining the integrity of robust monitoring designs (e.g., BACI designs, IMWs, etc.), addressing effectiveness questions will require implementing a combination of effectiveness monitoring approaches. To account for inherent variability, implementation of IMWs should be focused on where institutional controls on the integrity of the design can be maintained for at least 12 years, or about three generations. Project-based and/or watershed-based monitoring in concert with status/trend monitoring should be implemented where institutional control is less feasible.

Importance of Habitat Models

Not all habitat actions can be monitored, nor can the effects of actions be measured for all populations. In that light, analytical tools or models can be applied that describe the potential effects of habitat actions on population productivity across the many populations that will be treated with habitat actions. Such analytical tools range from the simple (e.g., professional-judgment-guided models) to the very complex (e.g., Ecosystem Diagnosis and Treatment model). The goal should be to use transparent models that can be applied across different landscapes and populations, and provide reasonably accurate results. It is important that habitat and fish population monitoring support the development of such analytical tools. This means that monitoring should be conducted at spatial and temporal scales sufficient to develop and populate models and to provide data to validate the models.

Assessing Effectiveness

- Different monitoring approaches with important trade-offs
- Status & trends is part of assessing effectiveness

Approach	Where applied	How long?	Certainty	Opportunities
Intensively monitored watersheds (IMW)	Population & watershed	Short	High	Rare
Sub-watershed monitoring	Subpopulation or sub-watershed			
Local project assessments	Site or stream reach			
Status & trend monitoring	Population & ESU	Long	Low	Many