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Best Practices in Endangered Species Recovery Planning: Lessons for the Conservation of Maine's Atlantic Salmon

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The call for federal listing of Atlantic salmon implies that such action will result in a recovery plan for the species that is superior to the state's Atlantic Salmon Conservation Plan. In this article the authors compare the Maine Plan against the findings of a recent review of Endangered Species Act recovery plans. The review, conducted by the Society for Conservation Biology in collaboration with the U.S. Fish and Wildlife Service, assessed the quality of a national sample of Endangered Species Act recovery plans with the intention of identifying "best practice." By comparing the Maine Plan to the findings of this review, the authors indicate areas where Maine's plan is strong and suggest areas where there may be room for improvement. ❧

INTRODUCTION

An extensive controversy has developed recently over a salmon-listing proposal[1] by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. The controversy centers around whether to list the populations of Atlantic salmon on certain Maine rivers as distinct population segments vulnerable to extinction and therefore as deserving of listing under the Endangered Species Act (ESA). Part of the controversy turns on purely technical issues, in particular on whether the individual river populations are genetically distinct enough to warrant classification as distinct population segments. A broader issue is whether the state of Maine's plan[2] for the conservation of Atlantic salmon on key rivers is adequate to provide the conservation measures needed to stop these populations from going extinct. The call for federal listing implies the notion that federal action will result in a recovery plan and, more widely, a recovery effort, for the species that will be superior to the state's Atlantic Salmon Conservation Plan (ASCP) and its effort. In this article we compare the ASCP against the findings of a recent review of ESA recovery plans, identifying the extent to which the Maine Plan reflects current understanding of good recovery planning practices and in what respects there may be room for further improvement.

As a standard of comparison for the ASCP we used the findings and recommendations of a study recently completed by the Society for Conservation Biology in collaboration with the U.S. Fish and Wildlife Service. Given the intrinsic difficulty of recovering listed species—by definition already threatened or endangered—there is no absolute standard as to the quality of a recovery plan. One cannot say that a plan with particular attributes will ensure recovery of the species: excellent plans may be developed, among other things, for species that were already in such dire straits when listed that extinction is inevitable, for species that are not subsequently allocated the funds needed to implement the plan, or for species for which implementation is inhibited by legal or land ownership issues. However, what is possible is to recognize good planning in the scientific and administrative accounting and agenda spelled out in the plan. A plan that

- clearly identifies the relative risks of various threats to a species;

- provides a firm scientific accounting of the basis of those risks;

- identifies biologically sound actions to mitigate those threats;

- defines biologically based (rather than arbitrary) criteria for a decision that the species has recovered enough to be de-listed;

- provides for scientifically and statistically sound monitoring of status; and,

- monitors, and responds to, the results of management actions,

is clearly superior to one that lacks these attributes. The analyses conducted within the Society for Conservation Biology/U.S. Fish and Wildlife Service initiative relied on such thinking to identify the best practices evident in recovery planning and to make recommendations to remedy shortcomings in present practice.

In our comparison of the ASCP we accept the conclusions and recommendations reached by the Society for Conservation Biology authors as to good recovery principles. Should these principles be poorly reflected in the Maine Plan, an ESA listing and recovery plan would seem a superior conservation strategy, whereas just a few omissions identified would constitute room for incremental improvement.

BACKGROUND

The Atlantic Salmon Conservation Plan

The Maine Atlantic Salmon Conservation Plan arose out of an October 20, 1995 Executive Order by Governor King in response to a proposal[3] under the federal Endangered Species Act to list Atlantic salmon in seven Maine rivers as threatened. The Executive Order appointed an Atlantic Salmon Task Force to prepare a conservation plan for the protection and recovery of Atlantic salmon runs in the rivers concerned (the Dennys, Machias, East Machias, Narraguagus, and

Pleasant rivers in Washington and Hancock counties, and the Ducktrap and Sheepscot rivers in Lincoln, Kennebec, Sagadahoc, Knox, and Waldo counties). The task force included scientists, academics, state employees, Native American sustenance fishers, conservationists, and private citizens knowledgeable about the salmon resources in these rivers.

In the light of a literature review and expert opinion, the task force made the fundamental assumption that recent declines in Atlantic salmon stocks have been due to limited recruitment originating in low marine survival during the first winter at sea. If this is true, then recovery of salmon populations depends on resolving a core problem outside the jurisdiction of the state of Maine. The ASCP, therefore, adopted a policy of ensuring that issues within the state's jurisdiction are not allowed to become a more severe limiting factor, and placed emphasis on habitat protection and enhancement, eliminating sources of mortality, and on the use of river-specific restocking to maintain numbers. The task force organized its effort through six working groups on aquaculture, agriculture, forestry, recreational fisheries, genetics, and on river-specific issues (which also addressed similar issues on the Kennebec, Penobscot, and St. Croix rivers and Tunk Stream); the reports of the last two were not included as attachments to the ASCP. The Maine Plan includes a systematic overview of the potential threats to salmon and its habitat in these rivers, of the most efficient methods of minimizing or eliminating those potential threats, and of the most effective methods to restore river-specific stocks. In addition, the task force developed plans for greater public education about salmon conservation issues.

Governor King's executive order implementing the plan gave the Land & Water Resources Council the responsibility of implementing the plan and monitoring its progress, while directing all state agencies to fully implement the plan. Responsibility for integrated oversight of the plan was later placed with the Atlantic Salmon Commission. A federal listing of Atlantic salmon populations in Maine would require the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to develop a recovery plan for the species and take oversight of its implementation. This would undoubtedly specify efforts to address the problem of marine survival but would also leave the agencies responsible for planning actions on other fronts—forestry, agriculture, aquaculture, and recreational fishing—all of which are expressly identified in a 1995 federal review of the status of salmon in Maine rivers[3] as needing conservation consideration in Maine. Legal issues also indicate that the federal listing of Atlantic salmon populations in Maine—populations in rivers largely running through private property—would almost inevitably involve critical habitat designation and its associated problems (below).

The national assessment of recovery planning

The ESA establishes a legal mandate to protect threatened and endangered species, with the goal of returning the listed species to a viable status. As part of the recovery process, the ESA requires the U.S. Fish and Wildlife Service or the National Marine Fisheries Service to develop and implement recovery plans for all listed species unless the agency determines that a recovery plan will not promote the conservation of the species. Recovery plans written for ESA-listed species identify threats to the species, designate particular actions or *tasks* to address each, and provide for monitoring of the implementation of these tasks and their effect on the species. Recovery plans are discretionary but constitute the central documents available to decision-makers responsible for the management and recovery of threatened and endangered species.

Given the significance of these plans as critical tools towards recovery of the species, in 1998 the U.S. Fish and Wildlife Service collaborated with the Society for Conservation Biology to review the quality of the ESA recovery plans.[4] Project organizers drew a random poststratified sample from the 931 species plans for which the U.S. Fish and Wildlife Service had primary responsibility as of 1985.[5] Twenty teams of graduate students and faculty at nineteen universities (including a team from the University of Maine and the present authors) completed and analyzed a massive questionnaire (roughly 2,500 questions) for each plan. These analyses have been written up for potential publication[6]

and, through the courtesy of their respective authors, we have been able to draw on their draft findings and recommendations in reviewing the ASCP as a surrogate for an ESA listing recovery plan. Note that we are writing for policy planners and analysts concerned with salmon in Maine, so the synthesis of the Society for Conservation Biology authors' work presented here is a partial one filtered by the specifics of the ASCP concerns.

First, we examine the treatment of five ecological topics central to recovery planning—threats, recovery criteria, monitoring, genetics, and population viability analysis—and compare the strengths and weaknesses identified against the corresponding elements in the Maine Plan. In a subsequent section addressing issues of plan implementation we discuss five management issues—task prioritization, plan revision scheduling, composition of recovery task force, land-owner issues, and stakeholders—in a like manner.

COMPARISON OF "BEST PRACTICE" IN ESA PLANS TO THE ASCP

Threats

The best of ESA recovery plans clearly identify the relative risks of the various threats to a species.

Atlantic salmon face a wide variety of threats. The ASCP summarizes these into five broad areas of impact: 1) death of individual fish to angling and commercial fishing; 2) chemical pollution; 3) habitat reduction and degradation, particularly by agriculture and forestry and other human activities modifying streams and rivers; 4) genetic drift and hybridization with landlocked salmon or with aquacultural escapees; and 5) interaction with other species, including competition with introduced fish, habitat modification by beavers, and predation by seals and cormorants. The federal review of the status of salmon in Maine

rivers[3] identified four areas—forestry, agriculture, aquaculture, and recreational fishing—as needing express conservation consideration. Such a wide spectrum of threats is typical of threatened and endangered species; forty-seven percent of the species listed under the ESA faced threats that were simultaneously major, chronic, and intense.[7] The typical listed species faces five to six threats simultaneously, with resource use, exotic species, construction, and change in habitat dynamics the most frequently cited threats. One of the difficulties that such a spectrum of threats poses for conservation activity is in knowing what the return is to investments in addressing any particular threat: even where a threat may be judged the most immediately pressing, its partial mitigation may simply reveal yet another threat as now the immediate obstacle to further recovery. Such a situation is an obstacle to decisiveness in prioritizing actions.

The ASCP's comprehensive approach to threats ensured that virtually every conceivable threat was identified and discussed within the plan, with an appropriate action listed by way of response to each. In general, the basis for each action is thoroughly discussed and the biological thinking behind it explained. In these respects the ASCP parallels the best of the recovery plans.

Of the some 352 itemized tasks (or groups of tasks) within the plan, some thirty (8.5%) were stated to be of low feasibility. However, even these difficult-to-implement tasks received mostly high or medium priority ratings, indicating that Maine's planners did not shirk identifying these difficult tasks as needing serious attention, even though they included several politically difficult issues (e.g., promoting municipal designation of local areas as critical salmon habitat, controlling access to rivers at salmon-critical locations, or modifying pesticide usage within watersheds). Consequently we found no evidence of major threats being rated as low priority, in contrast to the national picture where 37% of major threats nevertheless had no tasks at all to address them.[7] In short, within the ASCP there is little evidence of the national bias against addressing certain types of threats. Thus, the ASCP exceeds the typical ESA recovery planning in this respect.

One concern we have about the ASCP is its failure to rank threats *within* each river. As noted above, the comprehensive review of threats to salmon in Maine ordered threats only within the domains of the individual working groups. As a result, the relative risk of threats from within forestry, within aquaculture, within agriculture, and so on, was identified for the plan as a whole. In practice, though, the effective risks are to river-specific populations and the true need therefore is to know what threat ranks first, second, third, etc., within each river. While it is true that the plan sometimes assigns different priorities for action to the same threat on different rivers, within rivers, too many cluster together as of equal significance. The national analysis found that major threats tended to receive attention to a greater degree than minor threats, but even then more than a third of major threats went without action. More effective use of ranking of threats to ensure that scarce resources are devoted to the most critical issues was therefore recommended.[7,8] This is a particularly pertinent recommendation for Maine's multiple subpopulations.

Recovery criteria

Conservation goals oriented toward maintaining breeding habitat in Maine cannot be successful if the limiting factor is survival in the ocean.

The ultimate goal of a conservation plan is to return the listed species to a status in which its future is reasonably secure. This raises the question as to how to decide when the species has reached that goal. In 1988, the Endangered Species Act was amended to require that recovery plans include objective criteria for de-listing, to foster the adoption of objective, measurable criteria for measuring the success of recovery planning. Recovery criteria make explicit how progress and success are to be judged and provide focus for actions toward those goals, and the use of recovery criteria has increased markedly since 1988.[9,10] Population size and trends have been the quantitative metrics typically referenced (82% of plans), with recovery criteria related to habitat far less frequent (45%).[11] Criteria as to securement of habitat and criteria as to demographic recovery were less frequent again, at 36% and 25% respectively.

Maine's ASCP is rather poor against this background. It reflects the fundamental assumption that a recent period of low marine survival during the first winter at sea is negatively impacting Atlantic salmon stocks over a broad geographical area and is, therefore, limiting recruitment. If this is true, then recovery of salmon populations depends on resolving a core problem outside the jurisdiction of the state of Maine. In light of this explicit assumption, the ASCP adopted a policy of ensuring that no issue within the state's jurisdiction should be allowed to become a more severe limiting factor, and placed emphasis on habitat protection and enhancement, on eliminating sources of mortality, and on the use of river-specific restocking to maintain numbers. In consequence, the plan adopts a management goal for the seven rivers of producing a minimum annual total return of approximately two thousand adult Atlantic salmon, with an accompanying recreational harvest of roughly five hundred adult salmon above and beyond spawning requirements. The plan's simple demographic calculations then imply a minimum spawning escapement of 1,452 multi-sea-winter salmon annually (based upon a minimum egg deposition of 2.4 eggs/m^2 of habitat), which is intended to yield a production of 65,325 smolts (@ 3.0 smolts/habitat unit) in the seven rivers. As a recovery goal this is deficient in several respects.

One route to recovery suggested by this goal is to increase either the use of available habitat in the seven rivers or to increase the absolute area of suitable habitat there; the plan makes extensive provision for improving access by salmon to suitable habitat. However, the plan also describes the Atlantic salmon nursery habitat in three of the rivers as approaching full production, with two other rivers likely to reach that level in the foreseeable future. Hence, an increase in absolute area of habi-

tat is already envisioned as of limited scope. The historical record shows that habitat accessibility increased ten-fold during the 1970s and 1980s under the auspices of the Atlantic Salmon Authority, with associated increase in adult Atlantic salmon returns to Maine. Yet this was not sufficient to offset the subsequent decline in marine survival since the mid-1980s. Thus, there is an element of inconsistency in considering habitat accessibility to be a significant route to improved status, unless one postulates a lack of access (dams, by-catch of salmon in other river fisheries, and so on) as a significant factor in the decline. Such a postulate is in turn inconsistent with the argument that the decline is driven by conditions outside Maine. With habitat approaching saturation in several rivers and a record of decline in numbers despite past increase in habitat accessibility, habitat-based recovery criteria are inappropriate for salmon.

The second problem with the stated annual return of adult salmon as a recovery criterion is that it is currently being pursued through a restocking program. Thus, attaining that goal does not ensure equilibrium recovery. Indeed, restocking may not be able to keep pace with chronic underlying decline driven by poor marine survival, especially if pre-smolt survival is low. Only if the population can replace itself at these levels over two or three population turnovers can attaining this level of return be seen as effective recovery. Awareness of this issue, and of the need to specify a minimum duration of improved population levels (rather than merely crossing a threshold level), has become more evident among national recovery plans[10] and needs to be considered for salmon. This reliance on restocking as a vehicle to achieve a demonstrable quantitative goal that is yet not a true recovery criterion needs reconsideration. We suspect it is a major contributor to the doubts expressed by the latest U.S. Fish and Wildlife Service biological review[12] as to the adequacy of the ASCP in recovering Atlantic salmon.

Tracking progress toward meeting the criteria that would allow species to be downlisted or de-listed is particularly crucial. Among the national recovery plans there was indeed a high degree of implementation of tasks directly related to specified recovery criteria, with 80-91% of the plans providing for the tracking of progress toward meeting criteria for population, habitat or associated species.[11] The ASCP has a similarly high proportion of tasks devoted toward meeting its target goals, and its two progress reports indicate significant effort directed to improving such tracking. However, biases toward certain forms of action can be very strong. For example, nationally plans often assigned tasks to collect more demographic information even where such additional data had not been identified as useful in the plan.[8] Since plans often failed to describe how such data were to be analyzed once collected, or how the new data might lead to modified recovery strategies, such calls for additional data in recovery plans may often be almost by reflex and certainly ill-thought through. It is essential that recovery plans establish clear guidance as to how collected data are to be analyzed and integrated into the recovery process lest such tasks waste time and resources.[8] Hence, we suspect that some of the monitoring effort within the ASCP is to a degree moot since the goal is not coupled to a true recovered status. (We discuss this further below in relation to population modeling.)

Monitoring

Treatment of monitoring issues in the Maine Plan is generally good.

Monitoring activity can be divided into three categories:[11] monitoring of the *focal species* (i.e., the subject of the plan), monitoring of the *habitat* of the species (even if critical habitat was not formally designated), and monitoring of *associated species* (i.e., species that prey on, parasitize, or compete with the focal species, with exotic species being particularly prominent within this category). The first category monitors the population status of the species itself, the other two monitor threats to that status.

Virtually all recovery plans specified some monitoring of the focal species, but only 65% specified monitoring of species habitat and only 50% specified monitoring of associated species. Degradation and loss

of habitat, *particularly on private lands,* is a major factor in species endangerment in the United States;[13,14] unmonitored loss of habitat could result in unanticipated difficulties in recovery. Similarly, exotic species are of great concern as a threat to native species and they demand surveillance. The poor monitoring of these

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two categories, especially on private lands, is therefore a serious weakness in current recovery plans. Moreover, all too often the monitoring proposed within recovery plans was generalized and not specific to the types of threats affecting the species. For population monitoring, the national plans appear to be somewhat biased against monitoring demographic data: although the rationale and need for such data have typically been well-documented, related tasks were specified only two-thirds of the time and then were only partially implemented.[11]

Treatment of monitoring issues in the ASCP is, in contrast, generally good, even excellent, with monitoring provided across all three categories. The major strategic goal of the ASCP is to protect salmon habitat. The plan makes excellent provision in respect of protecting habitat, with timetables for mapping all habitat and achieving protection status for at least 80% of it by December 2001. The only remaining uncertainty is about the extent to which regulatory action will be taken to impose protection if cooperative agreements are not achieved. While provision is made in the plan for *considering* regulatory action and for pursuing acquisition of key habitat otherwise unprotected, it is without certainty of action. Even so, clear benchmarks are stated, allowing interested parties to determine objec-

tively whether the plan is achieving its stated goals. This goal is complemented by a parallel program of habitat enhancement, primarily focused on remedying degraded habitat. Again, clear benchmarks are stated. By national standards these provisions, if implemented, are first rate; only 66% of the ESA plans involving habitat-related threats went on to specify tasks to monitor them and less than half of these tasks were subsequently implemented.

However, with salmon rivers running predominantly through private lands in Maine, the national bias against implementing habitat-related monitoring tasks where the range of the species involved non-federal land needs more explicit consideration than currently afforded by the ASCP. Therefore, it is a concern that the 1999 Annual Report for the ASCP speaks of changing these benchmarks on the grounds of the original benchmarks being ambitious for most rivers. Although the report validly recognizes that the benchmarks should recognize the nature of land protection and the sheer number of projects along each river, any restatement of benchmarks to semi-quantitative or qualitative metrics would constitute a departure from best recovery planning practice. Recovery plans nationally take about ten years to achieve adequate implementation,[15] so ASCP change on this issue is probably premature.

Monitoring of the water quality goals stated in the ASCP is also well considered. Several of these goals involve relatively complex monitoring or management programs that could prove particularly expensive. In common with ESA recovery plans, absence of money may limit implementation of well-thought through program goals. In this respect the use by the Maine State Planning Office of models of river flow to provide assessment of how water withdrawals might impact juvenile salmon[16] is encouraging evidence of cost-effective use of resources available in support of the ASCP.

The monitoring of the species protection measures in the ASCP in general comply with the best recovery planning practices. However, a number of the monitor-

ing steps lack quantitative goals. Aquacultural escapes are one such issue, the metric proposed being a progressive reduction in storm-related escapees. This is a qualitative metric, intrinsically less satisfactory than a quantitative one. Of less concern is the absence of a stated metric in respect of salmon mortality to seals, cormorants, and eels. The ASCP lists only the obtaining of results of the appropriate research effort as outcomes in respect of the issue, whereas a more rigorous outcome would be a statement of a threshold mortality above which the feasibility of control measures would be investigated. At present the plan provides no indication of whether a 1%, 5% or 20% mortality would be of concern. The schedule of metrics for monitoring the proposed fish management is of high quality, with quantitative metrics stated in most cases. One other issue without a quantitative metric schedule—the adequate assessment of the various age classes in the salmon population—does warrant further discussion. Given the national bias against demographic data noted earlier, we would like to see a stronger treatment of the role of age class data for Atlantic salmon. We note in particular that no discussion is devoted to how the data described will be analyzed, nationally a typical symptom of lack of understanding of the utility of such data.

Genetics

Explicit consideration of the demographics of each river's population—potentially genetic in origin—is still lacking in the Maine Plan.

Inbreeding depression or genetic 'bottle-necking' is widely perceived in the conservation literature as a threat to the persistence of small populations, often because inbred populations have lower reproductive rates; this risk is therefore seen as a concern for threatened species.[17] In practice many species have, in fact, persisted in small populations over long periods, presumably evolving a genetic profile adaptive to their ecological setting. But since patterns in the genetic make-up of a population can be rapidly disrupted by differential growth of individual cohorts, the implications of genetic information are of most value when backed by a sound understanding of the species' demography.[18]

Genetic data have been relatively poorly represented in national recovery plans, yet have played a significant, though minor, part in the recovery planning process.[8] Inbreeding depression or genetic 'bottlenecking' was perceived as a threat in only 12% of plans reviewed by Moyle et al.; in these cases it is most often considered a substantial threat to persistence, although many of the perceived threats are anticipated rather than actualized. It appears that perception of genetics as a threat in these cases may be based more on a blanket acceptance of the theoretical expectation that small population sizes will lead to significant negative genetic effects on fitness, rather than on specific observations of such negative effects.[17] Recovery planners nationally often lacked a clear conception of how and why genetics may aid in species recovery, and genetic information was often requested in incorrect contexts or without good justification. Much of the genetic research proposed in recovery planning appears to be motivated by the hope of determining if there are low levels of genetic variation within and among populations, rather than by a clear vision of its utility or application in recovery efforts.[8,19] Moyle et al.[8] concluded that so little is understood about how the loss of genetic diversity caused by species rarity or decline affects demographic and ecological characteristics of such species, it is difficult to make a clear judgement as to whether low levels of genetic variability constitute a true threat to species persistence. Nevertheless, they concluded that genetic information is especially desirable, among other things, where taxonomy is uncertain and where the species is distributed over lands lacking formal conservation protection; it is most valuable when combined with corresponding demographic data.

These considerations are mirrored in the ASCP,

for Atlantic salmon are distributed in populations of uncertain genetic distinctiveness across multiple rivers largely bordered by private lands. The state's interest has focused on rebutting the "distinct population segment" status inferred for the river-specific populations by the federal listing proposal, i.e., in addressing a presumed uncertain taxonomy situation. Therefore, according to Moyle et al.'s analyses, a combination of genetic and demographic analysis is likely to be especially important for Atlantic salmon, in which river-specific subpopulations may or may not have detectable different genetic composition, yet still differ markedly in demography across rivers. Such combined genetic and demographic investigation is admittedly unusual in current recovery practice, with most recovery plans failing to address demographic and genetic perspectives concurrently. Indeed, Moyle et al. found a strong inverse relationship between the extent of genetic and of demographic information across taxa, with their findings specifically indicating a bias against adequate demographic investigation of reptiles, *fish,* amphibians, and invertebrates.

Thus, Atlantic salmon recovery seems likely to benefit from a greater integration of genetic and demographic data within the conservation planning for salmon. Two reservations are needed here. The first is the national finding that, even where data are collected in an appropriate context, understanding among recovery planners as to the utility of the genetic data in the recovery process was poor—with few plans indicating how the additional data called for would contribute to improved management. Second, even where demographic studies and genetic studies were recommended (respectively), the former were markedly more likely to be assigned high priority than the latter. This is a serious source of bias in recovery planning because limited funding is likely to be devoted to higher priority items on an action agenda. In the case of salmon, political concerns about the impact of a listing has driven investigation of the genetic composition of the river populations only toward the goal of rebutting distinct population segment status. Explicit consideration of the demographics of each river's population—potentially themselves genetic in origin—alongside the genetic data is still lacking in the Maine Plan and is an omission difficult to justify in the light of Moyle et al.'s review.

Population modeling and population viability analysis

Modeling is crucial in determining which of the litany of adverse factors is most critical.

Population Viability Analysis (PVA) is the use of quantitative methods to predict the likely future status of a population of conservation concern. Typically it provides an estimate of the probability that the population will have gone extinct by a specified future time but, as with all models, it can also be used to compare the likely consequences of alternative management.[20] Different types of PVA are possible depending on the type of population and demographic monitoring data gathered within a recovery plan; still, they yield correspondingly simple or detailed predictions about the future of the species, from simple numerical predictions of population size to complete distributional maps. Although the data-hungry nature of spatially explicit PVA is likely to be met only in exceptional circumstances,[21] the simpler forms require only monitoring data often specified within recovery plans. Nationally, data useful for the simplest PVA were collected in 94% of recovery plans but only 78% of these collected all the data needed for a PVA.[22]

In recovery planning for listed species, a significant gap existed between the desire to use PVA and the expertise required to do so.[22] Although nearly half of all recent plans assigned tasks to collect information about PVA, fewer than a quarter of these described the incorporation of the monitoring data into models for predictive analysis. Morris et al. emphasize that failing to think through how the population and demographic data to be monitored can be incorporated into PVA, results in a suboptimal return on the monitoring effort. Monitoring data not only indicates whether a population of an endangered species is recovering or declining but, when used to parameterize viability models, also allows sophisticated quantitative analyses as to which of several possible management interventions

has the greatest chance of success. For some species, the major threats and appropriate responses may be so overt that diverting resources to gather additional data to support a PVA would be inappropriate. In such circumstances good practice nevertheless demands that this rationale be documented within the plan.

This poor understanding of the power of modern PVA is evident in the ASCP. Although the plan makes provision for the systematic collection of key demographic data, elaboration of the use of such data is essentially non-existent. Instead, the plan appears to depend on a qualitative assessment of a population's relative health based on such data as redd counts (i.e., counts of individual salmon laying sites) and, in past years, rod catch information. (In contrast, the 1999 Annual Progress Report describes major progress in building quantitative models of water flow through several of the rivers as the basis for future water management. Still, for population research, the report cites only improvements in the collection of *data*.)

Again, the original plan dismissed (correctly, in our view) any reliance on the Fish and Wildlife Service Habitat Suitability Index (HSI)[23] model for salmon as an exercise in tracking "paper fish," but offered no consideration to alternative modeling strategies. The plan offers specific numerical goals for salmon in each of the focal rivers but without detail as to how these were derived. They appear to be what Emlen and Pikitch (1988)[24] termed "bookkeeping models," showing the results of assuming a breeding stock size and multiplying through figures assumed as to eggs laid per female, mean hatching rate, etc. No consideration is reported as to variability in these figures from year to year, nor how the variabilities for the different terms propagate to a final uncertainty. This is a serious omission by modern population modeling standards and can lead to gross over-estimation of the likely success of a given management regime. A formal PVA would not only take such uncertainties into account but would also allow for the introduction of explicit functions of survival or reproduction as a function of conditions in the river.

As an example of how enhanced models yield new information, consider determining survivorship as a function of water temperature or of river flow: one can then model the effects of a given temperature or flow regime on survival (and thus on population size), either with all other factors held constant or with each other factor also varying across its likely regime. Such *sensitivity analyses* are an integral part of PVA and can have tremendous power in revealing critical limiting factors. Should modeling variation in spawning area and variation in water flow, for example, show that the final population size is ten times more sensitive to changes in spawning area, spending a given budget on improving spawning gives ten times the return obtainable by spending the same money on water flow improvement. Even if good data are unavailable as to how survival decreases with, for example, water temperature, one can still model quantitatively the response obtained for decreases in temperature or for threshold effects as to critical temperatures—and determine how strong the dependence of survival on temperature must be to significantly impact the population level. Such analysis is far superior to relying on the qualitative statement that higher temperatures are deleterious and must be controlled.

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Morris et al.[22] concluded that recovery planning would be significantly enhanced if three recommendations were followed: training planners in government agencies about the value of PVA, involving PVA experts directly in the recovery planning process, and shaping the monitoring protocols adopted within recovery plans to permit use of the resulting data in PVA. Such modeling is likely to be particularly important in the context of Atlantic salmon, where a litany of potential adverse factors can be recited. Comparison of the Maine ASCP and its subsequent annual reports

with the Fish and Wildlife Service's updated biological report on the status of Atlantic salmon shows the influence of different perspectives. The state of Maine correctly sees enormous progress in reducing many sources of impact; the Fish and Wildlife Service acknowledges this progress but retains concern about any factor not totally eliminated. The agency, for example, expressed concern about the single poaching event recorded in Maine in 1998 as being a threat to the salmon population. This concern is well placed if the dynamics of the small salmon populations extant are so fragile that all mortality sources are additive in their effects; the concern is misplaced if mortality is compensatory and if other factors are disproportionately influential. Absent a rigorous population viability analysis of the future of salmon in Maine under an array of realistic assumptions, the service's "zero tolerance" view is as defensible as the state of Maine's.

IMPLEMENTATION CONSIDERATIONS

Prioritizing tasks through adaptive management

Maine's salmon plan significantly —though not comprehensively— embodies the principles of adaptive management.

A major issue in the recovery of threatened and endangered species is how to divide the limited amount of resources among the tasks necessary for species recovery. In a world of limited funding, recovery tasks that are less than imperative are considerably less likely to be implemented. Therefore, recovery plans involve decisions about the priority of tasks, and decisions about the extent of their subsequent implementation. However, rather than implement the priority actions in a rigid manner, an increasingly popular philosophy is to have recourse to the principles of

adaptive management.[25] This approach requires managers to eschew relying on incremental steps requiring full knowledge of likely outcomes and to take actions that directly address the problem of interest in conjunction with monitoring. The monitoring tracks the outcomes of the action closely enough to reverse course or, should the results warrant it, otherwise modify management. This philosophy is reflected in many of the more recent Fish and Wildlife Service recovery plans.[10]

The Fish and Wildlife Service assigns a priority score to each plan, and to tasks in a recovery plan, and also records the presence of conflict with human activities. (The "priority" score actually combines measures of task urgency and of how necessary the task is for eventual recovery.) These priorities, at least in principle, subsequently guide management actions. Across the national recovery plans, species involved in conflict with human activities were more likely to see their recovery tasks implemented than were species without conflict with humans. Still, beyond this there was little correlation between implementation and the priority the Fish and Wildlife Service assigned to a species.[15] Within plans, on the other hand, the available data suggest that recovery planners were more likely to do *something* about high-priority species than for medium- or low-priority ones (*ibid.*), but the actions taken were not necessarily the most pressing tasks. In some instances these latter are actions essential for the recovery of the species in the long-term but for which a compelling opportunity for early action appeared. In principle all the recovery plans should incorporate a well-designed monitoring program in support of adaptive management of the plan; recovery actions that are closely monitored can be modified relatively quickly to ensure the desired results and can lead to more efficient recovery of a species both in terms of time and money. In practice such monitoring was less well considered in the recovery process than was appropriate, presumably because it does not directly benefit the species in terms of increased abundance in the way that threat mitigation or captive breeding do.[11]

By the standards of the national analysis, Maine's salmon plan significantly, though not comprehensively, embodies the principles of adaptive management. It is

apparent that key monitoring is actively used to modify aspects of the recovery program embodied in the ASCP.[16] Various tasks listed in the plan make provision for alternate outcomes. One such example is the requirement that the Land and Water Resources Council review the definition of "significant Atlantic salmon habitat" if attempts to achieve voluntary cooperation from landowners in protecting salmon proves unsuccessful. However, such alternate outcomes are only erratically listed in the ASCP. In addition, the ASCP fails to make any explicit provision as to what should be done should the agency fail in its efforts to encourage municipalities to re-zone, as resource protection zones, locations considered to be significant Atlantic salmon habitat. Nor is any serious discussion provided in respect of the various river-specific tasks listed in the ASCP that are expensive or politically difficult to implement.

Revision of recovery or conservation plan

Explicit statement of what new information would trigger a substantive review of Maine's Atlantic Salmon Conservation Plan, and a default timetable for review, are desirable.

With the passage of time and the acquisition of new information, or because of a change in the status of the species, a recovery plan may be revised to provide for new management. When recovery plans have been revised, one would expect that the revision process would result in improved planning for the future. This expectation has been examined nationally.[26] In fact, plan revisions often failed to capitalize *explicitly* on the improved understanding of species' biology, status and threats resulting from the work undertaken between original and revised versions (though there may well be much undocumented use of the fruits of the original plans (*ibid.*)). Therefore, Harvey et al.[26] recommended that the Fish and Wildlife Service should clarify the implications of new information and should develop explicit criteria as to when a plan should be revised.

To a degree, the Atlantic salmon plan avoids this failure to capitalize on accumulating information via a "Findings" section in its annual progress reports. For each of the fourteen general goals of the ASCP, the management actions reported as progress are expressly reviewed against the benchmarks in the plan. However, the biological consequences of these actions inevitably take a longer time to become evident. In light of the Harvey et al. recommendations, there would be merit in planning for an explicit review of the accumulating biological knowledge every five years or so, coupled with a formal amendment of plan tasks in light of the review. In addition, one cannot read Harvey et al.'s review of the national situation without being struck by the absence of any timetable for review of the ASCP. The possibility that planned actions cannot be implemented for want of voluntary cooperation, and the need to undertake periodic review of the accumulated changes in salmon status as the plan unfolds, demand both explicit statement of what new information would trigger a substantive review of the ASCP and a default timetable for precautionary review. The gist of Harvey et al.'s conclusions is that failing to provide a timetable and an explicit protocol for action given unfavorable out-turn leaves the impression of arbitrary or haphazard decisionmaking. In the case of the ASCP the looming threat of a federal listing unwanted by the state should, in and of itself, be sufficient motivation to plan for formal review to ensure consideration of new information and developments. This issue is closely related to the issue of prioritization raised elsewhere in the present paper: if tasks are adequately prioritized—a failing of the ASCP—then completion of the high-priority work (which, by definition, should not be so voluminous as to be impossible to determine at least interim outcomes within a very few years) should serve as an automatic trigger of a major revision of the plan.

Influence of plan authorship

There is a lack of expertise in population modeling on the Maine team.

One would expect the quality of a recovery plan to vary with the spectrum of diverse expertise represented in its authorship. Nationally, plans with authors drawn from beyond the federal community provided a much clearer biological rationale for decisions in respect of recovery criteria to be used, provided a more explicit biological basis for recommended monitoring protocols (especially if academic biologists were represented), and were more likely to see the tasks identified as needed actually implemented.[4,27,28]

The ASCP stands up well in this respect. Considering the state of Maine as the equivalent of the federal government for this comparison, only six of the sixteen members (including staff) of the Atlantic Salmon Task Force itself were state employees. Professional biologists were also well represented among the non-state members Academic membership was less strong, with Professor Irv Kornfield from University of Maine's then Department of Zoology the sole academic member. However, one of the present authors (Owen), the then commissioner of Inland Fisheries and Wildlife for the state, served as such while on leave from an academic post in the University of Maine's Department of Wildlife Ecology. While the task force must be regarded as the equivalent of an ESA recovery team, the ASCP contains substantial written input—in the form of chapters and appendices—from a series of working groups on forestry, agriculture, and other issues impinging on, and themselves affected by, salmon conservation measures. Therefore, the membership of these groups spanned the wide biological and academic spectrum found effective nationally.

One area in which the ASCP team must be considered weak, however, is in the paucity of expertise in population modeling. Despite initial doubts, empirical evidence shows that PVA is an effective tool for assessing the optimum deployment of scarce conservation resources where species are limited by demographic factors.[29] Even nationally the use of PVA has been hampered by the limited involvement in recovery planning of quantitative ecologists with training in demographic analysis.[22] With this exception, however, the ASCP team appears to reflect the very best of recovery group composition principles and it is unlikely that any recovery team assembled after a federal listing would be much superior.

Land-owner issues

Monitoring salmon on private lands is no substitute for appropriate habitat management there.

The ownership of the land on which listed species dwell markedly influences recovery planning. Hatch et al. (in review)[28] divided recovery plans into four categories depending on: 1) whether the species range was exclusively on federal property; 2) whether a majority of the range was on federal property; 3) whether a majority was on private lands; or 4), whether it was exclusively on private property. For species exclusively on federal property the tasks listed in the recovery plans proved more likely to be implemented and, possibly because of this, the species was more likely to improve in status. (We note a possible bias here. Recovery planners may typically specify fewer explicit tasks—making them easier to implement in full—for species largely on federal lands, in the belief that the agency involved will be proactive in conservation.) In contrast, plans for species mostly or entirely on private lands were more likely to lack knowledge as to their recovery status.

Why such differences? The ESA constrains the freedom of action of private landowners only in limited ways, principally by its prohibitions on "take" of vertebrate species and against commercial exploitation of listed plant species, and if the Fish and Wildlife Service or National Marine Fisheries Service identifies

geographical areas as "critical habitat" considered essential for the conservation of the species. These are relatively limited restrictions on private landowners. On the other hand, although the ESA primarily limits the regulatory authority of federal agencies in permitting or undertaking actions that would adversely impact listed species, the agencies, in practice, are obligated to take the presence of a listed species on their land into consideration in *all* their actions; this may result in greater action in support of the species.

Several specific landowner issues reflected in national recovery planning have lessons for the ASCP. The ASCP states as one of its major goals the need to protect salmon habitat in the seven rivers. The intention is to ensure that conditions in Maine rivers would not limit recovery of the species if adverse conditions outside the state's jurisdiction were to improve. The Hatch et al. review suggests that this is unlikely to be an optimal strategy. Nationally, tasks calling for habitat management of any type were notably fewer within the plans involving land outside federal jurisdiction than within such jurisdiction, and habitat management tasks planned for species predominantly on private lands also were less likely to be implemented. Instead, these plans called for more monitoring tasks. Unfortunately, although monitoring of the focal species was then generally well implemented, tasks involving monitoring of *habitat* were less likely to be implemented the greater the proportion of private lands involved. In effect, these findings imply that the concentration of a species onto private lands resulted in more passive and poorly implemented monitoring and in less active management than would otherwise have been the case.

These findings have two implications for the ASCP. First, if one views state jurisdiction as an analogue for salmon of federal jurisdiction across other recovery plans, the limitations lying in the complexity of multiple landowners seem likely to hinder implementation of conservation tasks for salmon. One can already see this proclivity within the original ASCP, in the form of emphasis on immediate action on monitoring but only on soliciting cooperation over management from landowners and municipalities. Notably, the original plan generally made provision only for agen-

cies to "consider" regulatory action in the event of the cooperation sought not being forth-coming. Thus, the ASCP embodies the very practices identified nationally as likely to result in less-effective implementation of the conservation tasks listed. This does appear to have been recognized in the course of the first two years of the plan's existence, in that several state agencies (Land and Water Resource Council, Land Use Regulatory Commission, Department of Marine Resources, among others) have subsequently converted, or are converting, voluntary measures into regulation.[16] Additionally the level of cooperation with the ASCP obtained from Maine stakeholders appears to be extremely high: that every one of thirty-four landowners identified as having non-point source pollution issues—small enough to be legal but of potential impact on salmon—immediately corrected the problem when contacted indicates extraordinary interest in the salmon issue.[16] On the other hand, construction of a weir on the East Machias River, intended to reduce the risks of pen-raised fish interbreeding or competing with wild Atlantic salmon, was unable to proceed lacking cooperation from a key landowner.

The second implication of the above findings, and of special relevance to Maine, is that, on the basis of past recovery planning practice, there is little reason to expect a marked improvement in the management of salmon habitat in Maine in the event of a federal listing decision. First, the Fish and Wildlife Service has historically minimized the use of critical habitat designation (in the belief that the additional protection conferred by the designation does not offset the resources needed for the additional (e.g., economic) analyses that become necessary), and designation of critical habitat has had relatively little effect on the recovery planning process.[30] However, a series of recent court rulings has essentially precluded this stance for the future; thus, a federal listing of Atlantic salmon is likely to result in designation of critical habitat and its associated issues. Second, it is arguable that the best strategy toward overcoming the weaknesses originating in ownership patterns discussed above is to develop programs promoting voluntary collaboration. In this respect the state's current support of educational and cooperative

work through, for example, Project SHARE (Salmon Habitat and River Enhancement), seems more likely to win local support than would a federal program developed after a listing. Nationally, the biggest problem in managing recovery of listed species on non-federal lands has been difficulty of access,[31] which the ASCP reliance on voluntary cooperation may indeed be well-suited to overcoming. Indeed, Hatch et al. recommend a greater national emphasis on proactively educating and involving stakeholders on recovery issues. This would build on the benefits of partnerships forged during plan development in a coordinated manner—an emphasis already central to the Maine Plan. Yet an important caution also emerges from the Hatch et al. work: such cooperation may be forthcoming more readily to monitor salmon numbers than to monitor habitat conditions. Counting the number of salmon locally may seem to landowners to be less of an intrusion than having the condition of their property assessed as to suitability for salmon. The lesson we draw is that the ASCP needs to evaluate its success in eliciting landowner cooperation in full knowledge of this potential bias.

Incorporating stakeholder interests

Maine's provision for a full-time coordinator anticipates the most successful recovery plans.

The difficulties of coordinating effective species recovery efforts where multiple landowners are involved—and where multiple agencies have relevant jurisdiction—are manifold.[32,33] Yet surprisingly little attention has been given to how this influences the performance of an ESA recovery plan. Hatch et al.[28] tried to statistically predict the likelihood that the tasks listed in each recovery plan would actually be implemented. Implementation was more likely: a) the *fewer* federal employees involved in drafting the plan; b) the *fewer* environmental organizations involved in the drafting; c) the *more* local (state and other) government employees involved in drafting; d) the *more* other agencies and individuals involved; and e) the *fewer* the agencies involved in *implementation* (rather than drafting). These patterns originated in the problems of coordinating the agendas of diverse agencies. Implementation improved among the national plans if a coordinator was appointed[34] and if a central database of species information was maintained. Note, though, that for some plans, legal considerations mandated the allocation of these responsibilities across multiple parties. Thus, the basic principles emerging from their study were to draft the recovery plan with extensive consultation with stakeholders, but also to consolidate the subsequent implementation responsibilities to the maximum extent allowed by law.

What are the lessons for the ASCP? Experienced recovery practitioners suggest that the administration involved in a recovery plan is typically grossly underestimated and may be more challenging than overcoming the biological issues involved.[32,35] Hence, the Maine Plan's provision of a full-time coordinator anticipates the emphasis on coordination that is found in the more successful of the national ESA recovery plans. However, in terms of implementation, the ASCP does rely on a diverse spectrum of participants, ranging from state agencies through state-supported programs to independent industrial interests. Doing so is hardly surprising given the larger number of stakeholders for a species impinging on multiple individual land holdings, but Hatch et al.'s finding—that completion of tasks decreases as the number of responsible parties increases (even if in some cases the result of legal mandates)—is worrisome. The Atlantic Salmon Task Force included the commissioners or directors of key state departments (Marine Resources, Inland Fisheries and Wildlife, Agriculture, Maine Forest Service), thereby ensuring a cabinet-level mandate for interdepartmental cooperation among state agencies. However, this does little to consolidate the responsibility for implementation of tasks assigned outside these agencies. Indeed, whereas the extensive involvement of stakeholders in the *drafting* of the ASCP reflects best practice, the attempt to carry this involvement through to *implementation* must be seen as a significant weakness. Hatch et al. put it bluntly: "…division of labor among parties implementing tasks has a negative impact on progress."

Hatch et al.'s finding as to the value of maintaining a central database of information of the species of interest was not reflected in the original ASCP. However, the ASCP 1999 Annual Report[16] notes that the Atlantic Salmon Commission is actively building a central database of salmon information, with each state agency requested to provide quarterly updates of any information they hold. In line with modern thinking, as much of this database as possible will be spatially registered and will be made widely available to all cooperators. Therefore, this particular weakness of the original ASCP is being addressed.

CONCLUSIONS AND RECOMMENDATIONS

It should be clear from the above that in many respects the Atlantic Salmon Conservation Plan for Maine embodies the best of the recovery planning practices identified in the Society for Conservation Biology/Fish and Wildlife Service review of extant plans. Thus, a federal listing would be unlikely to generate a recovery plan *in respect of actions in Maine* that would be superior to the Atlantic Salmon Conservation Plan. The principal new element a federal plan could provide would be to address the problem of marine survival, an issue outside the state's jurisdiction and one that may, in any event, be intractable if originating in natural changes—such as in climate—rather than in human activities. Given the importance of private lands for salmon in Maine and the difficulties evident nationally in obtaining effective action on such lands, a federal plan ought to offer convincing promise of solving the marine survival problem before risking the loss of the hard-won collaboration of the present plan. Indeed, one might reasonably ask that the effects on salmon populations of conceivable management actions directed to the marine survival problem be modeled and compared against the modeled effects of actions within Maine before a commitment to a listing and its consequences are undertaken.

The Maine Plan is not perfect and its comparison against the national analyses does reveal two major

topics and seven minor issues where the plan offers room for incremental improvement. The major areas we recommend addressing are:

- The ASCP makes little use of modern population modeling techniques with which to assess both the relative merits of alternative management actions and the prognosis for the survival of Atlantic salmon in Maine. Population modeling is currently the only tool available with which to determine how effective Maine's current actions are relative to options likely to be exercised under a federal listing, and the absence of a comprehensive population viability analysis is a serious shortcoming in the plan.

- The Maine Plan makes great efforts to achieve comprehensive consideration of—and action to address—issues potentially affecting salmon in Maine. Still, this comprehensive review is not accompanied by adequate prioritization among possible management actions. The failure of the Maine Plan to rank threats *within* each river is a particular concern since the effective risks are to river-specific populations, yet within rivers the plan clusters too many threats together as of equal significance. The effective prioritization among tasks competing for limited resources, coupled with adequate modeling of their likely conservation value, is critical in ensuring cost-effective selection among Maine's options.

Thus, population modeling and prioritization of river-specific threats are two actions that promise improvement in Maine's salmon plan. Other minor

> Population modeling and prioritization of river-specific threats are the two unaddressed issues that most matter.

issues need consideration but do not offer anything like the same promise for advancing the conservation of Atlantic salmon in Maine. The points we recommend for review in light of the national analyses are:

- The fundamental assumption of the Maine Plan that Atlantic salmon are critically limited by conditions outside the jurisdiction of the state has led to anomalies in how recovery criteria are treated in the plan. In particular, the reliance on habitat enhancement to support a stated restocking level that has not been shown explicitly to be an equilibrium condition, and internal consistencies in the plan as to the scope for—and likely effectiveness of—habitat enhancement need justification. Modeling the anticipated effects of proposed enhancements would clarify many of these concerns.

- The possibility of a genetic basis to differences between rivers in the demographics of the populations deserves exploration in the light of recommendations as to national practice. Modeling the outcome of different assumptions about the extent of such a genetic (river-specific) basis to demography would do much to indicate the likely influence of this factor relative to others and would do so before any field investigations are even undertaken.

- Although species protection measures in the ASCP generally comply with the best recovery planning practices, a number of steps planned lack quantitative goals. Worse, the absence of planning as to how to analyze quantitative data makes it impossible to determine their adequacy. Asking how such data would be incorporated in the PVA (recommended above) would clarify where these weaknesses are critical.

- Stating explicit criteria as to what new biological evidence would trigger a substantive

review of the plan would remove an important source of uncertainty as to whether the plan is achieving its larger goals. Sensitivity analysis in the course of population modeling would likely reveal the most critical issues to incorporate in such criteria.

- The ASCP emphasis on voluntary efforts towards *implementation* of recovery tasks embodies the very practices identified nationally as likely to result in less effective implementation of the conservation tasks listed. The national finding that completion of recovery tasks decreases as the number of responsible parties increases suggests that this aspect of the Maine Plan should be reconsidered.

- Currently, the program of habitat enhancement has clear benchmarks for success but the Maine Plan needs to consider whether a national bias—that habitat-related monitoring tasks are often not implemented— might be a problem for Maine also.

- The Maine Plan needs to explicitly recognize that recovery plans nationally have taken far longer to come into full effect than is currently envisaged in Maine. ❧

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ENDNOTES:

1. "Endangered and Threatened Species; Proposed Endangered Status for a Distinct Population Segment of Anadromous Atlantic Salmon (*Salmo salar*) in the Gulf of Maine." *Federal Register.* 64 (17 November 1999): 62627.

2. Atlantic Salmon Commission. "Atlantic Salmon Conservation Plan for Seven Maine Rivers." Available at http://www.state.me.us/asa/ascp.html.

3. This proposal was later formally withdrawn by the U.S. Fish and Wildlife Service but listing was subsequently again proposed in a *Federal Register* notice. *Federal Register.* 60 (29 September 1995): 50532.

4. Boersma, P. D., P. Kareiva, W. F. Fagan, and J. Alan Clark. In review. "Explicit Science and Non-federal Participants Improve the Effectiveness of Endangered Species Recovery Plans."

5. The samples were drawn to produce a reasonable number of plans in key groupings, as defined by taxon, year of plan completion, single species versus multi-species plan, and original versus revised plan. The sample included one hundred single species plans, twenty-nine multi-species plans and six ecosystem plans. Sample plans were dated from 1977 onward and included 104 terrestrial and seventy-seven aquatic species (eighty-five of them plant species, ninety-six animal species), providing a sample of nearly 20% of all listed species for which recovery plans were written as of 1998.

6. At the time of this writing, these manuscripts were in the review process for publication. To adequately acknowledge their authors' work in the face of a review process that will extend beyond our own submission date, we have chosen to cite these manuscripts as "in review." Given the nature of the review process, it is possible that some of these manuscripts will not be accepted for eventual publication or may appear with modified titles.

7. Lawler, J., S. Campbell, A. D. Guerry, M. B. Kolozsvary, R. J. O'Connor, and L. C. N. Seward. In review. "The Influence of Conservation Threat on the Structure of Recovery Plans."

8. Moyle, L. C., J. R. Stinchcombe, B. R. Hudgens, and W. F. Morris. In review. "The Influence of Genetic and Demographic Data in the Recovery Planning Process and the Perception of and Response to Genetics as a Threat."

9. Gerber, L. R., and L. T. Hatch. In review. "Are we Recovering? An Evaluation of Recovery Criteria Under the U.S. Endangered Species Act."

10. Schultz, C. B., and L. R. Gerber. In review. "Are Endangered Species Act Recovery Plans on the Road to Recovery?"

11. Campbell, S. A. Clark, L. Crampton, A. D. Guerry, L. Hatch, P. Hosseini, M. B. Kolozsvary, J. Lawler, R. J. O'Connor, and L. Seward. In review. "The Role of Monitoring in Recovery Plans."

12. U.S. Fish and Wildlife Service. "1999 Biological Status Review for Atlantic Salmon." Available at http://news.fws.gov/salmon/asalmon.html.

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15. Lundquist, C. J., J. M. Diehl, E. Harvey, and L. W. Botsford. In review. "Factors Affecting Implementation of Recovery Plans."

16. Maine Atlantic Salmon Commission. "Atlantic Salmon Conservation Plan for Seven Maine Rivers: 1999 Annual Progress Report." Available at http://www.state.me.us/asa/99AnnRpt.html.

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20. Crouse, D. T., L. B. Crowder, and H. Caswell. "A Stage-based Population Model for Loggerhead Sea Turtles and Implications for Conservation." *Ecology.* 68 (1987): 1412-23.

21. Ruckelshaus, M, C. Hartway, and P. Kareiva. "Assessing the Data Requirements of Spatially Explicit Dispersal Models." *Conservation Biology.* 11 (1997): 1298-1306.

22. Morris, W. F., P. L. Bloch, B. R. Hudgens, L. C. Moyle, and J. R. Stinchcombe. In review. "The Use of Population Viability Analysis in Endangered Species Recovery Planning: Past Trends and Recommendations for Future Improvement."

23. HSI models determine, often from expert opinion, what features of habitat are correlated with an organism's presence or abundance, and assume that measuring these features thereafter indexes this abundance.

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25. Walters, C. J., and R. Hilborn. "Ecological Optimization and Adaptive Management." *Annual Review of Ecology and Systematics.* 9 (1978): 157-88.

26. Harvey, E., J. M. Hoekstra, R. J. O'Connor, and W. F. Fagan. In review. "Recovery Plan Revisions: Progress or Due Process?"

27. Gerber, L. R., and C. B. Schultz. In review. "Does Who Matter? Authorship and the Use of Science in Endangered Species Act Recovery Plans."

28. Hatch, L., M. Uriarte, D. Fink, L. Aldrich-Wolfe, R. G. Allen, C. Webb, K. Zamudio, and A. Power. In review. "Jurisdiction Over Endangered Species' Habitat: The impacts of People and Property on Recovery Planning."

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34. In matters relating to each listed species, the Fish and Wildlife Service routinely designates an individual as its lead, but both staff turnover and responsibility for multiple species mean that these positions more often provide liaison than active coordination.

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