USING SCIENCE IN HABITAT CONSERVATION PLANS

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EXECUTIVE SUMMARY

The Endangered Species Act of 1973 (ESA) was established to save species at risk of extinction and to protect the ecosystems upon which they depend. Toward that aim, the ESA makes it unlawful for any person to “take” a listed species. In 1982, the ESA was amended to authorize incidental taking of endangered species by private landowners and other non-federal entities, provided they develop habitat conservation plans (HCPs) that minimize and mitigate the taking. Since 1982, HCPs have rapidly proliferated, leading in turn to widespread concern among conservationists that these plans are not being prepared with adequate scientific guidance. Critics have argued that scientific principles must be better incorporated into the process of developing HCPs. In response to these criticisms, we reviewed a set of approved habitat conservation plans to evaluate the extent to which scientific data and methods were used in developing and justifying them. The review was conducted through a nationwide graduate seminar involving eight major research universities, 106 students, and 13 faculty advisors. Our analyses focused on the extent to which plans could be substantiated by science. Thus, even if based on the best available data (the legal requirement), a legally and politically justified plan could be deemed scientifically inadequate because, by more stringent scientific standards, the data were insufficient to support the actions outlined in the plan.

A Systematic Effort to Collect Quantitative Data on Science in HCPs

This investigation proceeded along two lines. First, individuals gathered data on 208 HCPs that had been approved by August 1997 in order to obtain basic descriptive information about plans. Second, the group conducted a more comprehensive analysis for a focal subset (43) of these plans. The HCPs in the focal subset range widely in geographic location, size, duration, methods, and approval dates. For this in-depth investigation, we developed two separate data questionnaires: one asked for information on the plans themselves, and the other focused on listed species and their treatment within HCPs. These questionnaires included information about what scientific data were available for use in formulating the HCP, how existing data were used, and the rigor of analysis used in each stage of the HCP process. As a whole, the questions were designed to generate a detailed profile of each HCP and to document the use (or lack thereof) of scientific data and tools. Plans were not judged overall; rather, questionnaires focused on different stages of the planning process, including the HCP’s assessment of (1) the *status* of the species; (2) the “*take*” of species under the HCP; (3) the *impact* of the take on the species; (4) the *mitigation* for the anticipated take; and (5) the biological *monitoring* associated with the HCP. All of the data sheets, plan descriptions, and other detailed results from this effort are available on the NCEAS website: **http://www.nceas.ucsb.edu/projects/hcp/**

Results

From our data on 208 HCPs, we were able to outline an overall picture of HCPs across the landscape. These 208 HCPs involve permits for incidental take of 73 endangered or threatened species. Of those 208, a great majority (82%) involve a single species, although the profile is skewed by more than 70 plans involving the golden-cheeked warbler (*Dendroica chrysoparia*) in Travis County, Texas. HCPs occur in 13 states; the largest concentrations are in Texas, Florida, and California. They range in size from only 0.17 ha (0.5 acre) of habitat to 660,000 ha (1.6 million acres) of habitat. The duration of plans also varies widely, from seven months for a plan in Travis County, Texas, to 100 years for the Murray Pacific Company’s HCP

in Washington. HCPs do not appear to be getting larger, smaller, longer, or shorter over time.

In our more comprehensive examination of the focal HCPs, we direct much attention to what we call scientific adequacy. It is important to note that an HCP would be labeled scientifically inadequate if insufficient data were available to justify an action formally, even though legally the plan might be defensible. HCPs and many other provisions of the Endangered Species Act require only that decisions be based on the best available data. Scientifically, however, to support a claim we require data that when analyzed give some statistical confidence of an assertion, and that confidence is often lacking in applications of science to conservation biology because of a paucity of data. For example, from a scientific perspective, the best data might suggest a particular relationship between loss of habitat and loss of individuals, but the data are so variable and scarce that one could never have scientific confidence in the presumed relationship. Our aim is not to change the law but to point out just how much science is being used, and can be used given the availability of data pertinent to HCP development. The conclusions we draw probably apply to many other facets of federal decisions regarding species listed as endangered or threatened.

Status/Take/Impact

Because they involve take of endangered species, HCPs must include information about the ***status*** of populations and habitats of the species, an assessment of how many individuals and how much habitat will be ***taken*** under the plan, and what ***impact*** that take will have on the species overall. We found that, for most species (74%), population sizes were known to be declining globally before the HCP was submitted; 21% were stable, and 5% were increasing. The most important threat to species was habitat loss, although habitat degradation or fragmentation and direct human-caused mortality also represented important threats. Notably, for only 56% of the instances in which a listed species might be "taken" by an activity was the predicted take quantitatively estimated. And only 25% (23 of 97) of species treatments included both a quantitative estimate of take and an adequate assessment of the impact of that take.

Mitigation

A crucial measure for the success of HCPs is the choice and implementation of measures to avoid, minimize, and mitigate impacts on the species included in the permit. If the appropriate measures are chosen and implemented in a timely fashion, the impact on the species in question might be effectively mitigated, justifying the issuance of an incidental take permit. For this analysis, we chose to evaluate avoidance, minimization, and mitigation measures as overall "mitigation," because they all involve offsetting potential impacts to species. Minimization and avoidance of the threatened species are by far the most common mitigation measures (avoidance is proposed for 74% of species, and minimization for 83%). Our analyses identify some important gaps in quality of data underlying mitigation proposed in HCPs. Overall, particular mitigation measures commonly suffered from an absence of data indicating they were likely to succeed, leading to a situation in which "unproven" mitigation measures were relied on in the HCPs. Given this uncertainty, one would expect that a mitigation measure should be evaluated prior to the onset of take. Unfortunately, such a precautionary approach was often lacking.

Monitoring

We determined whether biological monitoring (i.e., "effectiveness monitoring" or monitoring of trends in the populations that are potentially affected) was included for the HCPs in our sample. In this analysis, we looked at each plan as a sampling unit (n = 43), and we only considered information included in the plan or associated documents. For only 22 of the 43 plans was there a clearly outlined monitoring program. Of those 22 well-described monitoring programs, only 7 took the next step of indicating how the monitoring could be used to evaluate the HCP's success. Interestingly, although most plans do not include provisions for “adaptive management," when plans do include such provisions they are significantly more likely to include clear monitoring plans as well.

Availability and Use of Information Needed for Scientifically Based HCPs

In many cases, we found that crucial, yet basic, information on species is unavailable for the preparers of HCPs. By crucial, we mean information necessary to make determinations about status of the species, the estimated take under the HCP, and the impact of that take on the species. For example, in only one-third of the species assessments was there enough information to evaluate what proportion of the population would be affected by a proposed “take.” If we do not know whether one-half or one-hundredth of a species' total population is being affected by an action, it is hard to make scientifically justified decisions.

We assessed the overall adequacy of scientific analysis at each stage of the HCP process. Although this evaluation of scientific adequacy amounted to a largely qualitative assessment, the foundations of that assessment were well specified by series of background questions; “overall adequacy” was consistently well predicted by data obtained for these background questions. In general, the earlier stages in HCP planning are the best documented and best analyzed. In particular, species status is often well known and adequately analyzed, whereas the progressive analyses needed to assess take, impact, mitigation and monitoring are more poorly done or lacking. Our evaluations also indicate that the very large and the very small HCPs contain the poorest analysis. In terms of plan duration, it appears that shorter-duration plans have better estimates of the amount of take, but longer-duration plans have better analysis of the status of the species and the mitigation measures imposed.

Conclusions and Recommendations

Although our analysis points to several shortcomings of HCPs, we acknowledge that the HCP process is new, complex, and difficult. In general, the USFWS and NMFS are doing a good job with the data that are available. They do not have the resources to obtain the data that are needed for many of the decisions that must be made. Without such resources, the best scientific approach is to be more cautious in making decisions and to use the findings of this report to justify requests for additional resources.

Recommendations

1. We recommend that greater attention be given to explicit scientific standards for HCPs, but that this be done in a flexible manner that recognizes that all HCPs need not adhere to the same standards as high impact HCPs. A formalized scheme might be adopted so that small HCPs draw on data analyses from large HCPs, assuring that applicants are not paralyzed by unrealistic demands.

2. For the preparation of individual HCPs, we recommend that those with potentially large

impact (those that are large in area or cover a large portion of a species' range) include an explicit summary of available data on covered species, including their distribution, abundance, population trend, ecological requirements, and causes of endangerment. HCPs should be more quantitative in stating their biological goals and in predicting their likely impact on species. When information important to the design of the HCP does not exist, it may still be possible to estimate the uncertainties associated with the impact, mitigation, and monitoring, and to still go forward, as long as risks are acknowledged and minimized. Flexibility can be built into mitigation plans so that managers can be responsive to the results of the monitoring during the period of the HCP. When highly critical information is missing, the agencies should be willing to withhold permits until that information is obtained.

3. For the HCP process in general, we recommend that information about listed species be maintained in accessible, centralized locations, and that monitoring data be made accessible to others. During the early stages of the design of potentially high-impact HCPs and those that are likely to lack important information, we recommend the establishment of a scientific advisory committee and increased use of independent peer review (review by scientists specializing in conservation biology). This policy should prevent premature agreements with development interests that ignore critical science.

1. INTRODUCTION

1.1. The Endangered Species Act in Relation to this Study

The Endangered Species Act of 1973 (ESA) was established to save species at risk of extinction and to protect the ecosystems upon which they depend. Toward that aim, the ESA makes it unlawful for any person to "take" a listed species. This prohibition encompasses activities that directly kill or harm listed species, as well as activities that cause indirect harm through "significant habitat modification or degradation" (50 CFR §17.3). In 1982, the ESA was amended to authorize incidental taking of endangered species by landowners and nonfederal entities, provided they developed habitat conservation plans (HCPs) that minimize and mitigate the taking, and that receive approval by the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS). Any nonfederal entity, whether a private citizen, corporation, county, or state, can initiate an HCP. Once approved, an HCP results in an incidental take permit. The language of this amendment (Section 10a of the ESA - 16 U.S.C. §1539(a)) arose directly out of a model HCP designed to resolve a conflict between a development project and the needs of endangered species in the San Bruno Mountain area near San Francisco. Few landowners chose to undertake HCPs until the early 1990s. The USFWS approved only 14 HCPs from 1983 to 1992 (USFWS and NMFS, 1996), but since 1992 there has been an explosion of HCPs—225 were approved by September 1997, and approximately 200 are currently being formulated. Indeed, HCPs have become one of the most prominent mechanisms employed by the USFWS to address the problem of threatened and endangered species on private lands (Bean et al., 1991; Noss et al., 1997; Hood, 1998).

The rapid proliferation of HCPs has led to widespread concern among conservation advocates about the scientific information in these documents. From a policy perspective, critics charge (1) that HCPs may undermine species recovery because they can allow for impacts to species that are not fully offset, (2) that HCPs are developed without adequate biological information or scientific review, (3) that small-scale HCPs can lead to piecemeal habitat destruction and fragmentation, and (4) that meaningful public participation occurs infrequently (Hosack et al., 1997; Kaiser, 1997; Kostyack, 1997; Murphy et al., 1997; National Audubon Society, 1997; O'Connell and Johnson, 1997). Our objectives in this study were to conduct a major review of HCPs and to evaluate in detail the scientific merit of a substantial sample of HCPs currently in effect. We did not attempt to evaluate the biological success of HCPs or their attempt to balance economics with biology. That exercise would have been premature given the newness of most HCPs. Our emphasis is on scientific data and approach, whether they are adequate, and if not, what should be done. To strengthen the role of science in this process, we start with the premise that regardless of the compromises that may be made between economics and environmental concerns, HCPs should have clear scientific objectives, be based on the best available data, and employ well-tested procedures. It is important to emphasize that we scrutinized HCPs and their use of data and inference from a strictly scientific (as opposed to legal) perspective. We sought to determine whether a presumed impact, a proposed mitigation measure, and so forth could be scientifically substantiated given the data available. We adopted this strictly scientific stance because one of the outcomes of our analysis is a series of recommendations for improving the quality of scientific input; arriving at these recommendations required that we keep a clear vision of the highest possible scientific standards for HCP implementation. Although the focus of this report is science, it is useful to keep in mind more legal definitions of key terms such as "take," "compliance monitoring," "effects and effectiveness monitoring," etc. In Table 1 we define key legal terms and emphasize how our more biological use of language differs from some of these legal definitions.

1.2. HCP Requirements

Applicants proposing HCPs must specify the impact that will result from the incidental take of listed species, what the plan does to minimize and mitigate the impact, and what alternatives were considered (Table 2). NMFS is responsible for ultimately approving or rejecting the HCP (issuing the “incidental take permit”) for marine and anadromous species, and USFWS is responsible for the remainder of listed species. The applicant may develop an HCP independently, but USFWS often works with the landowner in the plan’s early stages, providing guidance as to what is or is not acceptable with respect to approval requirements. Typically, impact on species is minimized by limiting the geographic extent of harmful activities or the seasons when those activities are allowed (e.g., prohibiting timber harvest during the nesting season of an endangered bird). Mitigation often involves setting aside (through purchase or conservation easements) habitat elsewhere. USFWS or NMFS can only issue an incidental take permit if the HCP meets five criteria (Table 2). Incidental take permits are only issued for species listed as threatened or endangered, although for any unlisted species that is treated in the HCP as if it were listed, the landowner is assured of receiving a permit for that species when it becomes listed.

No set of particular actions must be specified in an HCP for it to gain approval, and overall the process is quite flexible. There is, however, standardized guidance in the form of the Habitat Conservation Planning Handbook distributed by NMFS and USFWS (USFWS and NMFS, 1996). The handbook gives general advice on all aspects of HCPs. It also suggests expediting small-scale HCPs, while indicating directions in which USFWS and NMFS wish to direct future HCPs, including habitat-based, multi-species planning and large-scale, multi-landowner plans. In addition, USFWS conducts training workshops across the country for employees who help applicants develop and implement HCPs.

1.3. The Impetus and Aims of This Study

HCPs are not purely scientific documents—they are compromises between the interests of resource development and conservation, and political and economic concerns play a major role. Some HCPs represent the outcome of negotiations that take years. HCPs have economic, political, and scientific dimensions. Because HCPs represent negotiated compromises, it is essential to know what exactly is “given up” in the process of arriving at a compromise. It is easy to identify what is given up from the viewpoint of a private landowner, because the dollar value of future land development or exploitation is readily calculable. It is much harder to quantify what is given up in terms of a species’ prospects for long-term survival. That is the challenge for the scientific component of HCPs.

To examine the scientific component of HCPs, we decided to use a highly structured, detail-driven approach to collecting information on HCPs. To date, criticisms and recommendations about HCPs have emphasized broad policy implications and have sketched general qualitative attributes of particular HCPs (Hood, 1998; Noss et al., 1998). We sought to develop a quantitative data base that sampled a “population of HCPs," so that our analysis would be relevant to HCPs in general, and not only to particular HCPs. This highly structured quantitative analysis complements the more flexible analyses previously published and, by uncovering broad trends within a substantial data base, will set the stage for further analyses.

To examine the role of science in HCPs, the National Center for Ecological Analysis and Synthesis (NCEAS) and the American Institute of Biological Sciences (AIBS) initiated a one-year project to analyze HCPs. A set of graduate seminars at eight universities (Florida State University; North Carolina State University; University of California, Berkeley; University of California, Santa Barbara; University of California, Santa Cruz; University of Virginia; University of Washington; and Yale University) were coordinated during the fall of 1997. These seminars comprised a total working group of 119 researchers, including 106 students and 13 faculty members. The group was charged with reviewing current plans to evaluate the extent to which scientific data and methods were used in developing and justifying the agreements. The group was also charged with recommending ways to strengthen the role of science in conservation planning**.** The group did *not* attempt to evaluate what effects the plans have had on biological systems or species. Because the vast majority of HCPs have been initiated since 1994, it is simply too early to evaluate whether the plans are working. Moreover, our goal was not a vague judgment of the overall quality of each plan or of the plans as a whole. Instead, the group focused on the scientific data and reasoning supporting the plans, paying particular attention to the key issues of take, impact, mitigation, and monitoring. All of the data sheets, plan descriptions, and other detailed results from this effort are available on the NCEAS website: **http://www.nceas.ucsb.edu/projects/hcp/**

This paper is both our synthesis of the data available at this website, and a reader's guide to the website. The scale of the data set is large—89,908 entries were recorded for HCPs (7,246 for the set of 208 plans, 75,094 for species questions pertaining to the 43 focal plans, and 7,568 for plan questions pertaining to the 43 focal plans). Throughout the paper, when discussing data we use the following key: AQ refers to questions applied to all 208 plans, SQ refers to species questions applied to the 43 focal plans, and PQ refers to plan questions applied to the 43 focal plans. The actual questions can be found in Appendix I.

2. METHODS AND RATIONALE FOR DATA COLLECTION AND ANALYSIS

2.1. Obtaining a Sample of HCPs for Descriptive Statistics

As part of our effort, we sought to characterize the largest possible sample of plans in terms of their most basic attributes. Data we attempted to identify for these plans included plan duration and area, basic species information included in the plans, and other factual descriptors of the agreements. Unfortunately, there is no centralized office or collection of HCPs. We therefore took advantage of the joint effort of the two nonprofit organizations, the National Wildlife Federation (NWF) and the Earth Justice Legal Defense Fund (EJLDF), to assemble HCPs in Washington, DC. As of November 1997, they had compiled 208 of the 225 HCPs completed at that time. The questionnaire applied to this sample of HCPs is given as Appendix I-C.

2.2. Detailed Data Collection for 43 Focal Plans

The time and energy required for careful evaluation of both an HCP and the relevant background information precluded a detailed investigation of all plans. We therefore selected 43 focal plans (21% of the all plans available at the time the project began) for detailed analysis. Plans were chosen non-randomly, to span the range of geography, size, duration, methods, and approval dates represented in the entire population of HCPs (Appendix II-B lists these 43 plans).

For the focal plans we performed three types of data collection. The first was accumulating evidence demonstrating the presence or absence of several types of scientific information. For this segment of our analysis, we chose *a priori* to define an "HCP package" as including the HCP itself, the incidental take permit (ITP), implementing agreement (IA), biological opinion, and any associated environmental review documents (EA/EIR/EIS). These documents were consulted for all focal plans for which they were available (some HCPs might lack some of these documents). Information contained in these and any other explicitly referenced documents was considered to be included in the plan. Second, we gathered general data about the HCP setting and the species covered by the associated incidental take permit. Many of these data were found in the documents listed above, but to augment them, corroborate conclusions made in the HCP documents, and provide a comparison to existing scientific knowledge, we completed surveys of relevant literature (which included both articles published in journals and the so-called "gray literature," represented by reports prepared by government agencies and consulting firms). In gathering this information, we considered all reports and publications available at least one year before the date of the HCP's approval as having been available for the HCP preparers. For 32 of the focal plans, we collected species-specific data for all species covered on the incidental take permit. For the other 11, we chose a taxonomically representative subset of the species covered. Finally, we gathered information about the local context and characteristics of the HCPs that included data about plan developers/preparers and the policy or social contexts in which plans were developed. Often, this profile was developed from both anecdotal and formal discussions with USFWS employees, consultants who worked on the development phase, and various stakeholders.

Our goal in analyzing these focal plans was not judgment of the overall quality of each plan, or plans as a whole, but rather a rigorous analysis of a variety of detailed questions about HCPs: What types of data or analysis do HCPs use well? What available information is ignored? Are data unavailable that are crucial to sound planning? Of the many steps in the planning for each species covered in an HCP, which are usually done well and which poorly? Which of the many features of a plan (size, duration, etc.) and of the plan's preparation (who prepared it, was there a scientific advisory committee?) are important in influencing its scientific adequacy? Answering these questions requires "dissecting" each plan—gathering information on its many factors and parts, so that statistical analysis can be used to judge what factors significantly influence the scientific quality of HCPs as a whole and to allow a clear assessment of the adequacy of existing HCPs. To ensure consistency of information gathering across groups, and to put the resulting data into an organized and analyzable form, we developed two separate data questionnaires; one asked for information on the plans themselves, whereas the other focused on species listed in the incidental take permit and the treatment in HCPs of these species (see website). In total, the Plan questionnaire contained 176 questions/subquestions per plan studied, and the Species questionnaire contained 789 questions/subquestions per species per plan (these complete questionnaires are given as Appendices I-A and I-B).

The questions asked in the two questionnaires fall into three categories:

- For both plans and species, many questions seek to detail simple (although not always simple to acquire) factual information about the HCPs, the species, and the preparation process.

Essentially all plan questions are of this type.

- For species, a large number of questions address the details of what scientific data and analyses were used in formulating different steps in the planning process. Most involved a set of four parallel questions, which for a broad array of data categories asked (1) whether information of this type was used in the HCP, (2) the source of the data, (3) the quality of the use of this type of data, and (4) whether any important data of this type were missing from the HCP. In addition, there are questions about the importance of these types of data for application to the species and situation at hand. Together these questions seek to determine what data were used in formulating the HCP, the quality of their use, and their relative importance.

- Finally, both for detailed types of biological information and for larger steps in the HCP analysis process, the species questionnaire asked for judgments of the quality of the analysis.

Because the data included in the plan and species questionnaires form the basis of our results, it is important to describe the approach we took in designing and then analyzing these queries. As a whole, the questions were designed to generate a detailed profile of each HCP, to document the use (or lack thereof) of many different types of scientific tools and data, and to characterize the availability of these tools and data. The questions evolved over the first weeks of the project, as online discussion led to the creation of new questions, the deletion or modification of existing questions, and official "consensus interpretation" of ambiguous questions. We do not presume that these questionnaires are comprehensive, but they were certainly sufficient to generate a large body of data on our 43 sampled HCPs, covering the full spectrum of HCP ingredients.

Three lines of reasoning led us to the final set of questions in each questionnaire. First, we did not feel that it was either scientifically justifiable or most productive to judge the adequacy of entire plans, so we sought to confine our "quality judgments" to much smaller segments of analysis. This approach should better reveal the strengths and weaknesses of HCPs and suggest improvements in the HCP process. Second, the battery of questions is large, both to minimize the danger of missed information and to leave open the door to unexpected findings or issues. Third, because it is difficult to make scientifically defensible judgments about the quality or adequacy of even small pieces of a plan, each question regarding adequacy follows an extensive series of questions about the details of the information and analysis that were used in the plan, that were left out, and that would be needed to improve the analysis. Our goal was to lead ourselves (and others reviewing our results) through a clearly articulated set of steps that would clarify our judgments about importance and adequacy of different types of information. It was impossible to write out a rigid and explicit definition of "adequate" or a ranking score for each question, because we were flexible in our scoring. For example, if an HCP involved only a small amount of land and minimal take, we would score a rather crude assessment of "impact" as adequate simply because it was obvious there was no need to be especially careful for such a negligible activity. In other words, as professional biologists, we asked what level of scientific proof was required for different activities, depending on those activities and their context. All scorings and evaluations were presented to the local university seminar group and thus were subject to internal peer review by up to 20 other biologists. This review was an important part of the process. The graduate students involved included many with masters degrees (about one-third), some with extensive work experience in environmental consulting or as employees of USFWS, and some who had actually helped write HCPs. The biological, statistical, and practical experience of this large cohort of graduate students compares favorably with those employees of USFWS who actually administer the HCP process.

In sum, our approach of using detailed questionnaires to evaluate HCPs was designed (1) to include unexpected but important information, (2) to allow the dissection of plans so that clear judgments could be made about their merits and faults, and (3) to make transparent the reasons for our judgments of quality. Although inevitably imperfect, our approach allows us to develop a detailed analysis of the limitations and the strengths of HCPs. In particular, it takes the analysis of HCPs away from the realm of unsubstantiated expert opinion and into an empirically based arena where arguments over methods and conclusions can be articulated, debated, and revisited.

2.3. A Framework for Judging the Biological Adequacy of HCPs

To be scientifically credible, HCPs must address a variety of issues for each species covered. Although in theory our data set allows us to address the scientific credibility of HCPs in their entirety, it is more informative to clarify the particular stages in habitat conservation planning where scientific knowledge or analysis may limit the scientific foundation of HCPs. How should the integrated process of HCP planning be dissected, however? Although there is no set of hard-and-fast rules or steps to which all HCPs must conform, the USFWS/NMFS HCP handbook mandates several issues that each HCP must address for species covered in the incidental take permit (USFWS and NMFS, 1996). Our review of HCPs, in combination with these mandated steps, led us to divide the HCP planning and analysis process into five stages:

- Analysis of current *status* of the species
- Analysis of *take* under the planned activities
- Analysis of the biological *impact* of the anticipated take.
- Analysis and planning of *mitigation* for the anticipated take.
- Analysis and planning of *monitoring* activities to follow the future status of the species, the actual take, and the effectiveness of mitigation procedures.

It is important to emphasize that failure to address any one of these stages adequately calls into question the adequacy of planning for a species, even if all other stages are addressed extremely well. For example, an HCP might have excellent data on the current status of a species, have excellent estimates of take and the impact of take on population health, and have a good monitoring plan, but if the proposed mitigation procedures are untested and there are no plans to allow for their review and modification, the plan is not scientifically credible. Similarly, a seemingly reasonable plan can be formulated that has good estimates of everything but the actual effect of the planned take on the population viability of the species. In this case, again, the entire plan is questionable, because there may be no good way to judge the real impact of the planned activities and hence the adequacy of planned mitigation work. These examples illustrate both that the division of plans into five stages is somewhat artificial and that each of these steps must somehow be addressed in an HCP for the whole plan to be a scientifically credible blueprint for balancing potentially damaging actions with potentially beneficial ones.

2.4. Units of Analysis

For the questions we address, two units of analysis are logical: (i) the individual HCP and (ii) the treatment of an individual species within an HCP. Plans are the basic unit in which

HCPs are approved and implemented, and many of the steps or issues in the HCP process are inextricably part of an entire plan's formulation, but species protection is the goal and mandate of the ESA and of the individual plans. Similarly, although plans with many species will be over-represented in a strictly species-by-species analysis, this is to some extent as it should be. We therefore use a combination of approaches; some analyses are done at the plan level and some at the species level. When performing most significance tests for species-level analyses, we either include plan as a factor in the analysis or use a weighting factor that discounts the effect of a species by the number of analyzed species from that plan (1/(number of species in the plan included in our analysis)). One factor we do not consider in most of our analyses is the occurrence of the same species in multiple plans; because each plan analyzes different impacts in different places, it seems correct to count each plan-species combination as a separate data point. We also minimized the bias that could arise from making judgments on the basis of a large number of "minor species," when a plan was actually written primarily for just one or two major species. It would be unfair to call the scientific foundation of such a plan weak because it failed to deal with the minor species but did a superb job with the major species. We deal with this possible bias in two ways: (1) by choosing as a subsample only a few species (and always only listed species) from plans with long lists of species to be covered by the Incidental Take Permit and (2) by rating a plan's overall adequacy with respect to monitoring and so forth primarily on the basis of how well it applied to the main species. For example the Washington Plum Creek plan covers four listed species (grizzly bears, gray wolves, marbled murrelets, and northern spotted owls) and 281 non-listed species (some of which were candidate species and may be listed in the future). For this plan, we examined only the four listed species, and, because this plan was really tailored to northern spotted owls, we used the plan's performance with respect to spotted owls as the major issue to be evaluated.

3. CHECKS ON DATA REPRESENTATION AND ACCURACY OF ANALYSIS

With 89,908 entries in our data base and analyses conducted by several different individuals and universities, there was obviously an opportunity for errors to creep into our data. To offset this problem, we enlisted the cooperation of the USFWS and sent them a preliminary draft of the manuscript, the questionnaires, and all of the data. The USFWS then coordinated a review of all of these materials. Importantly, the data were sent to the USFWS regions that had originally approved the HCPs of concern. After a heroic review process, the USFWS suggested changes for 4367 data entries. We made 4328, or 99.1%, of their requested changes. It is important to note the tremendous effort USFWS put into examining our data base, and also to acknowledge that USFWS in no way endorses or takes responsibility for our data or our interpretations of the data. We simply point out that the raw data themselves were reviewed internally by our own research group and externally by USFWS. There still certainly remain errors, but we doubt that the analyses we report would be substantially altered by the errors in the data. For example, observation errors for field counts of animals are often on the order of 10-40%, a magnitude of error we are confident we were well below. All analyses, with one exception, are performed on the corrected data, and the data on the website represent the corrected data. The one exception is our analyses of "school bias," in which we asked whether groups from the participating universities answered questions differently. For that analysis, we used the "uncorrected data," because error rate is one way in which the groups might differ.

For many of the analyses presented below, we use one of the two questions that summarize the adequacy of each of the five stages of the HCP process (see above). To assess whether they are valid measures of scientific adequacy, we regressed the graded-scale (1-6) measures of adequacy (see Appendix I-B) for each section on seven aggregate variables indicating the knowledge about, and analysis of, various categories of biological information about each species (see website and Appendix I). We used both one-way regressions using just one set of biologically distinct answers to detailed questions (e.g., data on changes in numbers or demography) and multiple regressions using combinations of variables. These multiple regressions usually had much lower sample sizes than did the simpler analyses, due to many combinations of missing values. All analyses were performed on normalized variables. For each of the five stages, some types of information or types of question (e.g., the presence of data versus the type of analysis of the data) had little effect on quality rating, whereas others were extremely good predictors. For each stage, the R^2 values for the single best regression are Status, 0.66; Take, 0.92; Impact, 0.59; Mitigation, 1.0; Monitoring (performed separately for monitoring of take, status, and mitigation), 0.92, 0.91, 0.92. Overall, the results from these analyses show that the summary rankings are well predicted by the details of data and analysis used at each step of the HCP process (see Tables 3 and 4, and Appendix III).

Because of the time and effort needed to find, read, and synthesize the full background data for each of the 43 focal HCPs, each plan was analyzed in depth by only one university. Because the participants at different universities differed in background, and because of the unique cultural differences among our groups (e.g., Yale versus U.C. Berkeley versus N.C. State University), we were concerned to test that the identity of the evaluating university did not substantially influence plan evaluation. Two problems could arise from such differences. One of these is loss of power to detect real differences and effects in the plans due to added noise. The second and more serious problem is systematic biases in the patterns we see among plans. Furthermore, as noted above, we are often interested in analyzing for species-level effects and must therefore account for the correlation in species answers due to plan-level effects.

To check for university biases, we fit a set of mixed linear models to species-level data using SAS PROC MIXED, which allowed us to assess the effects of institution on the adequacy ratings in five major areas (Status, SQ:B43; Take, SQ:C33; Impact, SQ:D47; Mitigation, SQ:E49; and Monitoring, SQ:F80). We used these models to determine whether universities differed with respect to ratings and whether these differences affected the statistical significance of the relationship of the five adequacy ratings to the factors Date, Duration, Multiple Species (yes/no), Taxon, and Area. In the model, university and plan were considered random factors, and Date, Duration, Multiple Species, Taxon, and Area were considered fixed factors (Date, PQ:181; Duration, PQ:178, Plan Species Number (from PQ:11, coded for three levels), Taxon SQ:A3; Area, PQ:182; Existence of Recovery Plan, SQ:A8). The results showed that only for Mitigation effects was the school to school variation a sizeable portion of the residual variation (Table 5). In sum, these tests for university biases suggest that there are generally not strong or consistent differences in the ratings of different universities—certainly nothing of a magnitude that is likely to influence our results or conclusions.

4. A DESCRIPTIVE OVERVIEW OF HCPs

Before beginning our analysis of how science is used in HCPs, we report the general characteristics and diversity of the HCPs in our sample of 208. In particular, we summarize descriptive data about where HCPs were implemented, who developed them, why they were developed, how large an area they address, how long they last, what species they address, and what approaches to habitat conservation planning are used. Second, we describe these same characteristics for our intensively studied sample of 43 focal HCPs and compare them to the larger set of 208 plans.

4.1. Attributes of Sample of 208 HCPs

More than 70 of the sample of 208 HCPs were coordinated and approved within the Balcones Canyonlands Conservation Planning area in Texas. Because these plans are very similar to one another and may bias general patterns of HCP characteristics, we report two results whenever appropriate: one based on data for all 208 plans and one excluding data for the Balcones Canyonlands plans.

Any nonfederal entity can develop an HCP in support of an incidental take permit application. Most HCPs (82%) were submitted by single private landowners (either corporations or individuals). Just 3% of HCPs were submitted by state and local governments. Fourteen percent were developed for lands under multiple jurisdictions (these could be public, private, or both); an example of a multiple-jurisdiction plan is the Orange County NCCP (see website plan narratives). If the Balcones Canyonlands plans, which were developed for numerous private landowners, are excluded, these proportions change to 72% private, 5% public, and 22% multiple jurisdiction. The areas covered by HCPs can differ dramatically—on an “area basis," the figures are 14% private, 18% public, and 67% multiple jurisdiction.

HCPs are developed because some action is expected to take threatened or endangered species and thus to have impact, which can be either reversible or irreversible. Reversible impacts include those that could be expected to diminish substantially in 100 years or less; examples include the impacts of timber harvest rotations or livestock grazing. Irreversible impacts are those that have a permanent effect on species or their habitats, such as urbanization or land conversion. Fourteen percent of HCPs will result in reversible impacts and 81% in irreversible impacts. Five percent will have both reversible and irreversible impacts. When Balcones Canyonlands plans are excluded, the proportions shift to 23% having reversible impacts, 69% having irreversible impacts, and 8% having both. Data collected for the 43 focal HCPs allowed a more specific characterization of land uses motivating HCPs. Within this smaller dataset, the primary land use changes were specifically defined, e.g. agriculture, logging, urban development. For each plan, various land uses were ranked according to their importance in motivating that plan; a ranking of 1 identified the land use change that was the primary motivation for the HCP (PQ:42-49). Although plans may be motivated by many different changes in land use, 56% of those we examined in depth (24 of 43) were motivated by construction of buildings; logging came in second at 19% (8 of 43).

We analyzed the duration and size distribution for HCPs using the larger data set of 208 plans. Land areas covered are extraordinarily diverse, spanning six orders of magnitude. The smallest approved plan protects the Florida scrub jay (*Aphelocoma coerulescens*) on just 0.17 ha (0.4 acres). The largest plan to date covers over 660,000 ha (over 1.6 million acres) of forest managed by the state of Washington Department of Natural Resources. Nevertheless, most HCPs are relatively small. The median size is less than 10 ha (24 acres), and 74% of HCPs cover fewer than 100 ha (240 acres). If Balcones Canyonlands HCPs are excluded, the median size increases to about 44 ha (110 acres), and 59% of HCPs cover fewer than 100 ha (250acres). For simplicity and comparative purposes, HCPs were categorized as small (0-10 ha), medium (>10-1000 ha), or large (>1000 ha). The largest proportion of all HCPs falls in the small size category (50%). When the Balcones Canyonlands plans are excluded, the largest fraction falls in the medium category (48%). No directional trend over time in the mean size of HCPs is apparent. Regressions with and without Balcones Canyonlands plans of log(area) of HCPs on year of approval yield slopes not significantly different from zero ($P > 0.14$ and $P > 0.07$, respectively). Some recently approved plans are larger than their predecessors, but other recent plans are smaller, suggesting only that the aerial extent of HCPs has diversified with time.

The length of time over which an HCP is to be implemented is correlated with the duration of the ITP for which the plan was developed. Plan durations are diverse, ranging from seven months for a plan in Travis County, Texas, to 100 years for HCPs implemented by the Murray Pacific Company in Washington. Two plans developed for private properties in Texas are to be maintained in perpetuity. Excluding those two plans, the median duration of HCPs is 10 years, and 60% of HCPs will be maintained for 20 or fewer years. Excluding the Balcones Canyonlands plans, the median duration of HCPs increases to 22.5 years. Over time, the durations of approved HCPs have diversified, but they exhibit no significant directional trend. When Balcones Canyonlands plans are excluded from analysis, a regression of plan durations on approval dates suggests that more recent plans may be longer, but the trend is not statistically significant ($P > 0.15$).

Although no HCPs show directional trends in either duration or area, these two characters are positively correlated with one another (Figure 1). A regression of HCP duration on HCP area yielded a positive relationship in which small HCPs tend to have shorter durations and larger plans longer durations ($P < 0.001$). Such a relationship seems reasonable because a larger planning area may necessitate a longer planning horizon.

The 208 HCPs examined cover 73 threatened and endangered animal species: 22 birds, 13 mammals, 19 reptiles and amphibians, 18 invertebrates, and 1 fish (Table 6). Fifteen species of plants are also covered under HCPs, even though the ESA does not mandate such protection on non-federal lands. The number of HCPs that cover various threatened and endangered taxa are presented in Table 6. The majority of HCPs (143) cover one or more bird species. Mammals and covered by 32 HCPs and amphibians and reptiles by 33.

Because HCPs can address conservation of single species, multiple species, or habitats, the assessment of status, take, impact, and mitigation measures vary accordingly. For single-species plans, they are species specific. Multi-species plans are essentially scaled-up versions of single-species plans. Assessments of status, take, and impact are done for each covered species; mitigation measures may address multiple species simultaneously but are still species-specific. Habitat-based plans represent a distinctly different approach. They are based on the premise that, by protecting the ecological integrity of a natural habitat, one also protects the many species within that habitat (USFWS and NMFS, 1996). Such plans de-emphasize species-specific analyses and mitigation measures, focusing instead on more holistic protection and management of the habitat. Most HCPs (84%) are single-species plans. Multi-species plans make up 12% and habitat-based plans only 4%. Excluding the Balcones Canyonlands plans shifts these proportions to 74% single-species plans, 7% multi-species plans, and 19% habitat-based plans. Habitat-based plans have only been developed since 1993, so their prominence among HCPs is likely to change in the future. Certainly there is increasing interest in assessing the quality of large habitat-based plans because of their larger spatial scale and biological breadth.

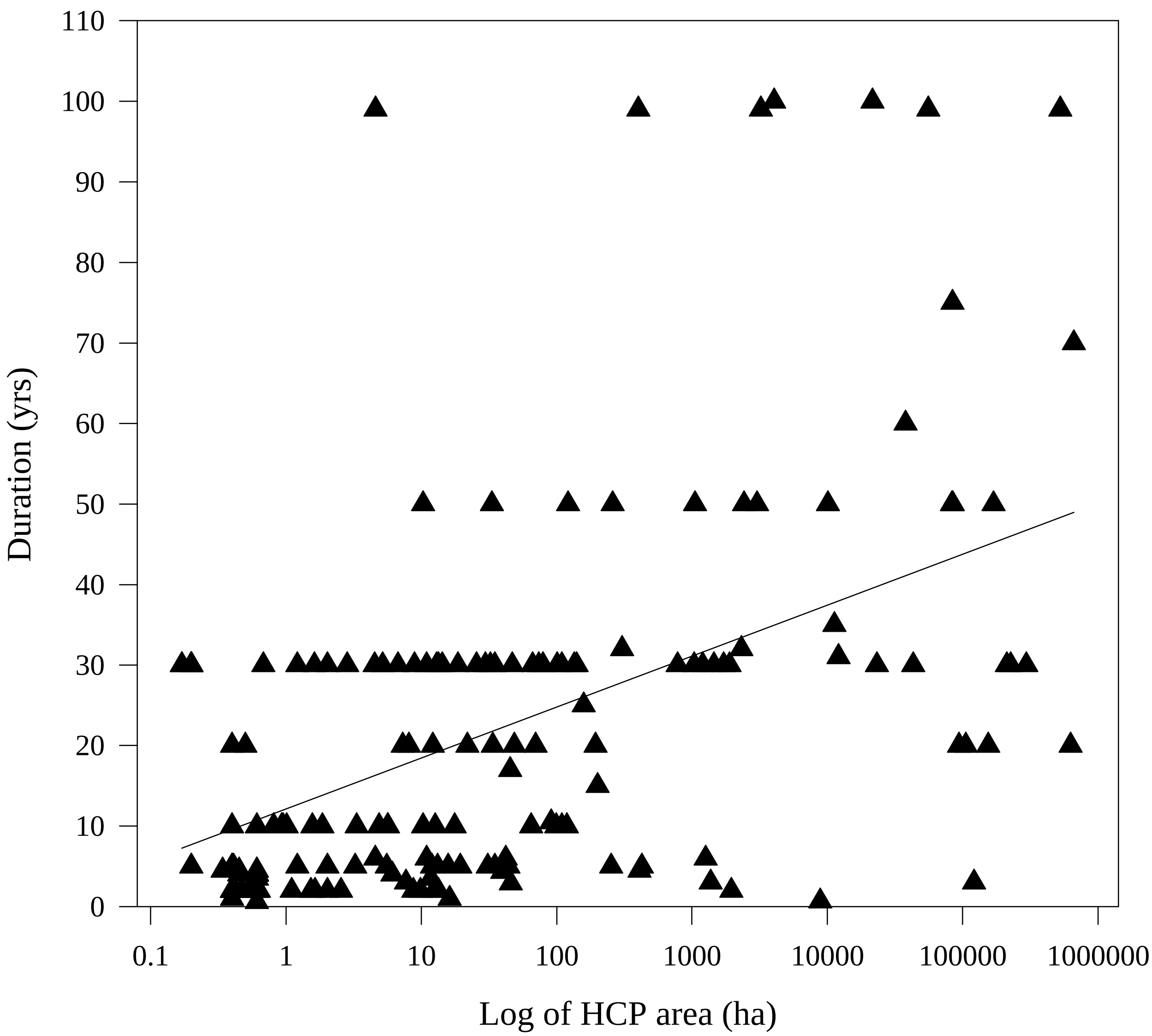

Figure 1. The relation between plan duration (AQ:3) and plan area (AQ:6a). The line shown is the best fit-linear regression, with R^2=0.27 and $p<0.01$. (N=192 HCPs)

4.2. Attributes of 43 Focal Plans

The following subsections compare characteristics of the 43 focal plans with those of the larger HCP population. We assert that the focal plans adequately represent the diversity of HCPs, allowing a general evaluation of how science is used in habitat conservation planning.

Time of Approval

When selecting focal HCPs, we biased our sample toward more recent plans. These presumably reflect current approaches and strategies in HCP development and are therefore more pertinent for the evaluation we have undertaken. Ninety percent of the 43 focal plans were approved after 1992, compared with 89% of the whole population of HCPs (PQ:3).

Applicant Types

To sample a sufficient number of plans developed by state and local governments and by multiple jurisdictions, we biased our selection of focal HCPs with respect to this characteristic. Among the focal plans, 71% were developed by private entities, 10% by state or local governments, and 19% for lands under multiple jurisdictions (PQ:65).

Area

We selected focal plans non-randomly with respect to size to avoid sampling bias due to the many small Balcones Canyonlands plans and to achieve more balanced representation of different-sized plans. As a consequence, the proportions categorized as small, medium, and large differ from those observed in the larger HCP sample. Nineteen percent of the plans selected were small, 40% were medium, and 42% were large (PQ:28).

Duration

Plan durations were categorized as short (up to 5 years), medium (> 5 to 20 years), and long (greater than 20 years). Twenty-three percent of the plans selected were of short duration, 20% of medium duration, and 58% of long duration (PQ:4 minus PQ:3).

Species

By selecting only 43 HCPs for intensive analysis, we necessarily reduced the number of different species protected under these plans. Nonetheless, 64 out of a possible 73 different listed species are covered in our focal-plan subsample. Birds, mammals, reptiles and amphibians, fish, and invertebrates were included.

Approach

The focal HCPs were chosen to represent the primary approaches to habitat conservation planning: single-species plans, multispecies plans, and habitat-based plans. Fifty-one percent of the focal HCPs were single-species plans, 21% were multispecies plans, and 29% were habitat based plans. These proportions differ from those for the larger HCP population in that multispecies and habitat-based plans are over-represented. We intentionally sought an overrepresentation of these large multispecies plans because they represent the major impacts in terms of total area and because there has been a move toward increasingly favoring these types of plans (although small single-species plans continue to play a role) (PQ:7 and PQ:8).

5. THE USE OF AVAILABLE DATA FOR HCP PLANNING

Before evaluating the five key components of HCPs (status, take, impact, mitigation, and monitoring), we first discuss the more general issue of data availability. In particular, we assess what data are altogether lacking, what data are available but not used, and the quality of analysis of available data.

5.1. Data Limitations

To assess data availability during HCP preparation, we first documented the proportion of cases for which we were unable to determine basic information on a species or effects of actions authorized in the HCP on the species. These analyses provide a view of how often scientists lack information on species for basic assessments. Note that we did not restrict our search for this basic information to the HCP or its supporting documents—we did a thorough literature search that covered peer-reviewed publications and the “gray literature." We found that the basic information necessary to make determinations about potential threats to species (SQ:A12-A21), the status of a species or its habitat (SQ:B26-B42), and the type and magnitude of take that will occur (SQ:C19-C28) were unavailable in many cases. For example, we could not determine whether or not there currently exists sufficient habitat to ensure a species' viability for one quarter of the species-plan cases we examined. If we do not know whether or not there is currently enough habitat to sustain a species, it is hard to determine the impacts of future losses or alterations of habitats. Lack of this kind of basic information can severely limit our ability to make correct assessments regarding the effect of proposed developments on a given species. Indeed, for only one-third of the species are there enough data to determine what proportion of the population will be affected by the proposed development. All of the aforementioned data assessments were made for the literature up to one year prior to permit approval.

5.2. Unused, but Available, Information

To determine whether HCP preparers did not use important data that were available, we reviewed all the information we could find that was *not* in the HCP and judged the importance of this information for assessment of status, take, impact, and mitigation strategies (QD responses to SQ:B1-24, C7-18, D7-30 and E7-30). In gathering this information, we considered all reports and publications that were available at least one year prior to the date of the HCP’s approval as available for the HCP preparers. The majority of the information we found was either cited in the HCPs or deemed not to be important to the conclusions drawn in the HCP. Thus, our analysis showed that HCP preparers do a good job of finding and citing relevant data; data omissions were judged to be significant only 15-25% of the time (Table 7). However, a few categories of data appear to be under-researched in HCPs. Of particular concern is the omission of information regarding cumulative impacts. For example, in 23% of the cases, we concluded that plans neglected information on cumulative impacts that would have altered the assessment of the impact of take. Data omissions were also potentially serious in the development of mitigation or minimization efforts (Table 7). Of particular note was the omission of information about the amount and quality of habitat with respect to feeding, breeding, and migration—these are key aspects of habitat that will be central to any mitigation for habitat loss.

5.3. Analysis of Available Data

For each category of species-specific information we reviewed, we evaluated the quality of the analysis and use of any data reported in an HCP (QC responses to SQ:B1-24, C7-18, D7-30, and E7-30). For analyses of status, take and impact, we found that, when data were available, the overall quality of their use was high (Table 8). Data on population sizes and habitat availability were generally used well in HCPs, whereas more detailed data on species or their interactions in the environment were more unevenly applied and stood out for their relatively low scores with respect to data use (Table 8). The most significant finding in this analysis is the poor use of existing data regarding extrinsic factors (such as anticipated human population growth with likely future pressures on the species) and environmental variability for designing mitigation strategies (Table 8). Information about possible catastrophic events and environmental variability is important when mitigation is designed, because such variability can often undermine otherwise effective mitigation.

6. ASSESSMENT OF STATUS, TAKE, AND IMPACT

6.1. Determining the Status of Species

Accurate determination of the status of endangered and threatened species serves to justify procedures outlined in the HCP and provides baseline data to be compared with similar estimates after development has occurred. A fundamental aspect of a species' status is knowledge of the critical threats to that species' viability. As part of our evaluation of HCPs, we identified the primary threats to the 97 species-plan combinations (some species occur in several different plans, so 64 species yield 97 combinations: Figure 2, SQ:A12-23) both at the local scale (within boundaries of the HCP) and at the global scale (over the range of the species). Overall, the most important threat to species is habitat loss, which was cited as primary threat for over 75% of the species, both locally and globally (Figure 2), followed by habitat degradation, habitat fragmentation, and direct human-caused mortality. Other sources of declines for species covered in HCPs include pollution, water diversion and/or damming, interactions with invasive species, and changes in community composition (which affect interactions with food, predator, parasite, and disease species).

A second basic feature of species status is the estimated trend in abundance or numbers of individuals in the populations in question, both within the HCP area (SQ:B30) and globally (SQ:B31). For those species where population trends were known, we compared the proportion of species that were increasing, stable, or declining in numbers within the HCP area and globally. For most of the species, population sizes were known to be declining in the HCP area (57% total; 53% declining at a moderate rate and 4% declining so rapidly that extinction is possible within the next 20 years). An intermediate number of species were known to be stable (40%), and, for a small fraction of the species included in HCPs, the populations were increasing (2%) (Figure 3). Changes in populations for these species at a global scale are similar to those observed within HCP lands. Populations range-wide are declining for 74% of the species, stable for 21%, and increasing for only 5% of the species in our sample.

The status of populations of endangered species is highly dependent on the maintenance

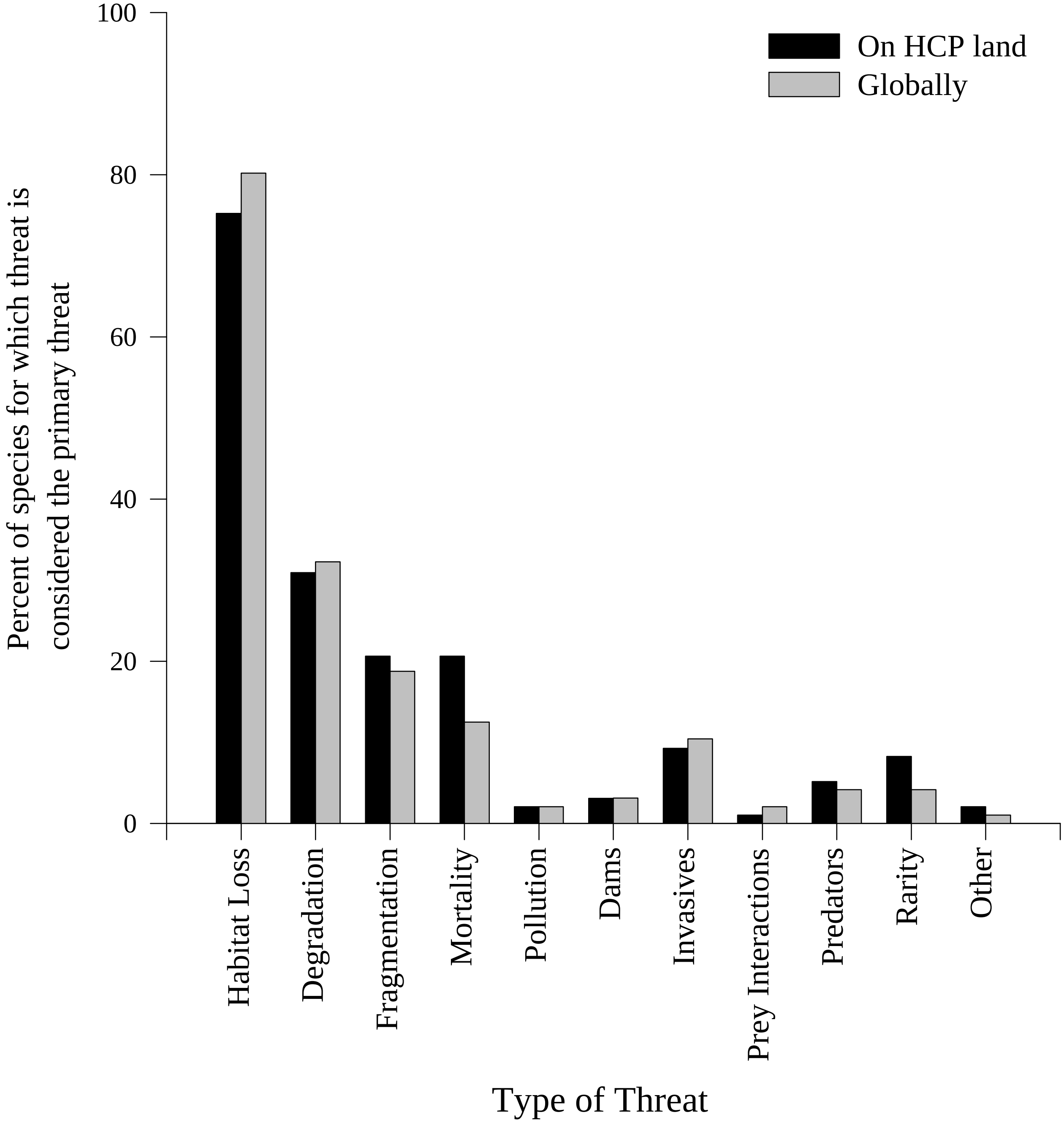

Figure 2. Major threats, at local and global scales, to species included in HCPs. For each threat category, columns indicate the number of times each type of threat was listed as most important (score of 1 for SQ:A12-22). Because multiple threats can be considered to be of major importance to any one species, the totals sum to greater than 100%. (N=97 species-plan combinations)

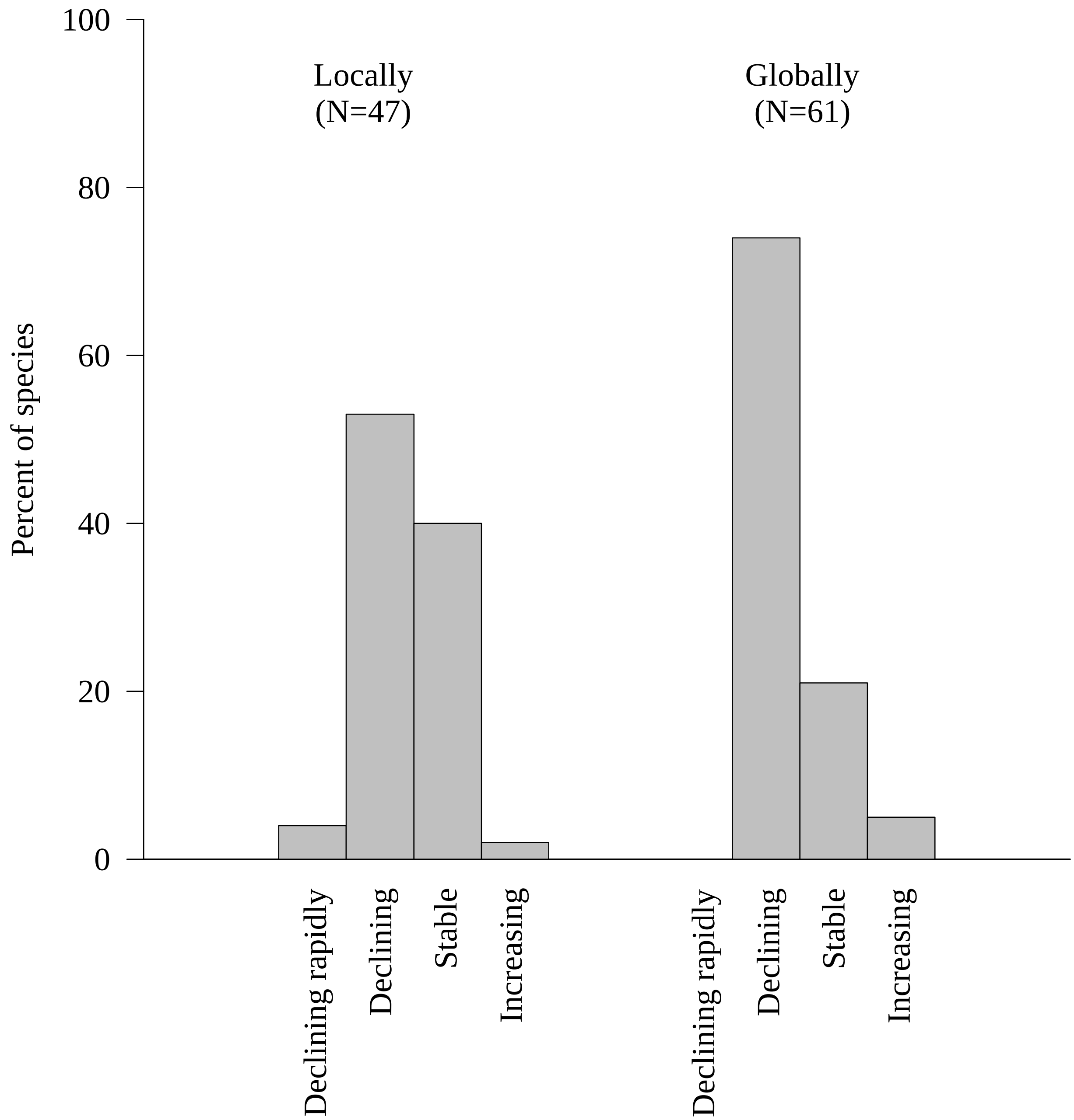

Figure 3. Local and global population trends (SQ:B30, B31) for species included in HCPs. For cases where population trends were known, we asked whether the impacted population was declining rapidly (with high probability of extinction within 20 years), declining, stable, or increasing in numbers. Sample sizes shown in parentheses.

of sufficient adequate habitat for the species. Trends in habitat availability (Table 9) are similar to those observed for populations: habitat availability is declining in the local HCP area for 63% and is stable for 37% of the species in the HCPs we reviewed. Habitat quantity is not increasing for any of the species we evaluated (Table 9; SQ:B34). Globally, habitat is declining for 88% of the species and stable for 12% and is not increasing for any of the species in our HCP sample (SQ:B35). The decline in habitat availability at larger scales underscores the importance of populations within HCP areas for overall viability of endangered species (Bean and Wilcove, 1997).

Most of the habitat remaining for species contained in the HCPs is of “medium” quality (51% of habitat in HCP area and 70% of habitat globally; Table 9; SQ:B28-29). We defined medium-quality habitat as that able to support self-sustaining populations but not able to produce an excess of individuals (i.e., not able to serve as consistent “source” populations). Habitat quality within the HCP area was generally rated of poorer quality than global habitat quality for the species in our HCP sample. In particular, 40% of the remaining habitat in HCP areas was deemed to be “poor” quality (i.e., not able to support isolated populations through time), whereas only 15% of habitat was determined to be poor globally.

6.2. Nature and Characterization of Take

Activities permitted in HCPs can result directly or indirectly in death of individuals of an endangered species, commonly referred to as “take” (ESA, 1982). Take also includes any type of harassment or harm to species and destruction or modification of a species’ habitat (USFWS, 1981). Take was predicted to occur for the majority of the species-plan combinations we reviewed (73%; SQ:C25). For the remaining species either take was not predicted to occur as a result of HCP activities or not enough information was provided in the HCP to reveal whether take would occur. In cases where it was explicitly stated in the HCP that take would occur if the permit were approved, the quantification of take varied tremendously among plans (SQ:C27). Predicted take, in terms of the estimated number of individuals that will be displaced or killed, is poorly estimated for most of the species in our focal HCPs—in almost half of the cases (49%) no data in the HCP or associated documents addressed the level of take likely to result from the proposed development.

For each species evaluated in our 43 focal plans, we also asked what percentage of the population on the HCP land would be taken as a result of the proposed activities (SQ:C26). In a large proportion of the cases (42%), the HCPs do not explicitly estimate this figure. Among the plans in which take was estimated, the expected level of take was most often "all or nothing" (Figure 4). In the majority of cases either a small percentage (1% or less) or all (100%) of the population on the HCP land would be taken as a result of the proposed activities; few predicted intermediate take levels.

Our data suggest that little emphasis is currently placed on accurately estimating the consequences of proposed activities for the species or population in the HCP area. A high percentage of the species listed on incidental take permits have no quantitative estimate of take, either as the total number of individuals lost or the percentage of the affected population taken. In the cases where predicted take is quantified, our data suggest that HCPs fall into two categories: the plans either minimize take (resulting in many cases with low take estimates) or they allow for removal of 100% of the affected population.

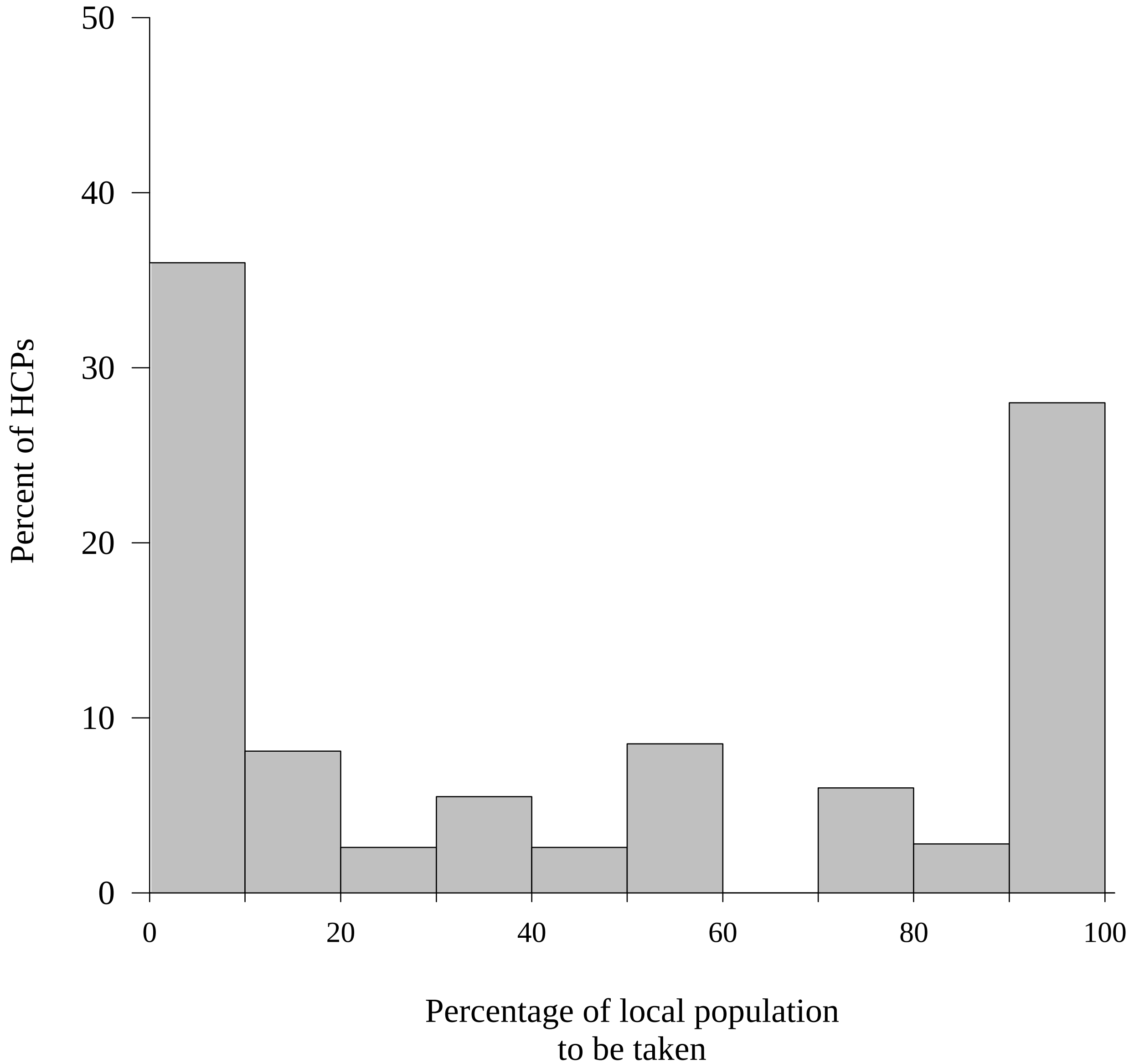

Figure 4. Percent of impacted local populations that will be taken as a result of the activities proposed in the HCP (SQ:C26). In the cases where the levels of take were estimated in the HCPs, either very few individuals from the impacted population are expected to be taken or the entire population is taken.

6.3. Assessing Impacts of Development on Endangered Species

Impacts on populations in HCPs can be defined as the combined effects of take and habitat modification on the viability of endangered species. Because of its complex nature, quantifying impact is difficult and requires not only accurate estimates of take but also an understanding of the population dynamics, species requirements, and demographic thresholds that apply in each individual case; these data are often necessary to full understanding of the biological consequences of proposed levels activities. We reviewed the types of threats that were considered in HCPs (QE responses to SQ:D32-45) and compared those to the categories of impact we deemed important for the species given our knowledge of their biology and status (QG responses to SQ:D32-44). We ranked all categories for each individual species-plan combination on a four point scale ranging from 1 (not an important impact) through 4 (a serious impact that will significantly affect the population). We ranked area of habitat loss, percent habitat lost, direct mortality, habitat fragmentation, cumulative impacts, and altered interspecific interactions as the six most significant effects for the species in our sample (Table 10). With the exception of cumulative impacts, we generally found high concordance between our rankings and the number of times that the same impact was considered in the HCPs we reviewed.

7. MITIGATION AND MONITORING

7.1. Mitigation in Habitat Conservation Plans

A crucial feature of HCPs is the choice of mitigation procedures aimed at minimizing the threats to species included in the incidental take permit (see, e.g., Bingham and Noon, 1997). In fact, this minimization of impact is required by the ESA (1982) and clearly outlined in the HCP Handbook (USFWS and NMFS, 1996). If the appropriate mitigation is chosen and implemented in a timely fashion, the impact to the species in question can be minimized to the maximum extent practicable, thus justifying the issuance of an incidental take permit. However, many scientists have criticized the mitigation plans proposed in HCPs because they have often seemed arbitrary, based more on political and economic constraints than empirical data on the species' ecology, life history, and specific requirements (Beatley, 1994; Bingham and Noon, 1997; Buchanan et al.,1997). Given the importance of mitigation for the success of HCPs, we focused our analyses on the scientific basis of mitigation measures proposed. HCPs that include more than one endangered species must mitigate for impact to all species included in the take permit. Therefore, because of the species- and plan-specific nature of mitigation measures, we considered each species within a plan as our unit for analysis.

7.2. Types of Mitigation Most Commonly Used

We treated minimization of impacts (e.g., modifying construction and/or development at the site to minimize changes to the species or its environment) and avoidance of impact (e.g., working during the non-breeding or inactive season) as categories of mitigation. Minimization and avoidance were by far the most common mitigation measures proposed (Figure 5; QH responses to SQ:E32-E42). Avoidance was proposed for 74% of species for which permits were issued, and minimization of impact at site of development was proposed for 83% of species). Most mitigation efforts for a specific endangered species involve a combination of procedures. Thus, many of the less common mitigation measures (such as land acquisition, translocation, habitat restoration, etc.) are used in combination with strategies for minimization and avoidance

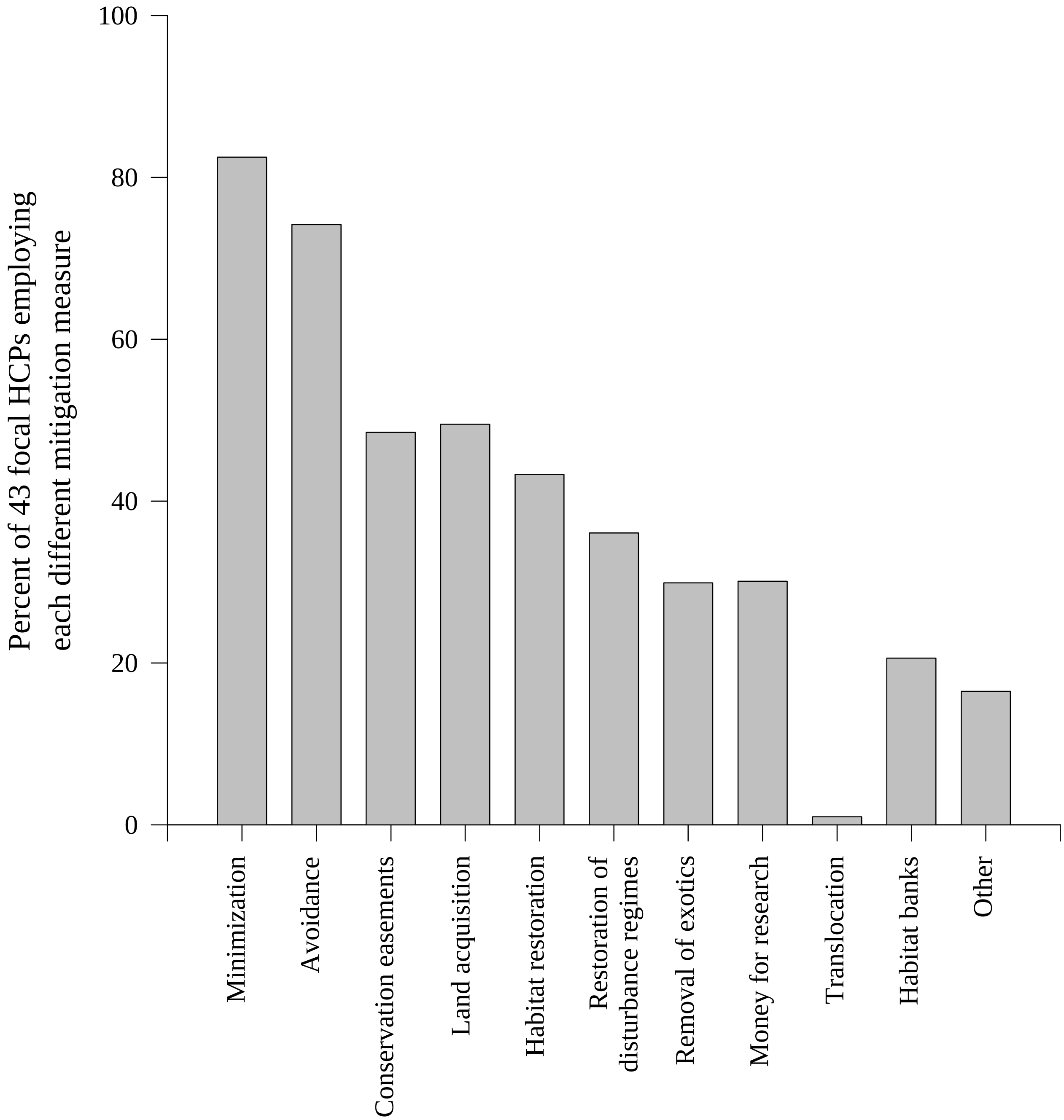

Figure 5. Frequency of specific mitigation measures proposed for all species in the 43 focal HCPs we examined (SQ:E32-42 QH). Minimization (defined as any measure at the site of development that minimizes the impact on the species while still carrying out the proposed activities) and avoidance are the most common forms of mitigation.

of impact on the threatened species. The high reliance on avoidance and minimization is not surprising, as these are usually the easiest and least costly procedures to implement.

7.3. Quality of Data Used in Determining Specific Mitigation Measures

The quality of data underlying particular mitigation measures proposed for each species was evaluated on a 4-point scale (a continuous quality index from 0, representing "no data" used to support the chosen mitigation procedure and its reliability, to 3, representing cases where data amply document that the proposed mitigation procedure is likely to be effective; QJ responses to SQ:E32-E42). On average, the quality of data used to justify mitigation measures was relatively low (Figure 6); that is, all mitigation procedures were based on data ranked as 2 or below in our quality index (indicating that the data are, at most, moderately understood and reliable). The mitigation measures based on the highest data quality are conservation easements, land acquisition, avoidance, and minimization. Other measures such as translocation often lack data demonstrating the feasibility of the proposed actions. In general, HCPs seem to rely more on mitigation measures with higher quality scores and less on those with low scores (QI responses to SQ:E32-E42). However, there are some exceptions; for example, when habitat banks (payment of money into an account, which is then to be used to purchase land that is supposedly ideal habitat for the species threatened by the proposed activities) are used, they tend to be a major component of mitigation programs, yet this mitigation approach has one of the lowest scores on our data quality scale (Figure 6). Given the generally low quality of data underlying many mitigation plans in HCPs, their success is not assured and, if implemented as proposed, may be very close to a "guess" in terms of curbing the impacts on the species.

7.4. How Well Mitigation Plans Address Threats to Endangered Species

Judging the actual success of mitigation procedures would require long-term information on the success of HCPs. Because very few plans have been in place for more than eight years, this is not an option. Hence we must rely on current indicators that mitigation measures are likely to be successful. For each of the species in our sample, we estimated the likelihood of success by answering two questions. First, we asked how often mitigation measures actually addressed the primary threat to the species in question. Second, we asked to what extent the proposed mitigation measures are likely to reduce the impacts of the primary threats. Whereas the USFWS is required to adopt mitigation and minimization measures that protect a species to the maximum extent practicable, our focus was more on whether scientific evidence was presented to substantiate that the best possible mitigation was being adopted.

We found that, for the great majority of the species we examined, the mitigation procedures addressed the primary threat to the species' continued existence (85%; SQ:E44). However, the overall adequacy with which proposed measures addressed the primary threats varied tremendously among species (Table 11; SQ:E45). Overall, we found that for only 57% of the species in the sample did mitigation measures proposed in the HCP address the primary threat to the species to a degree considered "sufficient" or better. In other words, although HCPs most often identify the primary threat to the affected species, only a little more than half of the time do mitigation plans adequately address that threat.

7.5. Implementation of Mitigation Plans

An important determinant of the success of mitigation is the adequate implementation of

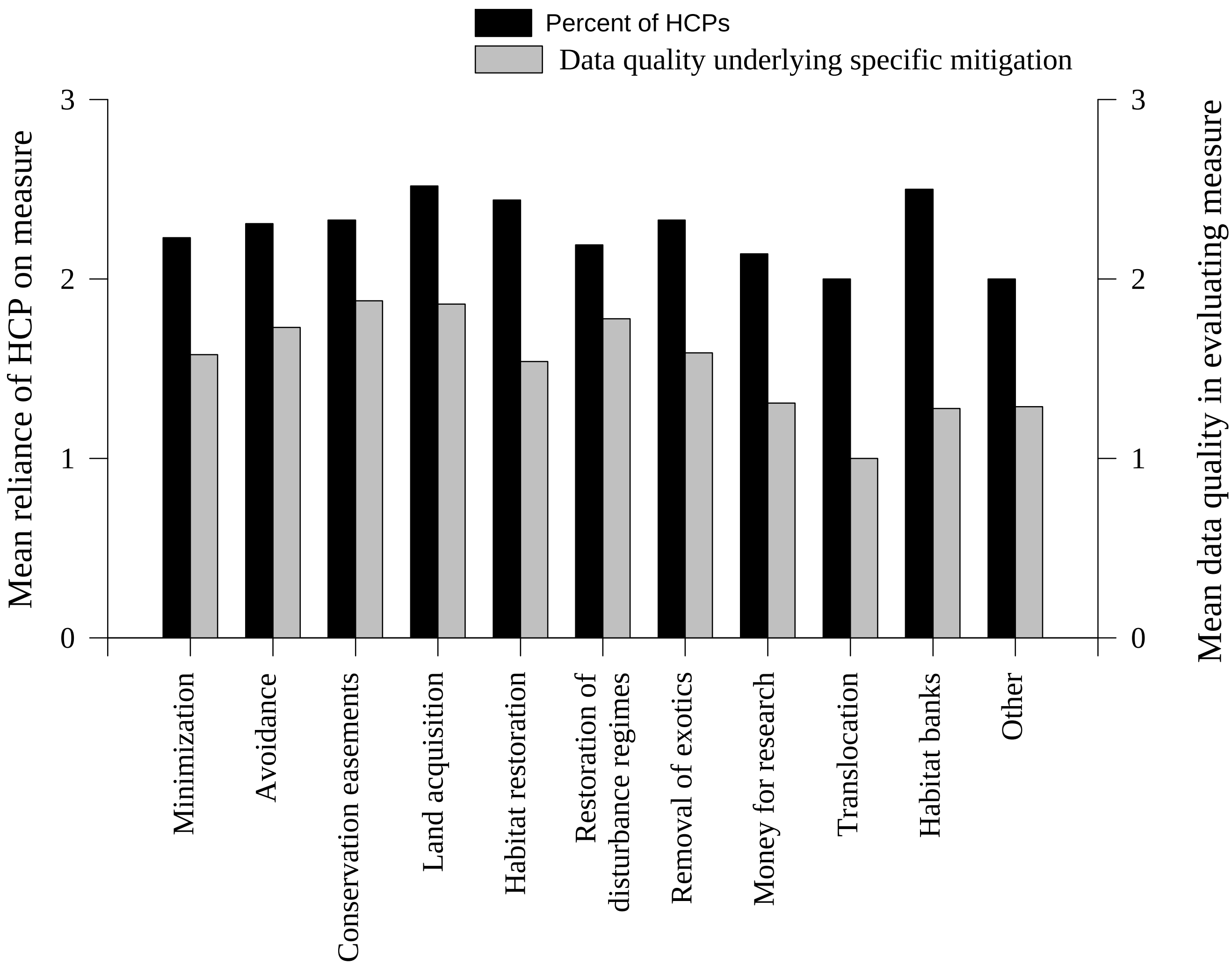

Figure 6. Data quality underlying the choice of proposed mitigation (SQ:E32-42 QJ) and reliance of HCPs upon those same mitigation measures (SQ:E32-42 QI). The quality of data underlying choice of mitigation for each species was rated on a 4 point scale ranging from 0 (no data to support the use of that measure and its reliability) to 3 (very good data, with mitigation known to work). The reliance of the HCP on these mitigation activities was also evaluated on a 4 point scale, ranging from 0 (no reliance on mitigation) to 3 (high reliance - this is one of the major mitigation measures used for the species). Bars represent the mean scores across all species examined.

the proposed measures. For maximum success rates of mitigation plans, it is important that the procedures be implemented in a timely fashion and preferably before the population of an endangered species is severely affected by activities proposed in the HCP. We examined two factors that affect the implementation of mitigation plans: funding for the measures and the timing of mitigation efforts relative to "take" of the impacted species.

Mitigation can be one of the most expensive steps in the development and execution of an HCP. Thus, it is important to determine the cost of the proposed measures, the source of funding for implementing mitigation, and the time period over which these funds are available. Under law, the plan for funding all expected mitigation measures should be outlined in the HCP; ideally the source of those funds should be determined *a priori* and not as the impact occurs in the course of development (we refer to the latter as a "pay as you go" funding program). We found that HCPs nearly always met these basic expectations: 98% of the HCPs outlined *a priori* the funding sources for the mitigation proposed (PQ:124), but only 77% had significant funds set aside to pay for mitigation at the onset of the HCP (PQ:125).

Another critical aspect of mitigation is the timing of proposed measures relative to impact. It is important that mitigation measures are started at the time of take or preferably before any take occurs, thus increasing the probability that unsuccessful mitigation procedures can be detected and corrected. In contrast, if most take occurs before mitigation measures are put into effect, chances of adaptively improving on failed mitigation efforts are reduced. We found that take occurred before mitigation in a substantial number of cases (23% of the species examined; PQ:126).

7.6. The Clarity and Effectiveness of Monitoring Programs

The first question to ask about monitoring is simply whether or not a clear monitoring program was outlined in the plan. We focused only on effectiveness monitoring, as opposed to compliance monitoring (see Table 1). An answer of “no” to this question does not necessarily mean that no monitoring is going on for the pertinent species, but rather that the text of the plan does not provide sufficient information or sufficiently explicit information to document that indeed a scientific monitoring program was part of the plan. Of course, a “no” could also mean that there was absolutely no monitoring whatsoever. For only 22 of the 43 plans was there a clear description of a monitoring program (PQ:60). The next obvious question concerns the effectiveness of those 22 clear monitoring programs we identified—in other words is the monitoring program designed in such a way that it would allow the success of the HCP to be evaluated? For this question the attributes of monitoring required for “evaluation of success” depended on the particular plan and the threats being mitigated, and they could involve factors such as number and location of sample sites, frequency of sampling, and nature of data recorded. Again, a “no” does not imply that monitoring in the field is necessarily insufficient, only that the information presented in the plan and associated documents did not provide any confidence that the monitoring could evaluate success. Under this interpretation, only 7 out of 43 plans had clear monitoring programs that were sufficient for evaluating success (PQ:167). Because our criteria for answering “yes” to the questions about clear and sufficient monitoring relied on what was actually included in the documents, the reality may not be as gloomy as the numbers above suggest. If the monitoring programs were consistently a part of all HCPs, then HCPs on average would be better, and the monitoring programs themselves would be more likely to be scientifically supported because of their role in planning. We delved deeper into the data to determine exactly what was missing with respect to questions about particular species and whether any class of plans seemed to stand out as having better than average treatment of monitoring.

Monitoring can have more specific goals than evaluating a plan's success. For example, monitoring could be implemented to estimate take (SQ:F5) or population status (SQ:F31) or to evaluate mitigation success (SQ:F57). Our more refined analysis of monitoring according to take, status, and mitigation echoes the earlier conclusion about generally poor monitoring. In particular, when broken up into the components of "take, status, and impact of mitigation," monitoring was found to be adequate for any component in 65% of the plans at most (Figure 7).

Adaptive management and monitoring are clearly interconnected because adaptive management requires monitoring data with which to evaluate the success of alternative management strategies. Although most plans did not include provisions for adaptive management, those that did were also significantly more likely to include clear monitoring plans (cross analysis of PQ:60 and PQ:61). In particular, 88% of the plans with provisions for adaptive management had clear monitoring plans, whereas less than 30% of the remainder had clear monitoring plans ($\chi^2 = 14.93$, $P = 0.001$).

Many more detailed questions could be asked about monitoring, but so few plans were judged to include clear or sufficient monitoring programs, that sample sizes are small. Moreover, the major results are clear with the most straightforward analyses:

1. Barely 50% of the plans contain clear monitoring programs, and they rarely include monitoring programs that are both clear and sufficient for evaluation of a plan's success.

2. The provision of adaptive management in plans was often associated with clear monitoring programs.

Monitoring should be a key component of an HCP because there is no way to evaluate the performance of an HCP without adequate monitoring. Our data compellingly show that monitoring programs are often either poorly described or nonexistent within the HCPs themselves and their associated documents. It might be argued that this lack of description does not matter as long as sufficient monitoring is implemented "on the ground" in the real world, but if the HCPs fail to spell out the details of monitoring programs, the adequacy of monitoring cannot be scientifically evaluated.

8. GENERAL PATTERNS AND FACTORS SHAPING SCIENCE IN HCPS

Above we have presented analyses of each of five stages of HCP planning (status, take, impact, mitigation, and monitoring). Here, we investigate the interactions between stages of the HCP process and test for patterns and principles that connect and synthesize the different aspects of the HCP planning process. In particular, we focus on the cumulative effects for HCP adequacy of several factors (e.g., differences between single-species and multiple-species HCPs) that are likely to indicate trends in future HCP science. In this section, we have for the most part used species as the sampling unit and used as dependent variables answers to questions regarding the overall quality of each stage of analysis (SQ:B42-43, C32-33, D46-47, E48-49, F79-80). We first present results showing overall patterns in adequacy and then discuss in more detail the

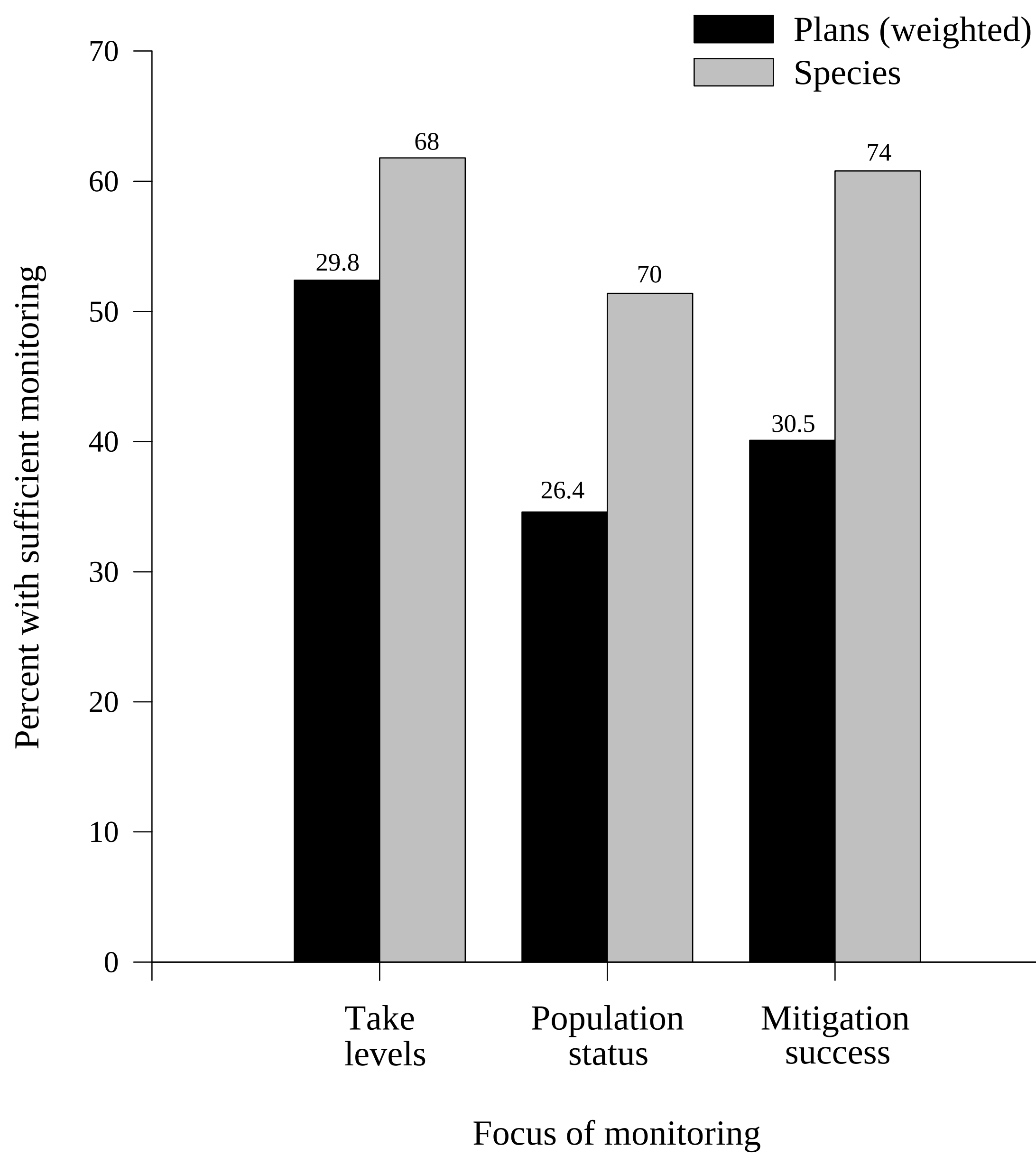

Figure 7. The percentage of monitoring programs deemed adequate with respect to their evaluations of take, status, and mitigation. The analysis was done in two different ways: For the plan-weighted analysis, each species in the plan is weighted by 1/(#spp. in the plan). For the species analysis, each species is treated as a separate and equally weighted unit regardless of how many other species might be subject to monitoring in the same plan. Sample sizes shown above each bar; fractional sample sizes are possible for plans because of the weighting factor.

importance of different aspects of species biology and plan characteristics for the scientific rigor of HCPs.

8.1. Multivariate Analyses of "Adequacy" Rankings and Correlations with Attributes of Plans

In general, the earlier stages in HCP planning are the best documented and best analyzed (Figure 8). In particular, species status is often well known and adequately analyzed, whereas the progressive analyses needed to assess take and impact are more poorly done or lacking; inadequate assessment of impact is especially common. We next consider what factors may explain the range of adequacy seen across different HCPs and different stages of analysis. Factors that we considered in our analyses were those that seemed most likely to influence the quality of HCP analysis, plus those that may indicate whether changes in HCP formulation will have desirable results. For example, both multispecies and large-area HCPs have been advocated, and thus we asked whether the area covered by an HCP or the number of species covered influenced the quality of biological analyses in HCPs. In particular, we tested for the effects of the following seven variables:

- Area covered by the Incidental Take Permit (PQ:28)
- Plan duration (PQ:4 minus PQ:3)
- Existence of an approved recovery plan (SQ:A8)
- Single-species vs. Multispecies Plan (PQ:7)
- Habitat-based vs. Species-based Plan (PQ:8)
- Taxon (SQ:A2)
- Date of permit (PQ:A3, categorized as Early [1983-1994] or Recent [1995-1997])

To test for effects of these variables on each of the five HCP planning steps, we performed a series of MANOVAs using standardized transformations of all variables. We first performed separate, one-way MANOVAs using each of the above variables, with the five ratings of analysis quality as dependent variables (SQ:B43, C33, D47, E49, F80). Next, we performed two multiway MANOVAs. The first used all seven independent variables; the second included only the five independent variables with one or more significant or near-significant ($P < 0.20$) effects in the first analysis. We used this combination of one-way and multiway analyses both because missing values considerably reduced the sample size of tests using all variables and because, without large sample sizes, multiway MANOVAs can provide only weak tests for effects. Finally, we repeated this entire set of analyses using weightings to account for unequal numbers of species per plan (weighting was by: 1/(number of species in plan)). Table 12 presents the overall results from these tests. In addition to these overall analyses, we also conducted a variety of other tests and comparisons to elucidate the effects of each factor on HCP quality. Below, we separately discuss HCP adequacy in light of each of these causal factors.

8.2. Correlations Between Scientific Quality and Area or Duration of Plans

The promotion of large-scale HCPs incorporating "ecosystem management" by Secretary of the Interior Bruce Babbitt and the USFWS is viewed by many biologists as a positive trend (Noss et al., 1997). In addition, an increasing number of large-scale HCPs are region-wide programs dealing with single focal species. Along with promulgation of these very large-scale HCPs, there is also an effort to expedite the development and approval of the smallest HCPs; the

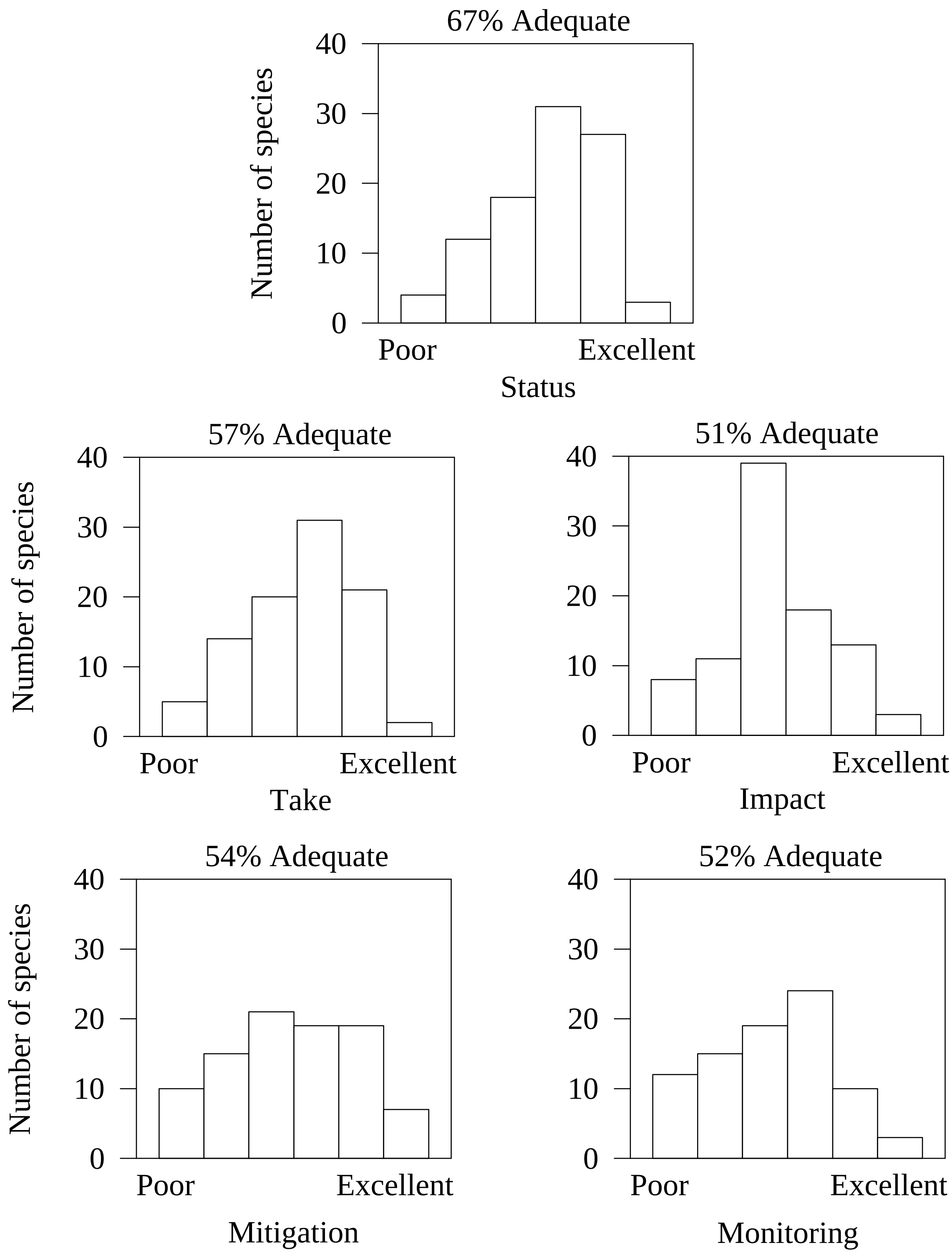

Figure 8. Quality of analysis and data at the five stages of HCP analysis: status (SQ: B43), take (SQ:C33), impact (SQ:D47), mitigation (SQ:E49), and monitoring (SQ:F80). Histograms show the number of species with analysis falling into each of six quality categories ranging from poor to excellent. Above each histogram is the percentage of species for which plans were scored as "adequate" as opposed to "not adequate" by a separate, binary ranking for that step of HCP analysis (SQ:B42, C32, D46, E48, F79).

HCP Handbook (FWS and NMFS, 1996) suggests both (1) that USFWS and NMFS encourage state and local governments and private landowners to undertake regional HCPs and (2) that "low effect" HCPs will be expedited and simplified as much as possible. "Low effect" HCPs are usually of small area and are defined as having minor or negligible effects on listed or candidate species and on other environmental resources. There has been a great proliferation of small HCPs, especially HCPs concerning the golden-cheeked warbler in Travis County, Texas, which account for 36% of all currently approved plans.

Our univariate analyses of overall adequacy provide some evidence that the area covered by a plan is related to four aspects of species-based planning—status, impact, mitigation, and monitoring (Figure 9) — but the lack of significant results from multiway MANOVAs suggests that these results are weak (Table 12). Looking toward the future, we cautiously share the general view that larger scale HCPs should be encouraged, but past HCPs lend no evidence that the largest HCPs will necessarily be "better" scientifically.

Among our 43 sample HCPs, none permitted before 1995 exceeded 30 years duration; since 1995, a number of plans have been signed whose duration exceeds 50 years. These increases in plan duration have important implications for land-use planning by the permitee and for the likelihood of plan success from a biological standpoint. Longer plans may be advantageous for permit holders because they relieve the threat of changes in regulations governing land use. Likewise, plans of longer duration may be advantageous to species if they result in more careful research, more flexibility in take activities, or greater protection or enhancement of habitat. On the other hand, a 100-year HCP that lacks provisions for adjustments in land use practices in the face of declines in focal species could result in severe biological losses with no regulatory means to avoid them.

Our MANOVA results suggest that HCP duration had contrasting effects on the three stages of analysis—the analyses of status, take, and monitoring (Table 12). For example, plans of longer durations were characterized by higher quality status assessments, but lower quality take assessments. These results indicate that the effects of plan duration are complex – neither consistently increasing nor decreasing the quality of science in support of the assessments.

8.3. The Existence of Recovery Plans and Scientific Adequacy

Under the Endangered Species Act (ESA), the federal government is charged with drafting recovery plans for listed species. The development of these plans entails the collection and collation of detailed information related to the abundance, distribution, habitat needs, and life history of a species, the identification of primary threats to the species, and formulation of management prescriptions that will result in the de-listing of the species. Although, for a variety of reasons, recovery plans have not been established for most listed species (Tear et al., 1993), it seems clear that recovery plans ought to provide much of the information and management context needed for the formulation of good HCPs. In particular, it has been argued that recovery plans can provide a global context for activities proposed under an HCP, particularly through assignment of critical habitat needed for species recovery (USFWS and NMFS, 1996; National Audubon Society, 1997).

Of the 97 treatments of species in our sample of HCPs, 59 had recovery plans established prior to the development of the respective HCPs. In some, the text describing these attributes of

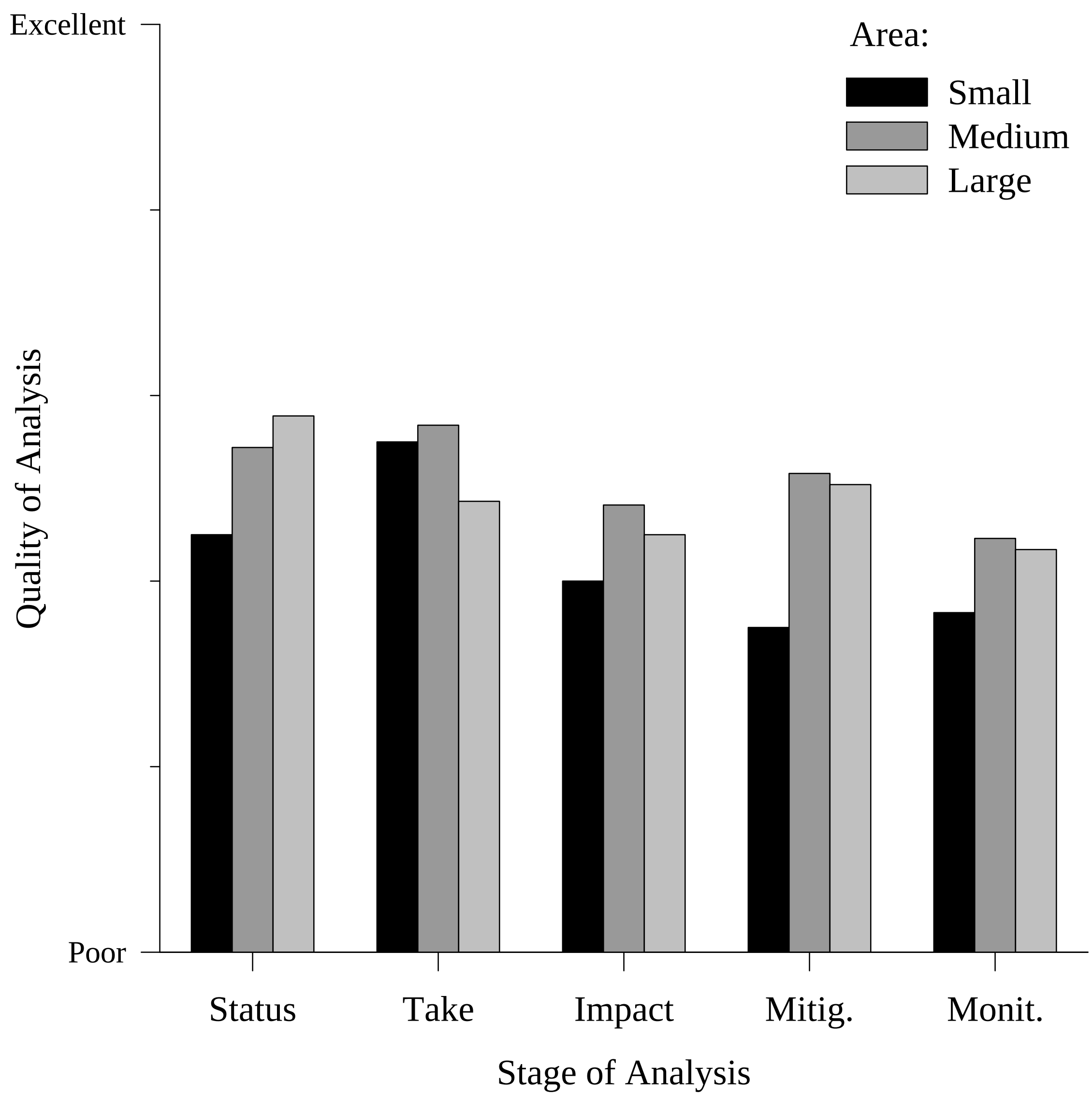

Figure 9. The effect of HCP area (PQ:28) on the quality of analysis and data at the five stages of HCP analysis (SQ:B42, C32, D46, E48, F79). In general, the results suggest that HCPs covering small areas (0-10 ha) are less likely to analyze status, mitigation, and monitoring adequately, whereas those covering large areas (>1000 ha) do a poorer job of analyzing take.

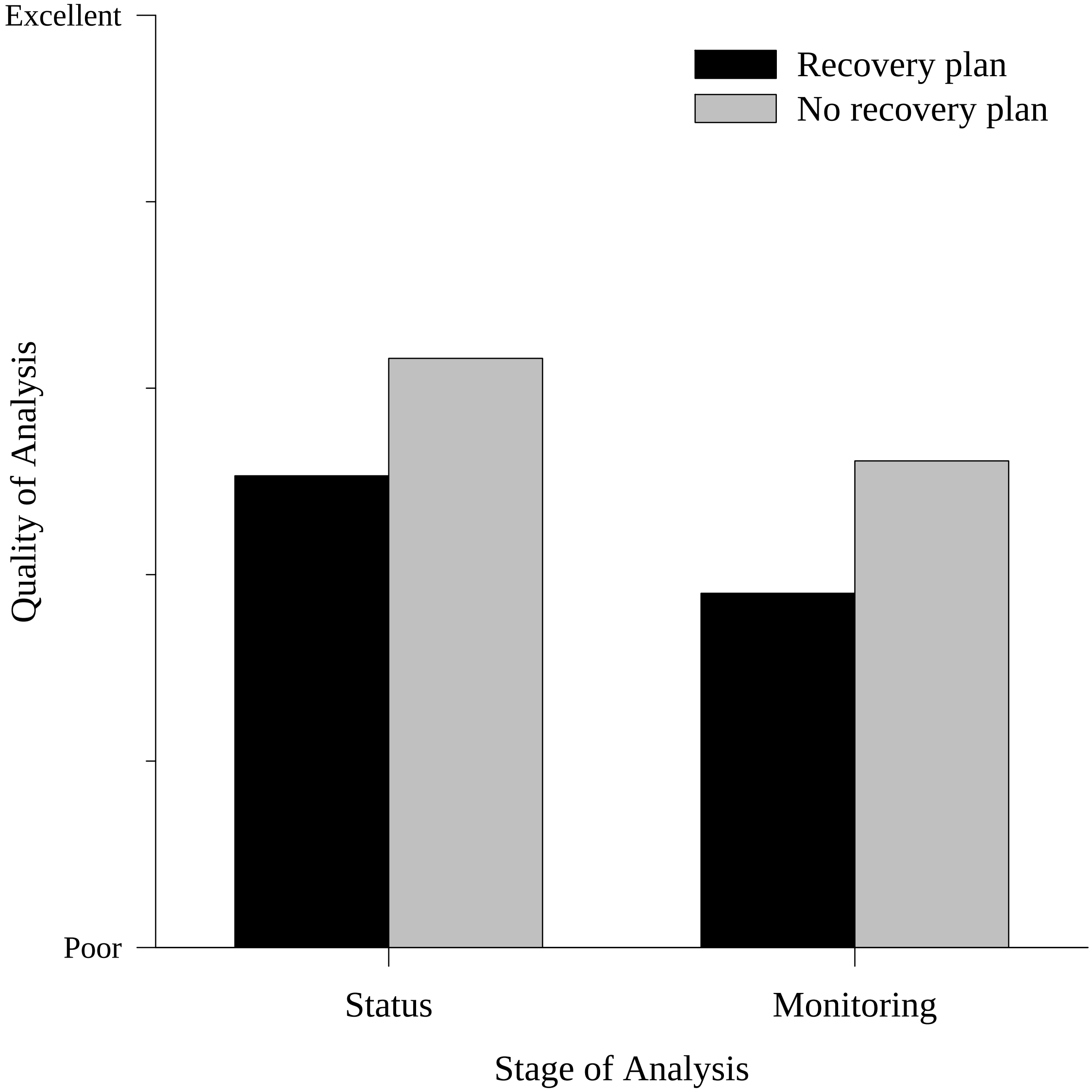

Figure 10. The effect of the existence of a recovery plan (SQ:A8) on the quality of analysis and data at several stages of HCP analysis (SQ:B42, F79). The results show that for both status and monitoring, the presence of a recovery plan is associated with a less adequate analysis.

species closely match the wording within the recovery plans themselves. Specific mitigation techniques, such as the design and placement of artificial nest boxes for red-cockaded woodpeckers (*Picoides borealis*) or the translocation of Utah prairie dogs (*Cynomys parvidens*), were borrowed directly from recovery plans in the development of HCPs. Discussions with HCP applicants and USFWS officials confirm this impression. Typically, when a recovery plan exists, it is used extensively by applicants in developing an HCP.

However, in contrast to expectations, there was evidence that adequacy of HCPs was negatively linked to the existence of a recovery plan (Table 12; Figure 10). In fact, using our yes/no delineations of adequacy, the trend was in the opposite direction for three of the five steps of HCP analysis (Table 13); a species was more likely to have adequate information included in its HCP if it did *not* have a recovery plan.

We also asked whether there was a relationship between critical habitat designation for a species and the quality of HCP analyses for those species that did have recovery plans. As for recovery plans, we found no evidence that adequacy of HCPs was positively linked to the existence of a critical habitat designation (Table 13). Again, the trend was in the opposite direction for each of five categories of information collected from HCPs. On average, a species was more likely to have adequate information included in its HCP if it did *not* have a critical habitat designation.

8.4. Quality of Different Types of HCPs

Treatment of multiple species in the same HCP is appealing to both landowners and the government because it can provide a single planning process with which to address simultaneously all of the potential rare species issues for an area. Furthermore, by obtaining incidental take permits for many listed and currently unlisted species, multispecies HCPs can provide far higher assurance to landowners that they will not encounter future impediments to development plans. This assurance is an especially important incentive to landowners in areas with high densities of proposed and candidate species (e.g., California and Florida). Increasing the number of species (from single species plans to multispecies plans) tended to increase the quality of impact assessment, but had no impact on all other assessments (Table 12). A second way of including many species under the mantle of HCP planning is through “habitat-based” HCPs. For example, the NCCP program in southern California (see website for a narrative description of this plan) takes this approach—species are grouped according to the habitat communities they require, and planning relies in part on the assumption that adequate protection for each species can be gained through protection for each habitat type. In habitat-based plans, information about habitat and fragmentation, and trends in those habitat characteristics, is used as the primary indicator of species status. Theoretically, information about habitat quality and quantity can be related in a rigorous, scientific manner to population status for a particular species, and in this way, habitat characteristics can legitimately be used as a proxy for missing information on population status. Overall, our MANOVAs show positive effects of habitat-based planning on the scientific quality of HCPs (Table 12; Figure 11). For example, one-way analyses and comparisons of yes/no adequacy rating provide evidence of positive effects on status, take, and monitoring assessment. Taken together, these results suggest that habitat-based planning has not resulted in lower scientific quality in HCPs and may in fact result in better, more scientifically defensible, planning efforts.

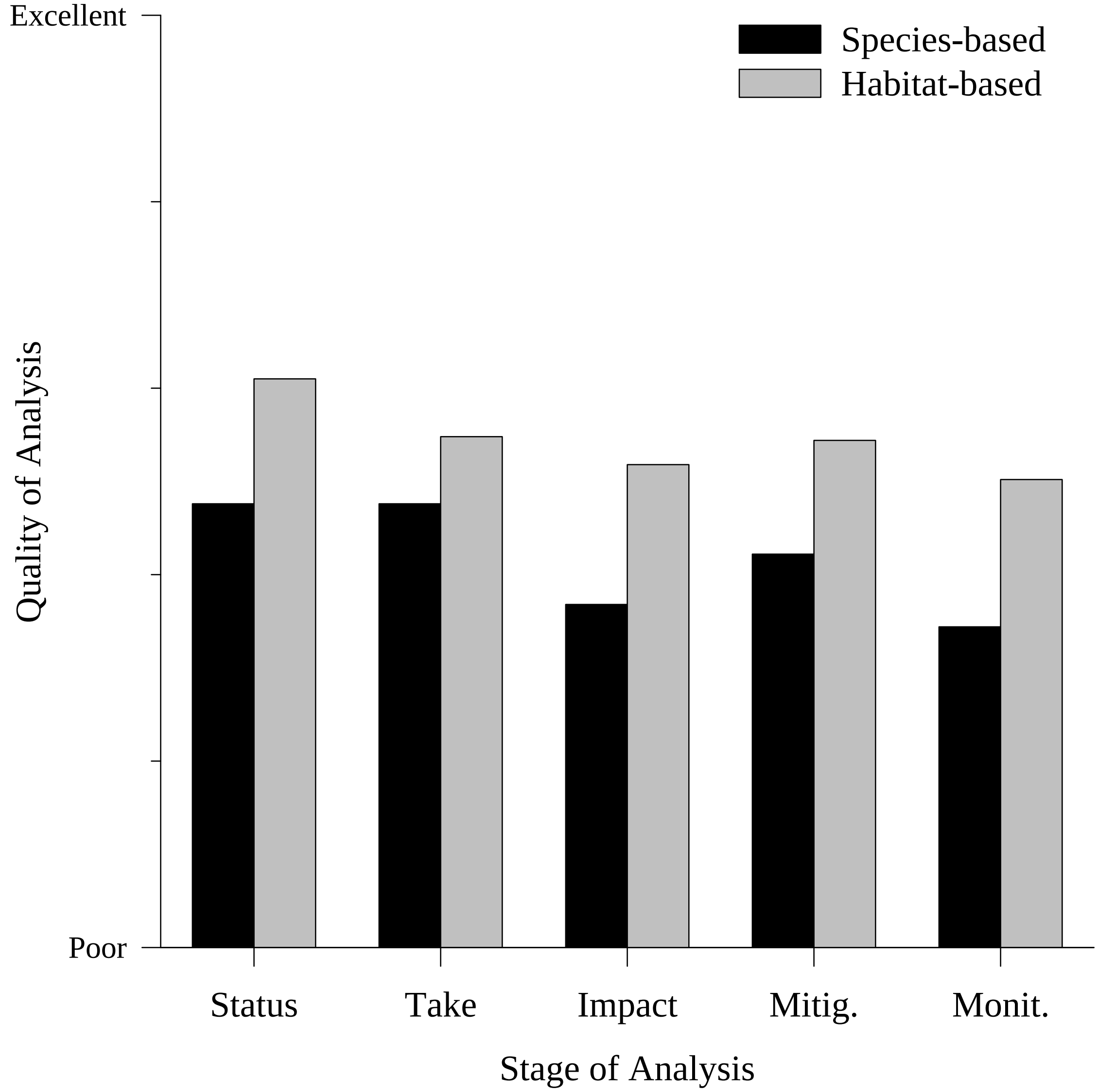

Figure 11. The effect of using a species-based versus habitat-based planning approach (PQ:8) on the quality of analysis and data at the five stages of HCP analysis (SQ:B42, C32, D46, E48, F79). The results indicate that at all stages of analysis, habitat-based HCPs are associated with better analysis and data.

8.5. Scientific Quality in Relation to Taxonomy and Date the HCP Was Signed

Major taxonomic groups differed strongly in how well or poorly planning was done, and also how these differences are manifested at different planning stages. We divided the species covered in our HCPs (except for the one fish species) into six taxonomic groups. Overall, taxonomic group was strongly related to adequacy of planning (Table 12), and these differences are also evident at three of the five stages of analysis: impact, mitigation, and monitoring (Table 12; Figure 12). Surprisingly, taxonomically determined differences in adequacy ratings seem to be much more easily explained by the difficulties posed by biology than they are by the political profiles or universal appeal of different groups. For example, plants had the most effective monitoring programs, probably as a result of their sessile—and thus easily studied—lifestyles. In contrast, mammals scored low with respect to impact assessment, monitoring, and mitigation. This pattern is probably due to the difficulty of obtaining good estimates of abundance, population trends, and demography for such mobile and largely nocturnal animals. Birds and herps (reptiles and amphibians) had intermediate ratings for each of the steps of analysis (Figure 12).

The date of issuance of the incidental take permits for our 43 focal HCPs ranged from a single plan in 1983 (San Bruno Mountain, the first HCP completed) to 25 plans in 1996-97. For several stages of planning, and for overall quality, more recent plans are better than older ones (Table 12). Perhaps the most biologically important aspect of this improvement is in mitigation analysis; before 1995, only 10% of species covered included "adequate" analysis of mitigation, whereas from 1995-1997, 59% of species were adequately analyzed. Similar improvements have occurred in all other steps of analysis, indicating that HCPs are—as their advocates have claimed—becoming more rigorous scientific documents.

9. CONCEPTUAL CHALLENGES TO THE QUALITY OF SCIENCE IN HCPs

Many of the gaps in HCP science reflect an absence of basic natural-history information, an absence of straightforward monitoring protocols, or inadequate reporting of data, but the HCP process is also challenged by subtler scientific issues, which are not easily remedied by greater care and thoroughness. The three conceptual hurdles we found to be most widespread were a failure to appreciate the potential complexity of assessing impact, the neglect of occasionally pertinent ecological theory, and violation of the precautionary principle in habitat planning.

9.1. Take Is Not the Same as Impact

As a first approximation, "impact" is clearly proportional to take, but simply reporting the number of individuals removed by an activity does not estimate the impact of this take on a species' viability or potential for recovery. At a minimum, there should be some indication of what proportion of a population (locally and globally) corresponds to a given take and of whether the take represents a loss from part of the species range that is a major source of population growth and vitality (as compared to a sink population, see Pulliam, 1988, and Wootton and Bell, 1992). In an ideal world one would perform some sort of population viability analysis to assess the impact of take on a population's viability, but data sufficient to conduct these analyses are scarce, and the analyses themselves conjure up an entire series of additional problems. However, for some cases involving well-studied species and large areas of land that

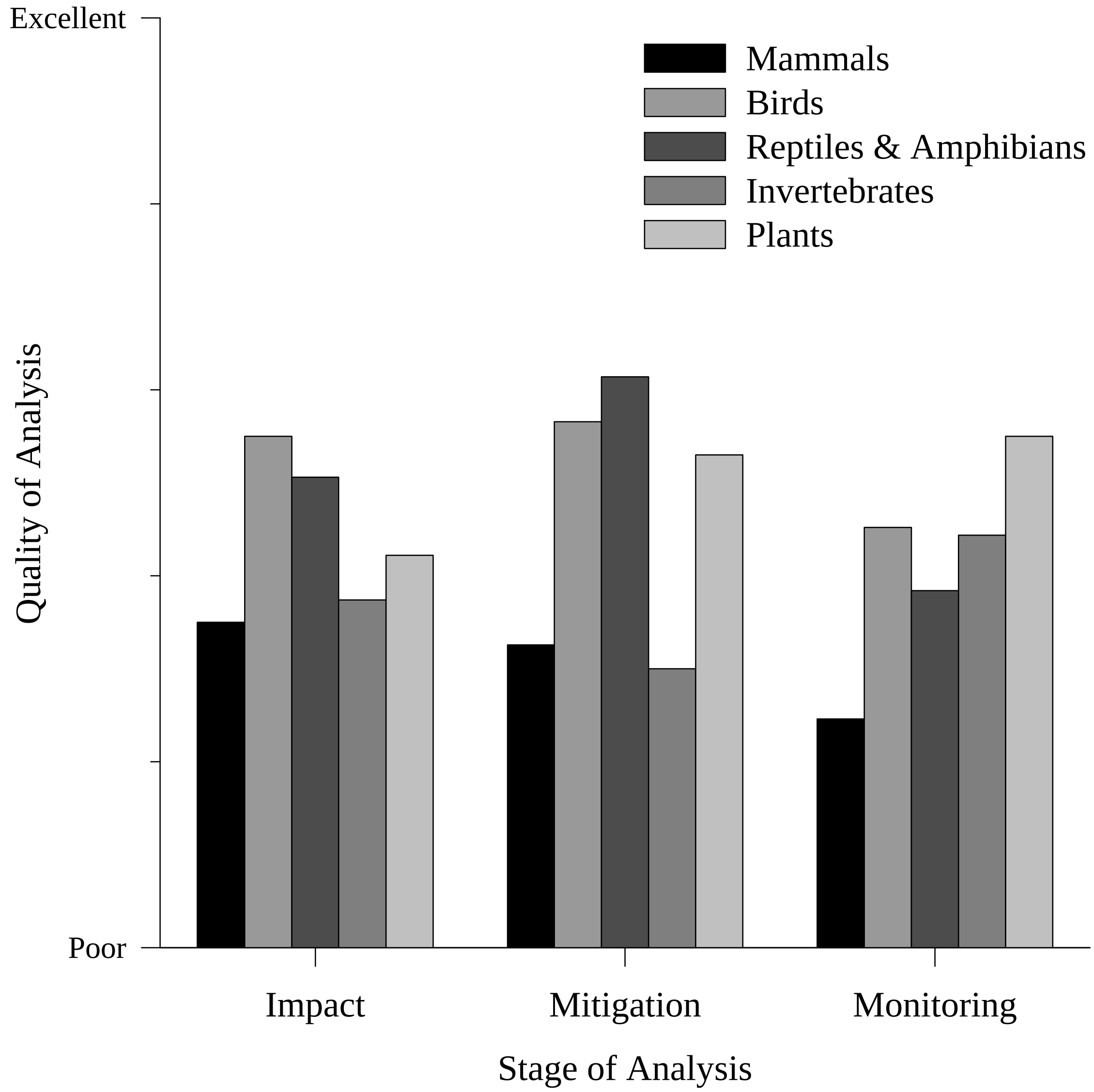

Figure 12. The effect of taxonomic group (SQ:A3) on the quality of analysis and data at several stages of HCP analysis (SQ:D46, E48, F79). Note that mammals have among the lowest scores of any group for all three steps of analysis.

comprise major portions of a species' range, some sort of viability analysis would be worthwhile (and indeed some HCPs do include population viability analyses). A more down-to-earth question would be to ask of any given take, what is lost beyond simply numbers? Is a genetically unique subpopulation lost? Is a substantial portion of genetic variability lost? Is a unique combination of species and habitat lost? Preparers of HCPs cannot be faulted for their limited assessments of take because the HCP handbook gives very little guidance on this matter. This is an area where a combination of population biologists and USFWS scientists could work together to develop some more specific guidelines.

9.2. The Use of Quantitative Methods and Ecological Theory in HCPs

Ecologists and conservation biologists have developed a large body of theory aimed at predicting impacts of management on populations and species (Burgman et al., 1993; Meffe and Carroll, 1994). The conservation literature abounds with suggestions that theory can lead to sound management decisions. We sought both to test and to refine this statement, using two related analyses. First, we determined the extent to which HCPs used quantitative tools and "theory" to assess impacts and mitigation strategies. We divided "theory" into ideas and methods arising from six different subdisciplines: population genetics, population ecology, behavioral and physiological ecology, island biogeography, community ecology, and ecosystem ecology. As an example, an HCP applying genetic theory might estimate inbreeding depression resulting from reduced population sizes related to the planned take. In the same HCP, the effect of take on a species might be estimated from a population model incorporating the influence of habitat loss on population size. We also determined the type of data used to bring a theory to bear on impact or assessment and the quality or appropriateness of the use of theory.

We found that most HCPs did not use theory to make assessments about the impacts of take or to support mitigation strategies. Of the 97 species-plan examples we examined, the six different categories of theory were applied to impact analysis between 8 and 44 times (for some species more than one variety of theory was applied) and to mitigation analysis between 8 and 50 times (Table 14; QB responses to SQ:D1-6 and E1-6). Genetic theory was used least, and theory related to population ecology was applied most often. When theory was used, it most often took the form of a quantitative statistical analysis; such analyses were clear and relevant about 60% of the time and inadequate in the remaining cases. None of the HCPs we analyzed used more sophisticated theories—quantitative models—to project the impacts of take on populations. Such models were also used very infrequently (8 cases total) to project the success of mitigation and minimization efforts. It is important to emphasize that we did not score HCPs as inadequate simply because they failed to use theory. We remark on the absence of theory in HCPs largely as a commentary on a major lack of connection between academic conservation biology and conservation practice.

9.3. Uncertainty and the Precautionary Principle

In many fields of environmental analysis, uncertainty is increasingly recognized as the universal background against which all decision-making takes place. This tenet and its consequences have become known as "the precautionary principle." This principle, long applied in fields as diverse as engineering and economics, holds that in the face of poor information or great uncertainty, managers should adopt risk-averse practices. That is, management actions should be chosen such that there is a correspondence between the uncertainty or lack of information underlying the decision and the size of the potential negative impact resulting from that decision. Adoption of these ideas can be formal or informal. That none of the HCPs we reviewed made explicit mention of the precautionary principle does not mean that the writers and evaluators of these plans did not use risk-aversion criteria in formulating HCP strategies. If HCPs adhere to the ideas of the precautionary principle, we would expect to see four clear patterns:

1. As available information becomes increasingly scarce or uncertain, HCPs should be of shorter duration and/or cover a smaller area.

2. As available information becomes increasingly scarce or uncertain, HCPs should increasingly avoid impact or be restricted to reversible impacts.

3. In all cases, but particularly when mitigation success or take levels are highly uncertain, mitigation measures should be applied before take is allowed.

4. HCPs should include contingencies based on the impact of take and whether or not mitigation efforts succeed. Such contingencies can only be applied in the context of adequate monitoring. Adaptive management in HCPs would provide for various management alternatives according to various future conditions.

One way of assessing the extent to which a precautionary approach is adopted in HCPs is to contrast strategies of mitigation for cases where data were judged to be sufficient and insufficient. For example, if there are insufficient data regarding the impact of take, then one might expect avoidance of take to be more commonly pursued than if there are sufficient data regarding impact. This was not the case. In fact, the precautionary approach of avoidance was either equally likely or even less likely where data were insufficient than where they were sufficient (`). Another precautionary approach is to minimize take, and again this precautionary strategy was either equally likely or even less likely to be pursued when data were lacking (Figure 13). Finally, according to our rating scheme, the most precautionary scenario would involve a mitigation approach that clearly minimized impact to the maximum possible extent. It is worth noting that this line of reasoning is not legally required of USFWS but rather is a more stringent scientific standard for mitigation than current law dictates. We found many HCPs that did pursue such a cautious approach, but it was no more likely when data were insufficient than when data were adequate (Figure 13). In several HCPs, adaptive management is mentioned (even if not clearly developed) as a component of the management scenario. One might think these instances would be most likely where data were lacking. Ironically, the opposite is true—plans for which the data regarding mitigation reliability were judged insufficient were significantly *less likely* to include a discussion of adaptive management than were plans with adequate data: 45% of the 38 cases with insufficient data (SQ:E48) included a discussion of adaptive management (PQ:61), whereas 77% of the 48 cases with adequate data did so ($\chi^2 = 9.5$, $P < 0.05$). In summary, although some HCPs are reassuringly cautious, greater caution was not related to lack of critical information about status, take, and impact. Thus, a precautionary approach does not seem to be evident as a pattern among a large sample of HCPs. Put another way, there is no evidence that the quality of data regarding status, take, and impact influences the approach to reducing impact adopted by HCPs.

10. RECOMMENDATIONS

In this section, we outline scientific standards to which we think HCPs should be held.

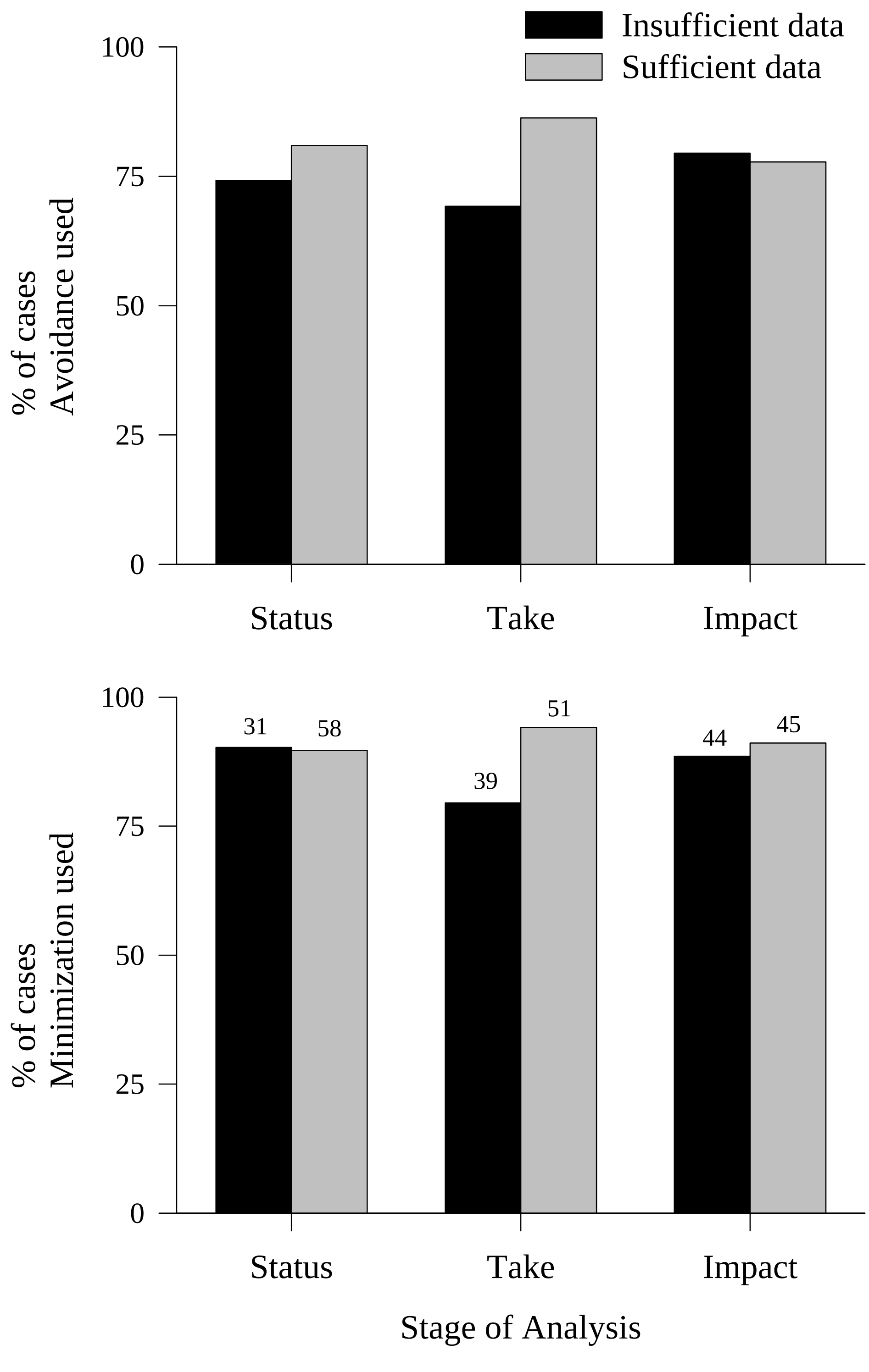

Figure 13. The percentage of cases in which avoidance (SQ:E32 QH) and minimization (SQ:E33 QH) measures were used when supporting data for status, take, and impact were either sufficient or insufficient (SQ:B42, C32, D46).

Our standards identify specific attributes that HCPs should have to be considered scientifically credible. We make these recommendations based on a thorough review and analysis of science in HCPs, but we also recognize that practical constraints may make it difficult to meet these standards. In many cases the landowner or contractor designs an HCP in the absence of critical data. The information required to develop an HCP is often nonexistent. Because this situation was common in the plans we reviewed, and it is likely to recur, we also provide a set of practical recommendations for handling a shortage of data or desired information scientifically. When data are lacking, uncertainty is large and unavoidable. It then becomes imperative that this uncertainty be explicitly acknowledged and measured in some way (even if only on a three-point scale of high, medium, low). We conclude by offering general policy recommendations.

10.1. Standards for a Scientifically Based HCP

Ideally an HCP would be based on knowledge of the basic population biology of all species covered in the incidental take permit, their ecological requirements, and a quantitative estimate of the impact of take on population viability. The plan would evaluate the cumulative effects of multiple plans and activities on covered species, as well as potential interactions among effects. Given limited resources and information available during HCP development, these standards will be difficult to achieve. Nevertheless, we need standards toward which planners can strive and against which HCPs can be measured.

The foundation of any HCP, and its supporting documents, must be data. Assertions such as "take will be 54 animals" do not constitute data. Data must *exist*, *be accessible*, and *be explicitly summarized* in the HCP in order to be scientifically credible. The absence of any of these three "ingredients" precludes a scientifically based HCP. Existence of the data is not sufficient; they must be included in the HCP and available for analysis. It is still possible for scientists to debate how best to use or interpret data, but there is no question that the data must exist in the first place. Data standards should be formalized: all large-area HCPs (or HCPs that cover a major portion of a federally listed species' range) should include an inventory and summary of available data on each covered species, including its overall distribution, abundance, population trends, ecological requirements, basic life history, and the nature of the causes of endangerment. Smaller HCPs can simply point to other HCPs or readily available data sources and inventories. All sources of data should be formally documented. An explicit acknowledgment describing what data are not available should also be included to allow a more accurate assessment of uncertainty and risk in the planning process. In order to provide more concrete suggestions, we consider status, take, impact, mitigation, and monitoring separately.

Status

Adequate determination of status requires that data on distribution, population trends, habitat needs and trends, and threats be examined. The analysis should be both local (within the HCP) and global (so that whatever is going on within an HCP can be put in a biological context). Determining status requires knowledge of a substantial amount of natural history—the threats to a species cannot be identified without considerable knowledge of that species' natural history. Similarly, population trends should be based on more than just a few years of census information.

Take

Take can generally be assessed either by census of a population and prediction of the portion that will be lost or by establishment of relationships between habitat area (and quality) and expected number of individuals contained within that habitat, which in turn allows one to predict reductions in population due to reductions in habitat. An explicit quantitative model should link the activity for which the HCP is initiated to loss of individual organisms, if at all possible.

Impact

Impact does not equal take. This simple fact must be emphasized, because it is neglected or overlooked in a large portion of existing HCPs. Measurement of impact on population or species viability requires data on population processes both within and outside of the HCP (minimally the same data discussed for “status”). If an HCP comprises a large area and a substantial portion of a species’ range, then some attempt should be made at developing a “model” (explicit, but not necessarily mathematical). This model should link take to key population processes. For example, taking 40% of a global population from a source population for the species' whole range is very different from taking 40% of a global population from a sink area. Similar arguments can be made for genetic and evolutionary impacts. Careful thinking about impacts can alter how one goes about summarizing take. For example, the types of individuals taken may be as important as their numbers—the removal of young reproductive individuals usually has the greatest impact on population growth and recovery, so avoidance or preferential take of this age class will profoundly influence the impact of the take. This possibility demonstrates that the quantification of take must be conceptually linked to insights about the population-level impacts of take.

Mitigation

The details of proposed mitigation measures must be explicitly described and accompanied by data regarding their effectiveness. Documenting effectiveness requires information on two levels. First specific effectiveness of the proposed measure should be documented. For example, if transplantation is proposed, what proportion of the transplanted individuals survive to reproduce? Second, the more general effectiveness of the mitigation measures in minimizing impact must be analyzed, so the outcome of mitigation actions must be linked to population processes of the target species.

Monitoring

Without adequate and appropriate monitoring, the success of plans cannot be evaluated. The principal criterion for determining the adequacy of monitoring should be the ability of a monitoring plan to evaluate the success of mitigation measures and the consequent effect on protected species. Monitoring frequencies, methods, and analyses should be designed to permit appropriate modification of mitigation measures in response to species status and should be explicitly documented in the HCP. Monitoring data should be incorporated into centralized data bases to facilitate access to information on the overall status of species and to facilitate assessment of cumulative impacts. Even if monitoring does not lead to rectifying mistakes in its associated HCP, it can furnish information from which future HCPs can be designed so that mistakes are not repeated.

Peer Review

Finally, HCPs should be open to peer review (review by scientists specializing in conservation biology). Although HCPs are the property and responsibility of the applicant, they concern protection of public resources (endangered and threatened species). Thus, the data, analyses, and interpretations made regarding status, take, impact, mitigation, and monitoring should be reviewed to ensure that the scientific foundations of the plans are sound. Peer review is already a standard for science in other regulatory arenas and should be incorporated into the HCP process. The need for peer review is not universal; small HCPs without large irreversible impacts require less scrutiny than large HCPs of long duration and broad ecological impacts.

10.2. Scientific Approaches to a Paucity of Data

The standards we have defined are difficult, if not impossible, to achieve because of a current paucity of pertinent data, but HCPs are not therefore fundamentally unscientific. They must simply use existing data in a scientifically credible fashion. Before we discuss recommended approaches to habitat conservation planning with data shortages, we must address two more general issues about data.

First, when pertinent data are lacking, the top priority before developing an HCP should be to acquire those data. How the data are collected, and by whom, is an issue that will have to be resolved among resource agencies such as USFWS and HCP developers, but there is no surer way to garner scientific credibility than to use data. When collection of all desirable data is not practicable, then the planning process should proceed with caution commensurate with the anticipated risks and uncertainties.

Second, when critical data are absent, an HCP should not be initiated or approved. It would be wrong to call the HCP process scientific, or even rational, if there were no option to halt the process in the absence of crucial information. We need not have all the desired data to produce an HCP—the planning process would be paralyzed because data will always be determined to be insufficient. Rather, the absence of crucial data for certain types of HCPs must be in principle a possible reason for not allowing take until the problem has been corrected. In general, the greater the impact of a plan, (e.g., plans with high impact are those with irreversible impacts, covering a large area or multiple species or spanning more than 20 years), the fewer gaps in critical data should be tolerated.

Shortage of Data on Status

When data on status are few, we must err on the conservative side. What must be avoided is the assertion of healthy status with few supporting data.

Shortage of Data on Take

For small-area HCP's (which we assume will involve small takes) an absence of data on take is acceptable, but for HCP's covering vast expanses of land, take must be quantitatively assessed; if it is not, the HCP process should not be entered into. This is a standard principle of risk assessment—when the hazards are large, the requirements for safety assurances become more severe. When take is not the most pertinent quantity to estimate (as when something like water quality for salmon is subtly degraded) but rather impacts are the issue, a careful assessment of impacts can replace attention to precise take numbers.

Shortage of Data on Impact

A scarcity of data on impacts of take can best be handled by best- and worst-case scenarios. Even without quantitative data, biologists can usually construct a worst-case scenario.

Shortage of Data on Mitigation

If no information validates mitigation as effective, then assessment of mitigation should precede any take. In addition, monitoring must be especially well designed in those cases where mitigation is unproven.

Absence of Explicit Description of Monitoring

Careful monitoring is in some cases a solution to data shortage. For example, when the effectiveness of mitigation is uncertain, monitoring can determine that effectiveness, but only if it is well designed (for example, as a before-and-after study of impact and control). When data are few, explicit measures are needed for using the information from monitoring to alter management procedures. That is, a precise criterion for "mitigation failure" must be specified, as well as procedures for adjusting management when that criterion is recognized. The key point here is that the existence of monitoring is not a solution to data shortage – a quantitative decision process must link monitoring to adjustments in management.

Responding to Uncertainty

In addition to the specific recommendations given above with respect to lack of data, there are general scientific principles for dealing with a lack of information. First, the precautionary principle argues that, in the face of poor information, risk-averse strategies should be adopted. That is, when data are extremely poor, HCP's should be limited to small areas or short duration. Scarce information requires particular care about activities that are irreversible (building a shopping mall as opposed to logging), and monitoring becomes more crucial for assessing the well-being of threatened species. Mitigation measures should be applied before take is allowed, so that their effectiveness can be evaluated. Perhaps the simplest approach would be to put in place scientific advisory panels for plans that lack information and have both long durations and large impact areas. This panel could advise on the development of the plan and its implementation; scientists from recovery teams would be logical choices as a starting point.

10.3. Policy Measures for Attaining More Effective Science in the HCP Process

The goal of our analysis was to evaluate the role of science in the HCP process. In this section we provide a set of recommendations for improving its quality and effectiveness. We recognize that science is not the primary motivation for HCPs and that they must address multiple, often conflicting objectives. They have political, economic, and social objectives as well as scientific ones. We also understand that Section 10 of the Endangered Species Act does not prescribe any scientific standard upon which the approval or disapproval of HCPs is to be based. Section 7 requires only that decisions be based on the "best scientific and commercial data available." While acknowledging these dimensions, we have nonetheless chosen to focus our study on evaluating how science is being used in the HCP process. Our assessment leads to the following recommendations:

1. We recommend that greater attention be given to explicit scientific standards for HCPs, but that this be done in a flexible manner that recognizes that low impact HCPs need not adhere to the same standards as high impact HCPs. A formalized scheme might be adopted so that small HCPs draw on data analyses from large HCPs, assuring that applicants are not paralyzed by unrealistic demands.

2. For the preparation of individual HCPs, we recommend that those with potentially large impact (those that are large in area or cover a large portion of a species' range) include an explicit summary of available data on covered species, including their distribution, abundance, population trend, ecological requirements, and causes of endangerment. HCPs should be more quantitative in stating their biological goals and in predicting their likely impact on listed species. When information important to the design of the HCP does not exist, it may still be possible to estimate the uncertainties associated with impact, mitigation, and monitoring, and to still go forward, as long as risks are acknowledged and minimized. Flexibility can be built into mitigation plans so that managers can be responsive to the results of monitoring during the period of the HCP. When highly critical information is missing, the agencies should be willing to withhold permits until that information is obtained.

3. For the HCP process in general, we recommend that information about listed species be maintained in accessible, centralized locations, and that monitoring data be made accessible to others. During the early stages of the design of potentially high-impact HCPs and those that are likely to lack important information, we recommend the establishment of a scientific advisory committee and increased use of independent peer review (review by scientists specializing in conservation biology). This policy should prevent premature agreements with development interests that ignore critical science.

To pursue these measures will require major agency initiatives or policy alterations. First, the coordination of efforts to protect and recover threatened and endangered species must be improved. This coordination will be essential to the accurate estimation of the cumulative impacts of various management efforts for threatened and endangered species. The data pertaining to these management activities (e.g., HCPs, recovery efforts on federal land, safe-harbor agreements on nonfederal land) should be organized into a single distributed data base system. These data must be accessible to agency and academic scientists for analysis and evaluation of the effectiveness of HCPs and recovery efforts. Better coordination and accessibility of scientific examinations of endangered species recovery does not require any legislative change, but it would require a funding commitment to put a centralized data base in place. Frankly, we think that centralized and readily accessible data on endangered species could do for species protection what centralized and accessible data on criminals and outstanding warrants has done for public safety protection. Surely, if we can do this for law enforcement, we can also do it for environmental protection.

Second, both academic and agency scientists should become more involved in the HCP process, for example through encouragement of peer review and the establishment of advisory committees. Recovery plans are currently peer-reviewed, and the culture to obtain such review already exists in the pertinent government agencies.

Last, we encourage USFWS and NMFS to conduct their own review of the HCP process from the perspective of identifying mechanisms for making the job of their agency scientists more clearly defined. This process could entail revision of the HCP handbook, pushes for better data access, and institutional commitment to peer review. The HCP process need not compromise the quality of its science just because it must balance science and negotiation with development interests. Clearly, it could sharpen the light cast by science if the guidelines for scientific input were improved. Reference to data, peer review, and significant adaptive management are too often absent from the HCP process. To remedy these deficiencies will require more resources. The USFWS is currently being asked to do too much with too few resources in this HCP process.

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Table 1. Key terminology pertaining to HCPs and the Endangered Species Act, and how this terminology relates to the review of scientific input.

Take:

> As defined by the ESA (Section 3(15)), *take* means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."
>
> where:
> ***Harass*** [refers to] an intentional or negligent act or omission which creates the likelihood of injury to wildlife to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. (50 CHR 17.3)
>
> ***Harm*** [refers to] any act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. (50 CFR 17.3)

Our Scientific Perspective: In this analysis when we asked whether take was adequately quantified we sought either an assessment of the numbers of individuals that would be lost, or a quantitative assessment of habitat lost for which there was a good foundation for translating area of habitat lost into numbers of individuals lost. Simply reporting area lost, without a clear idea of how it translates into numbers of individuals, would not be accepted as an adequate assessment of take.

Minimization and Mitigation:

> ***Minimization and mitigation*** usually take one of the following forms: (1) avoiding the impact (to the extent practicable); (2) minimizing the impact; (3) rectifying the impact; (4) reducing or eliminating the impact over time; or (5) compensating for the impact. Minimization and mitigation incorporate a wide variety of required components, such as establishing biological goals & objectives; habitat acquisition, restoration or enhancement; establishing or implementing monitoring program; or adaptive management strategies, if needed. The specific strategy or combination of strategies used will depend on the species and type of habitat involved.
>
> An adequate minimization and mitigation program is one based on sound biological rationale, is commensurate with the impacts of the activity proposed under the incidental take permit, and can be implemented. It is not always practicable for mitigation to precede take, although minimization and mitigation must generally keep pace with impact.

Our Scientific Perspective: In this analysis, we sought not only to evaluate whether the proposed minimization and mitigation activities are appropriate given the expected impacts, but also to determine how well currently available data support their use and reliability.

Minimization and Mitigation to the Maximum Extent Practicable:

> Where the adequacy of the minimization and mitigation is a close call, the record must contain some basis to conclude that the proposed program is the maximum that can be reasonably required by that applicant. This may require weighing the benefits and costs of implementing additional minimization and mitigation, the amount of minimization and mitigation provided by other applicants in similar situations, and the abilities of that particular applicant.

Our Scientific Perspective: We are not in a position to judge whether FWS met the "maximum extent practicable" standards. However, in cases where proposed minimization and mitigation activities may not be adequate, HCPs should clearly demonstrate why and how these activities are limited by practicability. We therefore assessed whether or not each plan contains language and data intended to show that the proposed minimization and mitigation activities are the maximum that could reasonably be required of the applicant.

Table 1. (continued)

Monitoring:

> Two types of monitoring are required in HCPs: compliance monitoring and effects and effectiveness monitoring. ***Compliance monitoring*** is where the Service monitors the applicant's implementation of the requirements of the HCP, and permit terms and conditions.
>
> ***Effects and effectiveness monitoring*** is where the applicant (or other approved, designated entity) monitors the impacts of the authorized incidental take (effects) and implementation of the minimization and mitigation strategies to determine if the actions are producing the desired results (effectiveness).

Our Scientific Perspective: We focus only on effects and effectiveness monitoring, which essentially represent monitoring aimed at tracking the response of a potentially impacted population to activities permitted under the HCP. If an HCP involves a very small piece of land with minimal likely population impact, a monitoring program might not be necessary, and in those cases our standards for assessing the clarity of monitoring were relaxed. In those cases, we simply required that the absence of a clear monitoring program was well-justified.

Table 2. Mandatory requirements of HCPs. These represent the five criteria for issuance of an incidental take permit (ITP), as described in the Endangered Species Act (16 U.S.C. §1539(a)).

The **landowner** (applicant for HCP approval) must specify:	Requirements by **FWS / NMFS** for HCP approval:
The impact which will likely result from such taking	The taking will be incidental to an otherwise lawful activity
Steps that will be taken to minimize and mitigate such impacts	The applicant will, to the maximum extent practicable, minimize and mitigate impacts of such taking
The funding available to take minimization and mitigation steps	There will be adequate funding to carry out the HCP
What alternative actions to such taking the applicant considered, and the reasons why such alternatives are not being utilized	The taking will not appreciably reduce the likelihood of survival and recovery of the species in the wild
Other measures that FWS / NMFS may require	The landowner agrees to include other measures that FWS or NMFS may have required, including reporting requirements that may be necessary to determine whether the terms and conditions are being complied with

Table 3. Relationship of overall adequacy scores to detailed questions for status, take, impact, and mitigation. To determine whether the overall adequacy ratings were valid reflections of the detailed information considered and omitted from each step in HCP planning, we regressed these ratings on three subquestions each (QB: was information used?, QC: what was the data quality?, and QD: how were the data used?) for seven variables (habitat data, trends in habitat, population data, genetics, metapopulation, community changes plus extrinsic factors, and catastrophes). In Appendix III, all single one-way regressions are reported. Below we summarize the results of the multiple regression for each "adequacy" summary score. Refer to Appendix III to see which independent variables were included in each model.

Adequacy Rating	**Question**	**P-value**	**N**	**R^2**
Status	QB	0.0001	94	0.26
	QC	0.05	41	0.59
	QD	0.05	65	0.64
Take	QB	0.005	13	0.92
	QC	0.0005	46	0.32
	QD	0.005	79	0.17
Impact	QB	0.01	35	0.59
	QC	0.005	31	0.58
	QD	*ns*	70	0.31
Mitigation	QB	*ns*	33	0.23
	QC	0.0001	12	1.00
	QD	*ns*	47	0.73

Table 4. Relationship of overall adequacy scores to detailed questions for three types of monitoring. To determine whether the overall adequacy ratings were valid reflections of the detailed information considered and omitted from each step in HCP planning, we regressed these ratings on three subquestions each (QL: what is quality of data to be collected?, QM: what is the connection between data and monitoring goals?, and QN: what is missing from planned data collection?) for seven variables (individual data, population data, individual rate data, genetics, metapopulation, community changes plus extrinsic factors, and habitat data). In Appendix III, all single one-way regressions are reported. Below we summarize the results of the multiple regression for each "adequacy" summary score. Refer to Appendix III to see which independent variables were included in each model.

Adequacy Rating	**Question**	**P-value**	**N**	**R^2**
Monitoring of Take	QL	0.05	63	0.42
	QM	0.0001	4	1.00
	QN	0.05	42	0.91
Monitoring of Status	QL	0.05	71	0.43
	QM	*ns*	3	0.25
	QN	*ns*	43	0.90
Monitoring of Mitigation	QL	*ns*	51	0.29
	QM	*ns*	3	0.25
	QN	0.05	45	0.88

Table 5. Checks on the importance of plan and school effects on answers to species-level questions. Results are shown for a set of mixed linear models using SAS PROC MIXED. We used these models to see if universities and plans differed with respect to ratings and whether these differences impacted the statistical significance of the relationship of the five adequacy ratings to the factors Date, Duration, Multiple Species (yes/no), Taxon, and Area. Each set of results shown was considering one fixed effect. Results reported are the p-values for models that do not (GLM p-value) and do (MIXED p-value) include the school and plan effects, and the variation explained by school effects and residual variation. Significant school effects are indicated by a low p-value in the mixed model row and a large school variation explained relative to residual variation.

Permit Date:

	Status	Take	Impact	Mitigation	Monitoring
GLM p-value	<.01	<.01	.02	.02	.04
MIXED p-value	<.01	<.01	.14	.27	.23
School variation	.01	.35	.13	.65	.26
Residual variation	1.17	1.20	.71	1.20	.99

HCP Duration:

	Status	Take	Impact	Mitigation	Monitoring
GLM p-value	.07	.01	<.01	<.01	.08
MIXED p-value	.15	.09	.32	.27	.31
School variation	.01	.20	.11	.50	.23
Residual variation	1.18	1.22	.70	1.20	.93

Multiple versus single species plans:

	Status	Take	Impact	Mitigation	Monitoring
GLM p-value	.83	.83	.15	.67	.43
MIXED p-value	.61	.73	.27	.52	.48
School variation	.18	.21	.25	.79	.30
Residual variation	1.21	1.17	.69	1.15	.94

HCP Area:

	Status	Take	Impact	Mitigation	Monitoring
GLM p-value	.02	.53	<.01	<.01	.06
MIXED p-value	.07	.73	.02	.06	.37
School variation	.01	.19	.19	.67	.33
Residual variation	1.20	1.18	.72	1.17	.98

Taxon:

	Status	Take	Impact	Mitigation	Monitoring
GLM p-value	.13	.74	.09	.03	<.01
MIXED p-value	.30	.35	.10	<.01	.19
School variation	.09	.25	.15	.88	.19
Residual variation	1.14	1.11	.63	.97	1.03

Table 6. Number of species (grouped by taxa) included in HCPs, and number of HCPs covering one or more species of these taxa (AQ:1c). Taxonomic groups are logical and convenient groupings, but do not represent taxonomic equivalents. Total number of plans in third column exceeds 208 because some plans cover species in more than one taxonomic group.

Taxa	**Number of species included in at least one HCP**	**Number of HCPs covering taxa**
Birds	22	143*
Fish	1	1
Mammals	13	32
Amphibians and reptiles	19	33
Invertebrates	18	16
TOTAL ANIMALS	**73**	**227**
Plants	15	7
TOTAL SPECIES	**98**	**234**

* >70 are for the golden-cheeked warbler in Travis County, Texas

Table 7. Proportion of cases, by data category, in which significant or starkly necessary species information was absent from HCP documents, despite being available in the literature (scored as QD=2 or 3). Separate results are shown for data regarding status (SQ:B1-24), take (SQ:C3-18), biological impact (SQ:D7-30), and mitigation (SQ:E7-30). Proportions 20% or higher are highlighted in bold. Sample sizes in parentheses. Data was not collected for certain categories under Take; in addition, note that several Take categories differ in emphasis (as indicated by an asterisk).

Data Categories	Status	Take	Impact	Mitigation
Habitat Affiliations	2 (94)		8 (85)	13 (85)
Amount & Quality of Feeding Habitat	9 (65)		9 (70)	**24** (63)
Amount & Quality of Breeding Habitat	15 (67)		11 (63)	**20** (65)
Amount & Quality of Migration Habitat	19 (42)		15 (48)	**35** (55)
Trends in Habitat Quality	8 (85)	12 (74)*	6 (72)	11 (72)
Trends in Habitat Amount	6 (83)	10 (82)*	5 (74)	6 (80)
Habitat Fragmentation	13 (80)	7 (82)	5 (74)	6 (81)
Population Size	6 (88)	1 (82)	7 (72)	12 (73)
Trends in Population Size	3 (80)	4 (77)	5 (74)	7 (75)
Population Trends by Habitat Type	2 (63)	10 (84)*	1 (70)	8 (64)
Demographics	16 (74)	10 (74)	11 (65)	14 (66)
Basic Genetics	19 (72)		8 (66)	16 (71)
Genetic Structure	8 (73)		6 (66)	13 (71)
Movement Abilities	6 (64)	10 (69)	5 (66)	15 (65)
Extrinsic Factors	13 (77)	4 (72)	6 (70)	**27** (77)
Interactions with Food Species	12 (61)	2 (68)	6 (63)	17 (60)
Interactions with Consumer Species	10 (72)	10 (68)	5 (65)	10 (74)
Indirect Interactions	3 (64)		0 (58)	2 (55)
Pollution	15 (79)	10 (77)	8 (64)	15 (78)
Climate Change	15 (74)		11 (63)	13 (71)
Successional/Disturbance Regimes	17 (89)		16 (77)	**24** (83)
Environmental Variability	17 (84)		**23** (65)	**24** (80)
Catastrophes	15 (85)		19 (69)	19 (80)
Cumulative Impacts & Interaction Effects	**23** (84)		14 (79)	**24** (83)

Table 8. In cases where species data (by category) was included in the HCP (QA=1, 2, or 3), proportion of these in which the data was **not** used in a good or excellent manner (QC=0 or 1). Separate results are shown for data regarding status (SQ:B1-24), take (SQ:C3-18), biological impact (SQ:D7-30), and mitigation (SQ:E7-30). Proportions 50% or above are highlighted in bold. Only values for sample sizes ≥20 species are included. Given this criterion for inclusion, five categories (Amount & Quality of Migration Habitat, Basic Genetics, Genetic Structure, Interactions with Food Species, and Climate Change) were omitted because sample sizes were too low for all stages of analysis. Sample sizes in parentheses. Data was not collected for certain categories under Take; in addition, note that several Take categories differ in emphasis (as indicated by an asterisk).

Data Categories	Status	Take	Impact	Mitigation
Habitat Affiliations	11 (91)		26 (69)	19 (78)
Amount & Quality of Feeding Habitat	31 (45)		**53** (34)	39 (36)
Amount & Quality of Breeding Habitat	21 (53)		32 (40)	23 (43)
Trends in Habitat Quality	18 (60)	25 (71)*	11 (47)	8 (47)
Trends in Habitat Amount	13 (67)	21 (38)*	19 (52)	24 (53)
Habitat Fragmentation	29 (56)	37 (40)	31 (48)	22 (49)
Population Size	17 (71)	6 (46)	23 (47)	19 (43)
Trends in Population Size	28 (54)	33 (30)	39 (44)	7 (40)
Population Trends by Habitat Type	29 (24)	23 (39)*	36 (25)	
Demography	**50** (20)			
Movement Abilities	36 (33)	28 (29)	30 (30)	23 (34)
Extrinsic Factors		**62** (21)	**68** (22)	**64** (25)
Interactions with Consumer Species	35 (20)	32 (22)	28 (29)	15 (27)
Pollution		15 (20)		
Successional/Disturbance Regimes	43 (46)		**58** (31)	29 (44)
Environmental Variability	43 (28)			**75** (20)
Catastrophes	**58** (26)			**63** (27)
Cumulative Impacts & Interaction Effects	46 (22)			48 (27)

Table 9. Local and global statistics on habitat quality (SQ:B28, B29) and trends in habitat quantity (SQ:B34, B35) for species included in HCPs. Sample sizes shown in parentheses.

	Within HCP area	Globally
Habitat quality		
Poor	39.7%	14.9%
Medium	51.3%	70.1%
Excellent	9.0.%	14.9%
	(N=78)	(N=67)
Trends in habitat quantity		
Declining rapidly	6.7%	7.4%
Declining	56.0%	80.3%
Stable	37.3%	12.4%
Increasing	0%	0%
	(N=75)	(N=81)

Table 10. Six impacts considered to be most important on average, based on our evaluation (SQ:D32-45 QG). Two or more impacts could be considered important for any one species, so the percentages do not sum to 100%. We ranked categories of impact according to their effect on the species on a 4 point scale (1=no noticeable effect; 2=some effect but not of serious consequence; 3=moderately important effect deserving of consideration; 4=a serious effect that will significantly impact the population). The values reported are the means of these scores across all species in the HCPs reviewed for each impact category. The right-hand column shows the percentage of times these impacts were considered in HCPs (QE).

Category of impact, ranked	**Mean importance of impacts (sample sizes in parentheses)**	**% of species for which impact was considered in the HCP (N=97)**
1. Total acreage of habitat lost	3.13 (70)	85%
2. Percent of habitat lost	2.69 (70)	53%
3. Total individuals killed	2.54 (70)	52%
4. Fragmentation of habitat	2.54 (76)	66%
5. Cumulative impacts	2.45 (74)	27%
6. Altered interspecific interactions	2.37 (71)	45%

Table 11. Adequacy in addressing primary threat (SQ:E45) and in minimizing impacts (SQ:E47) to species in HCPs. Samples sizes shown in parentheses.

	Sufficient or above	**Insufficient or below**
Adequacy in addressing primary threat to the species (N=87)	10% excellent 18% above average 29% sufficient	25% significantly lacking 13% inadequate 5% extremely poor
	Sufficient or above	**Insufficient or below**
Adequacy in minimizing impacts to the maximum extent practicable (N=82)	12% excellent 13% above average 27% sufficient	16% significantly lacking 17% inadequate 15% extremely poor

Table 12. Significant effects on steps in HCP analysis. Columns show results for the adequacy of each of the five planning stages, the dependent variables; rows are for each of the independent variables considered. All p-values of 0.10 or less are shown for unweighted one-way and multi-way MANOVAs (first and second lines per cell) and weighted (by 1/(# species per plan)) one-way and multi-way MANOVAs (third and fourth lines per cell). Multiway analyses include only those independent variables showing any significant effects ($p<0.05$) in preliminary multi-way analyses. Following each p-value in the table is a symbol denoting whether increasing values of the independent variable have positive (+) or negative (-) on the adequacy score. Probabilities for overall effects are Wilk's Multivariate λ.

	STATUS	**TAKE**	**IMPACT**	**MITIG.**	**MONIT.**	**OVERALL**
DURATION	*ns* *ns* <.01 (+) .02 (+)	*ns* <.01 (-) *ns* <.01 (-)	*ns* *ns* .03 (+) *ns*	*ns* *ns* .02 (+) *ns*	*ns* *ns* *ns* *ns*	.08 <.01 <.01 <.01
AREA	*ns* .04 (-)	*ns* *ns*	*ns* .07 (-)	*ns* *ns*	*ns* *ns*	*ns* .09
RECOVERY PLAN	<.01 (-) .03 (-) .04 (-)	*ns* .06 (-)	*ns* *ns*	*ns* *ns*	<.01 (-) .09 (-) .04 (-)	<.01 <.01 .08
SPECIES NUMBER	*ns* *ns*	*ns* *ns*	.08 (+) .04 (+)	*ns* *ns*	*ns* *ns*	*ns* *ns*
HABITAT-BASED	.01 (+) *ns* .01 (+) *ns*	.05 (+) <.01 (+) <.01 (+) <.01 (+)	<.01 (+) <.01 (+) <.01 (+) .01 (+)	.04 (+) *ns* .05 (+) *ns*	<.01 (+) *ns* *ns* *ns*	.03 <.01 <.01 .01
TAXON	.03 *ns* <.01 .06	*ns* .01 <.01 .01	.07 .02 <.01 <.01	<.01 .04 <.01 .05	.04 *ns* .02 <.01	<.01 <.01 <.01 <.01
DATE	<.01 (+) .04 (+) <.01 (+) <.01 (+)	<.01 (+) .03 (+) <.01 (+) .01 (+)	.03 (+) *ns* .03 (+) *ns*	.04 (+) *ns* .04 (+) *ns*	.02 (+) *ns* *ns* *ns*	.01 *ns* <.01 <.01

Table 13. Percent of species with and without recovery plans (SQ:A8) and critical habitat designations (SQ:A10) whose HCPs were deemed to have included adequate information and analysis to estimate status (SQ:B42), take (SQ:C32), impact (SQ:D46), mitigation (SQ:E48), and monitoring (SQ:F79) of the species. Of the 97 species analyzed, 59 had recovery plans and 21 had critical habitat designations. Sample sizes shown in parentheses.

	% of Species with Adequate Information			
	Recovery Plan		**Critical Habitat Designation**	
Category	**With**	**Without**	**With**	**Without**
Status	60 (58)	76 (21)	29 (21)	77 (52)
Take	58 (57)	43 (21)	45 (20)	56 (50)
Effect	52 (56)	40 (20)	35 (20)	52 (50)
Mitigation	52 (54)	55 (20)	45 (20)	48 (48)
Monitoring	42 (52)	61 (18)	37 (19)	46 (46)

Table 14. Use of ecological theory in HCPs to estimate the adequacy of impacts of take (SQ:D1-6) and of mitigation/minimization measures (SQ:E1-6). Six categories of theory are included: genetic (gene.), population ecology (popn.), behavioral/physiological (behav.), biogeographical (biog.), community ecology (comm.), and ecosystem (ecosys.). Analysis is rated as either expert opinion, qualitative data, quantitative data with limited or poor statistical analysis, quantitative data with clear and relevant analysis, or quantitative data with good modeling of processes to extrapolate into the future (QB responses). Data are for 97 species.

	Category of Theory					
	Gene.	Popn.	Behav.	Biog.	Comm.	Ecosys.
Impact Assessment						
Expert Opinion	4	0	9	9	7	5
Qualitative	1	9	11	5	11	2
Limited Quant.	1	17	3	3	5	2
Clear Quant.	2	18	7	5	12	13
Quant. Model	0	0	0	0	0	1
# Times Theory Used	8	44	30	22	35	23
Mitigation Assessment						
Expert Opinion	5	8	7	9	6	7
Qualitative	1	14	9	4	29	16
Limited Quant.	0	15	11	4	5	2
Clear Quant.	2	11	7	11	6	14
Quant. Model	0	2	0	3	2	1
# Times Theory Used	8	50	34	31	48	40

APPENDIX I-A.

Plan-based questions asked of 43 focal HCPs (referred to in text as "PQ" questions).

General guidelines:

<u>FOR ALL QUESTIONS**</u>**

-1 = Data/info does not exist
-2 = Not applicable
-3 = Could not be determined

<u>FOR YES/NO [y/n] QUESTIONS</u>

0 = No
1 = Yes

<u>FOR RANKED SERIES</u>

-1 = Not used at all
1 = Most important
2 = Next most important
…etc.

When ties exist, subsequent items are "gap ranked." E.g., if two items receive a ranking of 1, then the next most important item is scored as a 3 (not a 2).

<u>SPECIAL CATEGORICAL RESPONSES</u>

In cases where question-specific categorical responses are required, the category codes are indicated beneath the question.

#	FOCAL PLAN QUESTIONS (PQ)
1.	Year of application
2.	Year preparation began
3.	Year permit began
4.	Year permit expires
5.	Duration (in years) of preparation process
6.	[y/n] Is there intermittent review of the permit?
7.	Is this a single species (1) or multi-species (2) plan?
8.	[y/n] Is this a "habitat-based" plan?
9.	Number of permitees
10.	Is this a "Low impact" (0) or normal (1) HCP?
11.	Total number of species covered in permit
12.	Number of 'primary' species covered
13.	Number of 'secondary' species covered
14.	Number of 'indicator' species covered
15.	Number of ESA endangered species covered
16.	Number of ESA threatened species covered
17.	Number of non-ESA-listed species covered
18.	Number of non-ESA, but state-listed species covered
19.	Number of ESA-listed plant species that occur in the affected area and are mentioned
20.	Geographical extent of the plan *1 = Local (one county or less)* *2 = Regional (multi-county)* *3 = State* *4 = Multi-state* *5 = Marine open-ownership*
21.	Total area (in ha) of "HCP region" (i.e., including intervening, non-covered land)
22.	Area (ha) in this "HCP region" owned by federal government
23.	Area (ha) in this "HCP region" owned by state and local governments
24.	Area (ha) in this "HCP region" owned by private landowners
25.	Area (ha) in this "HCP region" undeveloped
26.	Human population density (persons/ha) in this "HCP region"
27.	Expected change in the human population in this "HCP region," over the plan's duration *1 = Shrink* *2 = No change* *3 = Modest changes* *4 = Rapid population growth (>doubling over plan duration)*

28.	Total area (ha) actually covered in permit
29.	Maximum distance (km) between points in areas covered
30.	[y/n] Is habitat in the area covered fragmented? *Note: Based on percolation ideas: if there are clear connections, for the most part, over the whole landscape, then NO (not fragmented). If any covered species can't percolate through, then YES*.
31.	Qualitative description of habitat fragmentation *1 = Most patches share >50% of boundaries with other habitat patches, or most patches are accessible to dispersers of the primary species* *2 = Most patches share <50% of boundaries with other habitat patches, but are not completely isolated, or most patches have some chance of communication with other patches through dispersers* *3 = Most patches share no boundaries with other habitat patches, and/or have effectively no chance of exchanging dispersers with other patches*
32.	Total number of fragments
33.	Mean fragment size (in ha)
34.	[y/n] Is the land ownership in the area covered fragmented?
35.	Qualitative description of property fragmentation *Same codes as for #31, but defining a patch to be a parcel of land owned by another person rather than a piece of distinct habitat*
36.	Mean size (in ha) of land parcels with separate ownership
37.	Total number of land parcels affected
38.	[y/n] Is the plan presented in a meta-population framework?
39.	[y/n] Does the plan use ideas from island biogeography?
40.	[y/n] Does the plan cover exact parcels, specified in the plan?
41.	[y/n] Is the plan to cover one or more ecological defined habitats? *Note: If the area does not make sense as a distinct ecological habitat or community, then NO. If the plan is designed to cover a distinct habitat or community, then YES.*

Ranked relative importance of the following as permit-motivating activities:	
42.	Logging
43.	Building of houses, offices, or other buildings
44.	Agriculture
45.	Livestock grazing
46.	Dams
47.	Water diversions
48.	Highway building
49.	Other

50.	[y/n] Are the primary impacting activities reversible? *Note: If the impacts are irreversible under the plan (e.g., housing development), then NO. If the impacts are at least partially reversible (e.g., logging), then YES.*
51.	Average timescale [in years] of habitat recovery to baseline condition
52.	[y/n] Do other HCPs include the focal species in same or contiguous areas?
53.	If yes to #52: Year of earliest such HCP
54.	If yes to #52: Proximity to this HCP *0 = In the same area* *1 = In contiguous areas* *2 = In geographically distant areas*
55.	[y/n] Are there other HCPs done for the same area this HCP, but for different species?
56.	[y/n] Are there other plans involving the species on nearby public lands (e.g. forest management plans)
57.	Duration (in years) of mitigation efforts under the plan [*999 = "in perpetuity"*]
58.	Duration (in years) of monitoring efforts under the plan [*999 = "in perpetuity"*]
59.	[y/n] Is there a reversion clause in the HCP for the event that the species goes extinct of changes in status?
60.	[y/n] Is there are clear monitoring plan proposed in the HCP?
61.	[y/n] Are there any clear, specific provisions for 'adaptive management' or other changes in management during the duration of the plan?
62.	*For the primary species*: Mean lifespan (in years) of an individual that makes it through the juvenile period

63.	*For the primary species*: Net reproductive rate (offspring per year)
64.	*For the primary species*: Clutch or litter size
65.	Type of owner(s) of the land to be permitted *1 = Private companies/individuals* *2 = Local governments* *3 = State governments* *4 = Mixture of ownership types*
66.	If there is a permitting agency: Type of agency *1 = Local government* *2 = State government* *3 = Federal government* *4 = NGO* *5 = Private company*
67.	If there is a permitting agency: Number of signers to plan
68.	Primary preparer of the HCP *1 = Private consulting firm* *2 = Academic scientists* *3 = Employees of land-holder* *4 = Employees of local government* *5 = State government employees* *6 = Federal employees*
69.	Extent of FWS/NMFS involvement in plan preparation *0 = Not at all* *1 = Moderate participation (e.g., some review and suggestions)* *2 = A major player that formulated much of the plan*
70.	[y/n] Did Service biologists ever visit the HCP site?
71.	Estimated total number of Service person-hours on-site
72.	Who primarily paid the preparers? *1 = Permit-holder* *2 = Local government* *3 = State government* *4 = Third parties (e.g., conservation groups)* *5 = Federal government* *6 = Committee with multiple representatives*
73.	Who primarily chose and approved the preparers? *1 = Permit-holder* *2 = Local government* *3 = State government* *4 = Third parties (e.g., conservation groups)* *5 = Federal government* *6 = Committee with multiple representatives*
74.	[y/n] Were known experts of the species (in the plan) involved in preparation or review of the document?

How many people of the following groups were on the steering committee?	
75.	Environmental group members
76.	Academics
77.	Other individuals
78.	Industry group people
79.	Company employees
80.	Government personnel in USFWS/NMFS
81.	Federal government personnel not in USFWS/NMFS
82.	Local government personnel
83.	Other

84.	[y/n] Is there a science advisory board for the plan?

How many people of the following groups are on the Science Advisory Board?	
85.	Environmental group members
86.	Academics

87.	Other individuals
88.	Industry group people
89.	Company employees
90.	Government personnel in USFWS/NMFS
91.	Federal government personnel not in USFWS/NMFS
92.	Local government personnel
93.	Other

94.	Total number of comments submitted about the plan during the public comment period
95.	Number of comments that raised substantive scientific points

How many people of the following groups submitted reviews and comments?	
96.	Environmental group members
97.	Academics
98.	Other individuals
99.	Industry group people
100.	Company employees
101.	Government personnel in USFWS/NMFS
102.	Federal government personnel not in USFWS/NMFS
103.	Local government personnel
104.	Other

105.	Was the plan altered as a result of public comment? *0 = No* *1 = Minor alterations* *2 = Significant alterations of the impacts, mitigation, or monitoring*

Who is primarily responsible for the following?:	
106.	Overseeing the mitigation *(see codes below)*
107.	Doing the mitigation *(see codes below)*
108.	Overseeing the monitoring *(see codes below)*
109.	Doing the monitoring *(see codes below)*
	1 = Private consulting firm *2 = Academic scientists* *3 = Employees of land-holder* *4 = Employees of local government* *5 = State government* *6 = Federal employees* *7 = Committee with multiple representatives*

110.	Number of species removed from consideration because of insufficient data
111.	Estimated number of hours put into plan preparation
112.	Total estimated cost of HCP preparation (in U.S. dollars)
113.	[y/n] Is there a clear assessment of how the proposed actions minimize possible impacts on species and habitats?

Rank the following mitigation strategies by their relative importance in the plan:	
114.	Safe harbors' land conservation/restoration
115.	Habitat banks
116.	Public land acquisition
117.	Maintain/restore disturbance regimes
118.	Conservation easements
119.	Rotating management regimes/easements
120.	Habitat restoration
121.	$$ for research
122.	Enhancement of existing habitat through directed manipulations
123.	Captive breeding programs

124.	[y/n] Is there a clear plan for who will fund mitigation/minimization?
125.	General timing of funding *1 = Substantial funds for mitigation and monitoring established before impacts occurred* *2 = Most funds are generated as impacts occur ("pay as you go")*
126.	[y/n] Will any actual mitigation procedures occur before take occurs?

Rank the relative importance of the following funding methods in this plan:	
127.	One-time development fees
128.	Continuing (e.g. yearly) development fees
129.	Tax check-off programs
130.	Assessment districts under state, city, or county ordinance
131.	Direct contribution from state, city, or county funds
132.	Federal funds
133.	Funds from other, private sources (e.g. conservation groups)

Rank the relative importance of the following categories of information/analysis in the plan's assessment of the current status of the habitat/species (within the permit area):	
134.	Species-specific information (genetics, demographics, etc.)
135.	Species diversity information
136.	Community structure/dynamics info. (e.g. altered trophic interxns)
137.	Habitat quantity and trends in quantities
138.	Habitat quality distributions and trends in qualities
139.	Habitat fragmentation and trends in fragmentation
140.	Altered/maintained disturbance regimes
141.	Other

Rank the relative importance of the following categories of information/analysis in the plan's assessment of the effects of the proposed impacts on the habitat/species:	
142.	Species-specific information (genetics, demographics, etc.)
143.	Species diversity information
144.	Community structure/dynamics info. (e.g. altered trophic interxns)
145.	Habitat quantity and trends in quantities
146.	Habitat quality distributions and trends in qualities
147.	Habitat fragmentation and trends in fragmentation
148.	Altered/maintained disturbance regimes
149.	Other

Rank the relative importance of the following categories of information/analysis in the plan's assessment of the effects of the proposed mitigation on the habitat/species:	
150.	Species-specific information (genetics, demographics, etc.)
151.	Species diversity information
152.	Community structure/dynamics info. (e.g. altered trophic interxns)
153.	Habitat quantity and trends in quantities
154.	Habitat quality distributions and trends in qualities
155.	Habitat fragmentation and trends in fragmentation
156.	Altered/maintained disturbance regimes
157.	Other

Rank the relative importance of the following categories of information/analysis in the plan's monitoring schemes for the habitat/species:	
158.	Species-specific information (genetics, demographics, etc.)
159.	Species diversity information
160.	Community structure/dynamics info. (e.g. altered trophic interxns)
161.	Habitat quantity and trends in quantities
162.	Habitat quality distributions and trends in qualities
163.	Habitat fragmentation and trends in fragmentation
164.	Altered/maintained disturbance regimes
165.	Other

166.	How did the actual take compare to the plan's prediction? *0 = Actual less than anticipated* *1 = Approximately equal* *2 = More take than predicted*
167.	[y/n] Was the monitoring plan sufficient to evaluate the plan's success?
168.	[y/n] Did substantial changes in extrinsic factors occur that the plan did not anticipate?
169.	[y/n] If so, did implementation of the plan change to adequately account for these problems?
170.	[y/n] Did new information arise on the species in the plan that would substantially change the planned take, monitoring, mitigation, etc?
171.	[y/n] If so, did implementation of the plan change to adequately account for these problems?
172.	[y/n] Have the mitigation methods and standards used in the HCP been used in subsequent plans?
173.	[y/n] Are there new listings of species covered in the plan?
174.	Number of newly listed species that live in the affected area, but are not covered in the plan
175.	How does the level of enrollment in the plan (for permitting plans to which different landowners subscribe) compare to anticipated enrollment? *0 = Actual less than anticipated* *1 = Approximately equal* *2 = More take than predicted*
176.	[y/n] Was the "extraordinary circumstances" caveat ever invoked?

APPENDIX I-B.

Species-based questions asked of 43 focal HCPs (referred to in text as "SQ" questions).

General guidelines:

<u>FOR ALL QUESTIONS**</u>**

- -1 = Data/info does not exist
- -2 = Not applicable
- -3 = Could not be determined

<u>FOR YES/NO [y/n] QUESTIONS</u>

- 0 = No
- 1 = Yes

<u>FOR RANKED SERIES</u>

- -1 = Not used at all
- 1 = Most important
- 2 = Next most important
- …etc.

When ties exist, subsequent items are "gap ranked." E.g., if two items receive a ranking of 1, then the next most important item is scored as a 3 (not a 2).

<u>SPECIAL CATEGORICAL RESPONSES</u>

In cases where question-specific categorical responses are required, the category codes are indicated beneath the question.

<u>FOR ADEQUACY RATINGS</u> *[Used for B43, C33, D47, E45, E47, E49, F80]*:

- 1 = Excellent
- 2 = Above average
- 3 = Sufficient
- 4 = Significantly lacking in data or analysis to reach conclusions
- 5 = Inadequate
- 6 = Extremely poor

<u>CODES FOR QA-QN SUBQUESTIONS</u> *[Used when indicated in brackets]:*

QA: Was this information used in the HCP?

- 0 = No
- 1 = Global information was used, but not local
- 2 = Local information was used
- 3 = Both global and local information was used

QB: What was the data quality?

- 1 = Expert opinion
- 2 = Qualitative 'data'
- 3 = Quantitative data with limited and/or poor statistical analysis
- 4 = Quantitative data with clear and relevant analysis
- 5 = Quantitative data used with good modeling of processes to extrapolate into the future

QC: How was the data used to make the assessment?

- 0 = Nonexistent; no clear or logical relationship between the information and conclusions
- 1 = Some connection, but utterly inadequate to base assessments on
- 2 = Reasonably good
- 3 = Excellent analysis; conclusions follow clearly and believably from the data and analysis

QD: Importance of missing information. For this type of information was significant information or analysis THAT DID EXIST missing from the HCP?

- 0 = Nothing significant missing
- 1 = Some information that was available was missing, but not too important
- 2 = Significant information was missing that would have changed some quantitative conclusions
- 3 = Starkly necessary information was missing that would have changed the conclusions qualitatively and substantially

QE: [y/n] Did the HCP consider this as effect?

QF: What did the HCP conclude about this effect?

1 = Not a noticeable effect at all
2 = Some effect, but not of any consequence
3 = A moderately important effect that bears consideration
4 = A serious effect that will significantly impact the population

QG: What is your assessment of this possible effect on the species/population from the planned HCP activities?

1 = Not a noticeable effect at all
2 = Some effect, but not of any consequence
3 = A moderately important effect that bears consideration
4 = A serious effect that will significantly impact the population

QH: [y/n] Was this measure considered in the HCP?

QI: How much reliance is there on this measure in the plan?

0 = None
1 = Very little
2 = Some, but of secondary importance
3 = The, or one of the, major mitigation measures used in the plan

QJ: For this particular mitigation measure, how good is the data to back up its use and reliability?

0 = None
1 = Very little, or quite unreliable
2 = Moderately well-understood and reliable
3 = Proven to work

QK: Is the mitigation to be done mostly on or off the HCP lands?

1 = On
2 = Off

QL: What is the quality of the he data to be collected?

0 = Not collected
1 = Expert opinion/assessments
2 = Qualitative 'data'
3 = Quantitative data with limited and/or poor statistical analysis proposed
4 = Quantitative data with clear and relevant analysis
5 = Quantitative data used with good modeling of processes to extrapolate into the future

QM: Is there a clear connection between the data to be collected and monitoring goal?

0 = Nonexistent; no clear or logical relationship between the information and monitoring goals
1 = Some connection, but utterly inadequate to base assessments on
2 = Reasonably good
3 = Excellent analysis; conclusions follow clearly and believably from the data and analysis

QN: For this species and the impacts, mitigation measures, etc. planned, how are there data of this type that are crucial for an effective monitoring program?

0 = Nothing significant missing from planned monitoring
1 = Some information is missing, but mostly the planned efforts are adequate
2 = Some data that are quite important will not be monitored
3 = Starkly necessary information will not be monitored

#	FOCAL SPECIES QUESTIONS (SQ)
A. Basic Status and other general information	
A1	HCP Code number (as assigned by NCEAS/AIBS)
A2	Species scientific name
A3	Taxonomic group *1 = mammal* *4 = fish* *2 = bird* *5 = invertebrate* *3 = reptile/amphibian* *6 = plant*
A4	Treated as a "primary" (1) or "secondary" (2) species
A5	[y/n] Is this a 'habitat-based' HCP?
A6	State or Local Legal status *(see codes below)*
A7	Federal Legal status *(see codes below)*
	1 = Candidate *2 = Threatened* *3 = Endangered*
A8	[y/n] Is there a recovery plan?
A9	If yes to A8: Year recovery plan was established
A10	[y/n] Has critical habitat been designated?
A11	If yes to A8: Year critical habitat was designated
Ranked severity of threats to this species (separate rankings for *on HCP land* and *Globally)* :	
A12	[HCP, Globally] Habitat loss
A13	[HCP, Globally] Habitat degradation
A14	[HCP, Globally] Habitat fragmentation
A15	[HCP, Globally] Direct Human-caused mortality
A16	[HCP, Globally] Pollution
A17	[HCP, Globally] Water diversion/damming
A18	[HCP, Globally] Invasive species
A19	[HCP, Globally] Changes in food species
A20	[HCP, Globally] Changes in predator/parasite/disease species
A21	[HCP, Globally] Natural rarity
A22	[HCP, Globally] Other
A23	[HCP, Globally] Unknown
A24	[HCP, Globally] No known threats at this time
A25	[y/n] Is the species endemic to the counties in which HCP lands occur?
A26	[y/n] Is the species endemic to the state(s) in which the HCP lands occur?
A27	Mean lifespan (in years) of an individual that makes it through juvenile period
A28	Net reproductive rate (Ro)
A29	Clutch or litter size
A30	Duration of the plan (in years), as a whole
A31	Does the duration of the plan as a whole make sense in light of the species lifespan, life history, etc.. plus the knowledge/ignorance of the species and the effects of the plan upon it? *1 = There is little reason to think that the plan duration accounts for the species biology* *2 = There is a plausible match between the species biology and the plan duration* *3 = There is an explicit accounting for the species biology; the plan seems well-tailored to the species*

B.	**Assessment of current status:**
Types of information used to assess Background and Current Status:	
B1	[QA-QD] General Habitat affiliations
B2	[QA-QD] Amount and quality of feeding habitat and quality
B3	[QA-QD] Amount and quality of breeding habitat
B4	[QA-QD] Amount and quality of migration habitat
B5	[QA-QD] Trends in habitat qualities
B6	[QA-QD] Trends in habitat amounts
B7	[QA-QD] Habitat fragmentation/habitat isolation
B8	[QA-QD] Population size
B9	[QA-QD] Trends in population sizes

B10	[QA-QD] Population trends by habitat types
B11	[QA-QD] Demographic rates/demographic models
B12	[QA-QD] Basic genetics (e.g. current homozygosity and inbreeding problems)
B13	[QA-QD] Genetic structure and unique value of certain populations
B14	[QA-QD] Movement abilities of individuals
B15	[QA-QD] Effects of future changes in extrinsic factors
B16	[QA-QD] Changes in/interactions with food species
B17	[QA-QD] Changes in/interactions with consumer species
B18	[QA-QD] Less direct species interactions (e.g. trophic cascades)
B19	[QA-QD] Pollution data
B20	[QA-QD] Climate change data
B21	[QA-QD] Succession, predictable disturbance regimes (e.g. fire, flooding)
B22	[QA-QD] Normal Environmental stochasticity (e.g. yearly weather fluctuations)
B23	[QA-QD] Natural or anthropogenic catastrophes
B24	[QA-QD] Cumulative effects (interaction of factors)
B25	[QA-QD] Other
Assessments made in the HCP about current status:	
B26	[y/n] In HCP area: Is there currently enough habitat for the species' safety?
B27	[y/n] Globally: Is there currently enough habitat for the species' safety?
	Note: 'Safety' is taken to mean that there is enough habitat to ensure a minimal or no likelihood of extinction of the population of species.
B28	In HCP area: Quality of most remaining habitat
B29	Globally: Quality of most remaining habitat
	1 = Poor; populations are likely to decline through time if isolated *2 = Medium; populations may be self-sustaining, but produce no excess individuals* *3 = Excellent; populations can act as sources*
B30	In HCP area: Population trends
B31	Globally: Population trends
	0 = Declining very rapidly (extinction considered possible within 20 years) *1 = Declining, on the whole* *2 = Stable, on the whole* *3 = Increasing, on the whole*
B32	In HCP area: Average rate of changes in populations: (Estimate of lambda)
B33	Globally: Average rate of changes in populations: (Estimate of lambda)
B34	In HCP area: Trends in habitat quantity
B35	Globally: Trends in habitat quantity
	0 = Declining very rapidly (extinction considered possible within 20 years) *1 = Declining, on the whole* *2 = Stable, on the whole* *3 = Increasing, on the whole*
B36	In HCP area: Rate of changes in habitat amounts *(estimate of annual multiplication rates)*
B37	Globally: Rate of changes in habitat amounts *(estimate of annual multiplication rates)*
B38	In HCP area: Trends in geographic range
B39	Globally: Trends in geographic range
	0 = Contracting very rapidly *1 = Contracting* *2 = Stable* *3 = Expanding*
B40	In HCP area: Rate of range change *(estimate of annual multiplication rates)*
B41	Globally: Rate of range change *(estimate of annual multiplication rates)*
B42	[y/n] Qualitative Assessment: Is there sufficient data on the background to actually determine something clear about status?
B43	Rate overall adequacy (1-6):

C. Assessment and Conclusions about Taking	
C1	Overall, was the analysis of take based upon calculations of habitat loss (1), or loss of individuals of the species (2)?
Category of Information Used to Assess Predicted Take:	
C2	[QA-QD] General, unspecific expert opinion
C3	[QA-QD] Loss of general habitat for the species
C4	[QA-QD] Loss of habitat accounting for different habitat qualities
C5	[QA-QD] General Population densities
C6	[QA-QD] Habitat-specific densities
C7	[QA-QD] Life history data in relation to take
C8	[QA-QD] Population sizes
C9	[QA-QD] Trends in population sizes
C10	[QA-QD] Demographic rates/demographic models
C11	[QA-QD] Movement abilities of individuals
C12	[QA-QD] Effects of future extrinsic forces (climate change, invasive species)
C13	[QA-QD] Habitat fragmentation/population isolation
C14	[QA-QD] Edge effects
C15	[QA-QD] Changes in/interactions with food species
C16	[QA-QD] Changes in/interactions with consumer species
C17	[QA-QD] Trophic cascades
C18	[QA-QD] Pollution and other indirect impacts
Ranked relative importance of the following as elements of the take that will occur:	
C19	Loss of adult individuals
C20	Loss of juveniles and propagules
C21	Harassment of individuals
C22	Loss of habitat
C23	Degradation of habitat
C24	Indirect effects
Conclusions in HCP about take levels:	
C25	[y/n] Will take occur?
C26	Predicted percentage of the impacted population that will be taken
C27	Total predicted number of individuals that will be taken
C28	Life stage that will primarily be taken *1 = Juveniles* *2 = Adults*
C29	Duration (in years) of take
C30	[y/n] Are life-stages, sex, etc.. of individuals to be taken estimated?
C31	[y/n] Will critical habitat be affected by the activities of the HCP?
C32	[y/n] Qualitative Assessment: Is there sufficient data and analysis to actually determine something clear about take?
C33	Rate overall adequacy (1-6):

D.	**Assessment of Effects on Population and/or Species**
General Theory:	
D1	[QA-QD] Genetic
D2	[QA-QD] Population ecology
D3	[QA-QD] Behavior and physiology
D4	[QA-QD] Island biogeography
D5	[QA-QD] Community ecology
D6	[QA-QD] Ecosystem ideas
Species Specific Analysis and Data:	
D7	[QA-QD] General Habitat affiliations
D8	[QA-QD] Amount and quality of feeding habitat and quality
D9	[QA-QD] Amount and quality of breeding habitat

D10	[QA-QD] Amount and quality of migration habitat
D11	[QA-QD] Trends in habitat qualities
D12	[QA-QD] Trends in habitat amounts
D13	[QA-QD] Habitat fragmentation/habitat isolation
D14	[QA-QD] Population size
D15	[QA-QD] Trends in population sizes
D16	[QA-QD] Population trends by habitat types
D17	[QA-QD] Demographic rates/demographic models
D18	[QA-QD] Basic genetics (e.g. current homozygosity and inbreeding problems)
D19	[QA-QD] Genetic structure and unique value of certain populations
D20	[QA-QD] Movement abilities of individuals
D21	[QA-QD] Effects of future changes in extrinsic factors
D22	[QA-QD] Changes in/interactions with food species
D23	[QA-QD] Changes in/interactions with consumer species
D24	[QA-QD] Less direct species interactions (e.g. trophic cascades)
D25	[QA-QD] Pollution data
D26	[QA-QD] Climate change data
D27	[QA-QD] Succession, predictable disturbance regimes (e.g. fire, flooding)
D28	[QA-QD] Normal Environmental Stochasticity (e.g. yearly weather fluctuations)
D29	[QA-QD] Natural or anthropogenic catastrophes
D30	[QA-QD] Cumulative effects (interaction of factors)
D31	[QA-QD] Other
Types of Effects Considered Important in HCP:	
D32	[QE-QG] Total Acreage of habitat lost
D33	[QE-QG] Total Individuals killed
D34	[QE-QG] % habitat degradation
D35	[QE-QG] % habitat lost
D36	[QE-QG] % Individuals killed
D37	[QE-QG] Fragmentation of habitat
D38	[QE-QG] Reduced movement rates
D39	[QE-QG] Edge effects
D40	[QE-QG] Altered intra-specific interactions
D41	[QE-QG] Altered inter-specific interactions (e.g. disease & exotics)
D42	[QE-QG] Genetic consequences
D43	[QE-QG] Non-point source pollution
D44	[QE-QG] Interactions of factors (i.e., cumulative impacts)
D45	[QE-QG] Other
D46	[y/n] Qualitative Assessment: Is there sufficient data and analysis to actually determine something clear about the impacts of the taking?
D47	Rate overall adequacy (1-6):

E. Assessment of Mitigation/Minimization Measures	
Category of Information Used to Assess General Theory:	
E1	[QA-QD] Genetic
E2	[QA-QD] Population ecology
E3	[QA-QD] Behavior and physiology
E4	[QA-QD] Island biogeography
E5	[QA-QD] Community ecology
E6	[QA-QD] Ecosystem ideas
Species Specific Analysis and Data:	
E7	[QA-QD] General Habitat affiliations?
E8	[QA-QD] Amount and quality of feeding habitat and quality
E9	[QA-QD] Amount and quality of breeding habitat
E10	[QA-QD] Amount and quality of migration habitat
E11	[QA-QD] Trends in habitat qualities
E12	[QA-QD] Trends in habitat amounts.

E13	[QA-QD] Habitat fragmentation/habitat isolation
E14	[QA-QD] Population size
E15	[QA-QD] Trends in population sizes.
E16	[QA-QD] Population trends by habitat types
E17	[QA-QD] Demographic rates/demographic models
E18	[QA-QD] Basic genetics (e.g. current homozygosity and inbreeding problems)
E19	[QA-QD] Genetic structure and unique value of certain populations
E20	[QA-QD] Movement abilities of individuals
E21	[QA-QD] Effects of future changes in extrinsic factors
E22	[QA-QD] Changes in/interactions with food species
E23	[QA-QD] Changes in/interactions with consumer species
E24	[QA-QD] Less direct species interactions (e.g. trophic cascades)
E25	[QA-QD] Pollution data
E26	[QA-QD] Climate change data
E27	[QA-QD] Succession, predictable disturbance regimes (e.g. fire, flooding)
E28	[QA-QD] Normal environmental stochasticity (e.g. yearly weather fluctuations)
E29	[QA-QD] Natural or anthropogenic catastrophes
E30	[QA-QD] Cumulative effects
E31	[QA-QD] Other
Types of mitigation/minimization measures considered and proposed:	
E32	[QH-QK] Avoidance of impacts, while still doing the proposed activity
E33	[QH-QK] Minimization of impacts, while still doing the proposed activity
E34	[QH-QK] Land acquisitions
E35	[QH-QK] Conservation easements
E36	[QH-QK] Habitat banks (exchange rates)
E37	[QH-QK] Translocations
E38	[QH-QK] Restoration of total habitat areas
E39	[QH-QK] Maintain/restore disturbance regimes
E40	[QH-QK] Remove exotics
E41	[QH-QK] Money for research
E42	[QH-QK] Other
Types of mitigation/minimization measures considered and proposed:	
E43	[y/n] Is mitigation part of a larger strategy?
E44	[y/n] Does the mitigation plan address the primary threats to the species continued existence?
E45	Rate overall adequacy in addressing primary threats (1-6)
E46	[y/n] Does the plan demonstrate that the impact on the species was minimized to the maximum extent possible, providing economic data to support this?
E47	Rate overall adequacy in demonstrating impact minimization (1-6)
E48	[y/n] Qualitative Assessment: Sufficient data? Determine likely success of the mitigation planned? Use of this mitigation approach justified? Succeed with likelihood? Are the mitigation ratios supported by data?
E49	Rate overall adequacy (1-6)

F. Assessment and Planning of Monitoring Program	
Monitoring of take levels:	
F1	Who is monitoring take? *1 = Private consulting firms* *2 = Academic scientists* *3 = Employees of land-holder* *4 = Employees of local government* *5 = State government employees* *6 = Federal employees* *7 = Committee/consortium with multiple representatives* *8 = NGO*
F2	[y/n] Is there clear evidence that the monitoring personnel/groups will be chosen to be competent to carry out the task well?
F3	Duration (in years) of the planned monitoring [*999 = “in perpetuity”*]

F4	Frequency (in rounds per year) of monitoring activities
F5	[y/n] Are data to be collected sufficient to determine take levels?
F6	[y/n] Is there an unambiguous plan to change the HCP strategy in response to new monitoring information?
What data will be collected and analyzed to monitor take?	
F7	[QL-QN] Physiological data
F8	[QL-QN] Behavioral data
F9	[QL-QN] Presence/absence data
F10	[QL-QN] Population densities
F11	[QL-QN] Population size
F12	[QL-QN] Population trends
F13	[QL-QN] Survival rates
F14	[QL-QN] Reproductive rates
F15	[QL-QN] Growth rates
F16	[QL-QN] Genetic data
F17	[QL-QN] Movement rates
F18	[QL-QN] Metapopulation dynamics/source-sink, etc.
F19	[QL-QN] Invasive species data
F20	[QL-QN] Effects of climate change data
F21	[QL-QN] Data on food or consumer species
F22	[QL-QN] Inter-specific interactions (e.g. disease) affecting species
F23	[QL-QN] Amount and trends in Habitat quantity
F24	[QL-QN] Amount and trends in Habitat quality
F25	[QL-QN] Pollution and other physical factors
F26	[QL-QN] Data on life history stage duration, numbers, etc.
Monitoring for general population health: assessment of no net harm?	
F27	Who is monitoring the population? *1 = Private consulting firms* *2 = Academic scientists* *3 = Employees of land-holder* *4 = Employees of local government* *5 = State government employees* *6 = Federal employees* *7 = Committee/consortium with multiple representatives* *8 = NGO*
F28	[y/n] Is there clear evidence that the monitoring personnel/groups will be chosen to be competent to carry out the task well?
F29	Duration (in years) of the planned monitoring [*999 = "in perpetuity"*]
F30	Frequency (in rounds per year) of monitoring activities
F31	[y/n] Are data to be collected sufficient to determine population status?
F32	[y/n] Is there an unambiguous plan to change the HCP strategy in response to new monitoring information?
What data will be collected and analyzed to monitor population status?	
F33	[QL-QN] Physiological data
F34	[QL-QN] Behavioral data
F35	[QL-QN] Presence/absence data
F36	[QL-QN] Population densities
F37	[QL-QN] Population size
F38	[QL-QN] Population trends
F39	[QL-QN] Survival rates
F40	[QL-QN] Reproductive rates
F41	[QL-QN] Growth rates
F42	[QL-QN] Genetic data
F43	[QL-QN] Movement rates
F44	[QL-QN] Metapopulation dynamics/source-sink, etc.

F45	[QL-QN] Invasive species data
F46	[QL-QN] Effects of climate change data
F47	[QL-QN] Data on food or consumer species
F48	[QL-QN] Inter-specific interactions (e.g. disease) affecting species
F49	[QL-QN] Amount and trends in Habitat quantity
F50	[QL-QN] Amount and trends in Habitat quality
F51	[QL-QN] Pollution and other physical factors
F52	[QL-QN] Data on life history stage duration, numbers, etc.
Monitoring of mitigation success	
F53	Who is monitoring the mitigation? *1 = Private consulting firms* *2 = Academic scientists* *3 = Employees of land-holder* *4 = Employees of local government* *5 = State government employees* *6 = Federal employees* *7 = Committee/consortium with multiple representatives* *8 = NGO*
F54	[y/n] Is there clear evidence that the monitoring personnel/groups will be chosen to be competent to carry out the task well?
F55	Duration (in years) of the planned monitoring [*999 = "in perpetuity"*]
F56	Frequency (in rounds per year) of monitoring activities
F57	[y/n] Are data to be collected sufficient to determine mitigation success ecologically?
F58	[y/n] Is there an unambiguous plan to change the HCP strategy in response to new monitoring information?
What data will be collected and analyzed to monitor mitigation success?	
F59	[QL-QN] Physiological data
F60	[QL-QN] Behavioral data
F61	[QL-QN] Presence/absence data
F62	[QL-QN] Population densities
F63	[QL-QN] Population size
F64	[QL-QN] Population trends
F65	[QL-QN] Survival rates
F66	[QL-QN] Reproductive rates
F67	[QL-QN] Growth rates
F68	[QL-QN] Genetic data
F69	[QL-QN] Movement rates
F70	[QL-QN] Metapopulation dynamics/source-sink, etc.
F71	[QL-QN] Invasive species data
F72	[QL-QN] Effects of climate change data
F73	[QL-QN] Data on food or consumer species
F74	[QL-QN] Inter-specific interactions (e.g. disease) affecting species
F75	[QL-QN] Amount and trends in Habitat quantity
F76	[QL-QN] Amount and trends in Habitat quality
F77	[QL-QN] Pollution and other physical factors
F78	[QL-QN] Data on life history stage duration, numbers, etc..
F79	[y/n] Qualitative Assessment: are there sufficient data and analyses proposed to actually determine something clear about the usefulness and the actual use of the monitoring planned?
F80	Rate overall adequacy (1-6):

APPENDIX I-C.

Questions asked of all 208 plans (referred to in text as "AQ" questions).

<u>FOR ALL QUESTIONS**</u>**
-1 = Don't know/Not enough info
-2 = Not applicable

<u>FOR YES/NO [y/n] QUESTIONS</u>
0 = No
1 = Yes

#	ALL HCP QUESTIONS (AQ)
1a.	Name, Permit #, County and State of HCP
1b.	Year permit was issued
1c.	FWS Region with jurisdiction over HCP *1 = Pacific* *5 = Northeast* *2 = Southwest* *6 = Mountain-Prairie* *3 = Great Lakes – Big Rivers* *7 = Alaska* *4 = Southeast*
1d.	Taxa of species listed on permit (referred to as "covered species") *1 = Mammal* *4 = Fish* *2 = Bird* *5 = Invertebrate* *3 = Reptile/Amphibian* *6 = Plant*
1e.	Common names of covered species
1f.	Scientific names of covered species
2a.	Who requested the incidental take permit? *1 = Single landowner* *2 = Multiple landowners* *3 = Subpermitting agency*
2b.	Permit holder: Public or Private entity? *1 = Public* *2 = Private* *3 = Both*
3.	Duration (in years) of HCP [*999 = "in perpetuity"*]
4.	Does the HCP provided coverage for as yet unlisted species? *0 = No* *1 = Explicit statement about **general** coverage for species becoming listed* *2 = Statement regarding **specific** species becoming listed* *3 = No surprises clause, with no mention of other species becoming listed*
5a.	[y/n] For each species covered, does the plan quantify take?
5b.	[y/n] Does the plan quantify the projected impact?
6a.	Area (in hectares) covered by the HCP
6b.	Area (in hectares) that will be subject to impacts affecting the primary species
6c.	Area (in hectares) protected from these impacts for at least the duration of the HCP
6d.	Area (in hectares) to be improved through mitigation activities
7a.	Over what time frame will protected habitat be protected? *1 = Short term (<10 years)* *2 = Less than or equal to duration of HCP* *3 = Longer than HCP duration, but not in perpetuity* *4 = In perpetuity*
7b.	Will damage be permanent (e.g., housing development) or temporary (e.g., timber harvest)? *1 = Permanent* *2 = Temporary* *3 = Both*

8.	[y/n] Does the plan provide evidence (cite references) that mitigation/minimization activities will work for each species listed on the permit?
9.	Projected cumulative effects of Take and Mitigation on the population of each species *1 = Positive* *2 = Negative* *3 = Neutral*
10a.	[y/n] Are there specific criteria for deciding if mitigation activities are working?
10b.	[y/n] Will the level of take or mitigation activities be changed based on this decision?
11a.	[y/n] Was the **Incidental Take Permit** consulted in completing this questionnaire?
11b.	[y/n] Was the **Implementing Agreement** consulted in completing this questionnaire?
11c.	[y/n] Was the **HCP** consulted in completing this questionnaire?
11d.	[y/n] Were **NEPA documents** consulted in completing this questionnaire?
12.	Ecological planning approach *1 = Single-species plan* *2 = Habitat-based plan* *3 = Multiple-species plan*
13a.	Brief summary
13b.	Additional comments on analysis of this plan
14.	[y/n] Is this plan a part of the Balcones Canyonlands Conservation Plan?

APPENDIX II-A

List of species included in the 43-plan focal analysis
[Complete data for these plans can be found on the associated website]

Scientific name	Common name
Gambelia sila	Blunt-nosed leopard lizard
Caulanthus californicus	California jewelflower (St. Francis cabbage)
Dipodomys ingens	Giant kangaroo rat
Vulpes macrotis mutica	San Joaquin kit fox
Dipodomys nitratoides nitratoides	Tipton's kangaroo rat
Dipodomys stephensi	Stephens' kangaroo rat
Desmocerus californicus dimorphus	Valley elderberry longhorn beetle
Aphelocoma coerulescens coerulescens	Florida scrub jay
Peromyscus polionotus ammobates	Alabama beach mouse
Chelonia mydas	Green sea turtle
Lepidochelys kempii	Kemp's ridley sea turtle
Eretmochelys imbricata	Hawksbill sea turtle
Dermochelys coriacea	Leatherback sea turtle
Caretta caretta	Loggerhead sea turtle
Peromyscus gossypinus allapaticola	Key Largo cotton mouse
Neotoma floridana smalli	Key Largo woodrat
Aphanisma blitoides	San Diego coastalcreeper (Aphanisma)
Astragalus trichopodus var. lonchus	Ocean locoweed (Santa Barbara milkvetch)
Atriplex pacifica	South coast saltscale (Davidson's saltbush)
Calochortus catalina	Catalina mariposa lily (Santa Catalina mariposa lily)
Calandrinia maritima	Seaside calandrinia (Seaside pussypaws)
Polioptila californica californica	Coastal California gnatcatcher
Dudleya virens	Bright green dudleya (Alabaster plant)
Baccharis vanessae	Encinitis baccharis (Coyote bush)
Branchinecta sandiegoensis	San Diego fairy shrimp
Ceanothus cyaneus	Lakeside ceanothus (San Diego ceanothus) (San Diego buckbrush)
Cordylanthus maritimus maritimus	Salt marsh bird's-beak
Dudleya variegata	Variegated dudleya (Variegated liveforever)

Ericameria palmeri ssp.palmeri	Palmer’s ericameria (Palmer's goldenbush) (Palmer's heathgoldenrod)
Lepechinia cardiophylla	Heart-leaved pitchersage
Rallus longirostris levipes	Light-footed clapper rail
Monardella hypoleuca lanata	Thickleaf mountainbalm (Felt-leaved monardella)
Phrynosoma coronatum blainvillii	San Diego horned lizard
Rana aurora draytonii	California red-legged frog
Rosa minutifolia	Small-leaved rose (Baja rose)
Panoquina errans	Salt marsh skipper butterfly
Solanum tenuilobatum	Narrow-leaved nightshade (Purple nightshade)
Cupressus forbesii	Tecate cypress
Bufo microscaphus californicus	Southwestern arroyo toad
Cercocarpus minutiflorus	Smooth mountain mahogany
Cnemidophorus hyperythrus beldingi	Orange-throated whiptail
Neotoma lepida intermedia	San Diego desert woodrat
Perognathus longimembris pacificus	Pacific pocket mouse
Quercus dumosa	California scrub oak
Campylorhynchus brunneicapillus cousei	Coastal cactus wren
Gopherus agassizii	Desert tortoise
Cynomys parvidens	Utah prairie dog
Icaricia icaroides missionensis	Mission blue butterfly
Callophrys mossii bayensis	San Bruno elfin butterfly
Thamnophis sirtalis tetrataenia	San Francisco garter snake
Dendroica chrysoparia	Golden-cheeked warbler
Vireo atricapillus	Black-capped vireo
---	**several Karst invertebrates*
Phaeognathus hubrichti	Red Hills salamander
Strix occidentalis caurina	Northern spotted-owl
Ursus arctos	Grizzly bear
Canis lupus	Gray wolf
Howellia aquatilis	Water howellia
Brachyramphus marmoratus marmoratus	Marbled murrelet
Speyeria zerene hippolyta	Oregon silverspot butterfly
Empetrichthys latos latos	Pahrump poolfish
Picoides borealis	Red-cockaded woodpecker
Falco femoralis septentrionalis	Aplamado falcon
Tympanuchus cupido attwateri	Attwater’s prairie chicken

APPENDIX II-B

List of 43 Focal Plans

[Complete data for these plans can be found on the associated website]

ID #	HCP Name	State
00.	Travis County Private Residence	Texas
01.	Chevron Pipeline Replacement Project	California
02.	Teichert Inc., Vernalis Aggregate Project	California
03.	Metropolitan Bakersfield	California
04.	J. Laing and Sons	California
05.	Riverside County HCA	California
06.	City of Waterford	California
07.	City of Marysville	California
08.	Lennane Investments	California
09.	Cushenbury Sand & Gravel Quarry	California
10.	Clark County Desert - Long Term	Nevada
11.	Washington County, Utah	Utah
12.	Gower-Connel Construction	Utah
13.	Coleman Company	Utah
14.	San Bruno Mountain	California
15.	Ocean Trails	California
16.	San Diego MSCP	California
17.	Orange County NCCP	California
18.	Coast Range Conifers Propert	Oregon
19.	Port Blakely/Robert B. Eddy Tree Farm	Oregon
21.	Washington Dept. of Natural Resources	Washington
22.	Spring Mountain State Park	Nevada
23.	Luce, Gregory	Alabama
24.	Sage Development Co., LLC.	Alabama
25.	D&E Investments	Alabama
26.	Volusia County	Florida
27.	Fort Morgan – Paradise Joint Venture	Alabama
28.	Nichols/Hendrix/Post Corp.	Florida
29.	Balcones Canyonlands	Texas
30.	Bee Cave Oaks Development	Texas
31.	Volente Group	Texas
32.	Wilmon Timberlands, Inc.	Alabama
33.	Union Camp Corporation	Alabama
34.	On Top of the World	Florida
35.	Red Oak Timber Co.	Louisiana
36.	N.C. Sandhills Regional RCWCP	North Carolina
38.	Aplomado Falcon Reintroduction (SH)	Texas
39.	Gulf Coast Prairies (SH)	Texas
40.	Hill, Joseph A.	Florida
41.	Wal-Mart	Florida
42.	Cochran, Robert L. (Waterside Down)	Florida
43.	RNR Properties, Ltd.	Florida
44.	Plum Creek Timber	Washington

APPENDIX III.

Detailed results of analyses to test the validity of using overall adequacy scores.

Many of the analyses assume that the measures of ‘overall adequacy’ for each of the five steps of HCP analysis are robust, non-arbitrary estimates of analysis quality. To test this assumption, in the tables below we present the results of regression analysis of these overall ratings upon composite variables that summarize the answers to the more detailed questions about the information and analysis used at each step of the HCP process. We performed these analyses for the summary questions about Status, Take, Impact, Mitigation, and three subsections of Monitoring. All analyses were performed on normalized variables. Each table below shows the results for one-way regressions using just one set of biologically distinct answers to detailed questions (e.g., data on changes in numbers or demography), as well as results from multi-way regressions using combinations of variables. Note that these multi-way analyses usually have much lower sample sizes, because they could not use many cases due to missing values. Overall, the results from these analyses show that the overall ranking questions are very well-predicted by the details of data and analysis used at each step of the HCP process.

The following data are for section B (Background & Current Status) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: B43).

Variable	Question	P-value	N	R^2
Habitat data	QB	0.0001	94	0.26
(SQ: B1)	QC	0.0001	90	0.22
	QD	*ns*	93	0.08
	All	0.0001	277	0.19
Trends in	QB	*ns*	43	0.44
Habitat data	QC	*ns*	41	0.40
(SQ: B5-B7)	QD	0.01	77	0.35
	All	0.0005	162	0.42
Population data	QB	*ns*	9	0.54
(SQ: B8-B11)	QC	*ns*	10	0.63
	QD	*ns*	63	0.32
	All	*ns*	82	0.40
Genetics	QB	*ns*	6	0.20
(SQ: B12, B13)	QC	*ns*	6	0.17
	QD	*ns*	71	0.21
	All	*ns*	83	0.25
Metapopulation	QB	*ns*	22	0.12
(SQ: B14)	QC	0.005	26	0.58
	QD	*ns*	63	0.09
	All	0.005	112	0.25
Change	QB	*ns*	-	-
(SQ: B15-B18, B24)	QC	*ns*	-	-
	QD	*ns*	49	0.41
	All	*ns*	51	0.37
Catastrophes	QB	*ns*	-	-
(SQ: B19-B23)	QC	*ns*	-	-
	QD	0.05	69	0.48
	All	0.01	70	0.51

The following models are assembled with all statistical significant data for that question.

Subquestion	Model Variables	P-Value	N	R^2
QB	Habitat	0.0001	94	0.26
QC	Habitat Meta	0.05	41	0.59
QD	Trends Catas	0.05	65	0.64
All	Habitat Trends Meta Catas	*ns*	47	0.66

The following data are for section C (Take) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: C33).

Variable	Question	P-value	N	R^2
Opinion data	QB	*ns*	44	0.06
(SQ: C2)	QC	0.0005	46	0.32
	QD	*ns*	70	0.09
	All	0.01	160	0.15
Habitat data	QB	*ns*	17	0.09
(SQ: C3-C6)	QC	*ns*	20	0.34
	QD	*ns*	71	0.30
	All	*ns*	108	0.31
Population data	QB	*ns*	3	1.00
(SQ: C7-C10)	QC	0.0001	4	1.00
	QD	*ns*	70	0.32
	All	*ns*	77	0.38
Edge effects	QB	*ns*	24	0.21
(SQ: C14)	QC	*ns*	24	0.09
	QD	*ns*	81	0.08
	All	*ns*	129	0.11
Fragmentation	QB	0.005	13	0.92
(SQ: C11, C13)	QC	*ns*	13	0.52
	QD	*ns*	66	0.24
	All	0.05	92	0.40
Change	QB	*ns*	-	-
(SQ: C12, C14-C17)	QC	*ns*	-	-
	QD	*ns*	64	0.28
	All	*ns*	64	0.28
Catastrophes	QB	*ns*	22	0.14
(SQ: C18)	QC	*ns*	22	0.18
	QD	0.005	79	0.17
	All	0.01	123	0.17

The following models are assembled with all statistical significant data for that question.

Subquestion	Model Variables	P-Value	N	R^2
QB	Fragment	0.005	13	0.92
QC	Opin	0.0005	46	0.32
QD	Catas	0.005	79	0.17
All	Opin Fragment Catas	*ns*	55	0.22

The following data are for section D (Impacts of Take) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: D47).

Variable	Question	P-value	N	R^2
Habitat data	QB	0.001	69	0.24
(SQ: D7)	QC	0.01	66	0.18
	QD	0.05	83	0.10
	All	0.001	218	0.16
Trends in Hab data	QB	0.05	35	0.50
(SQ: D11-D13)	QC	0.001	31	0.58
	QD	*ns*	70	0.26
	All	0.005	136	0.37
Population data	QB	0.0001	9	1
(SQ: D14-D17)	QC	0.0001	8	1
	QD	*ns*	58	0.26
	All	0.05	75	0.46
Genetics	QB	-	-	-
(SQ: D18, D19)	QC	0.0001	4	1.0
	QD	*ns*	65	0.04
	All	*ns*	72	0.05
Metapopulation	QB	*ns*	26	0.04
(SQ: D20)	QC	*ns*	24	0.11
	QD	*ns*	64	0.05
	All	*ns*	114	0.13
Change	QB	-	-	-
(SQ: D21-D24, D30)	QC	-	1	-
	QD	*ns*	55	0.24
	All	*ns*	56	0.26
Catastrophes	QB	-	-	-
(SQ: D25-D29)	QC	-	1	-
	QD	*ns*	60	0.37
	All	*ns*	61	0.38

The following models are assembled with all statistical significant data for that question.

Subquestion	Model Variables	P-Value	N	R^2
QB	Habitat Trends	0.01	35	0.59
QC	Habitat Trends	0.005	31	0.58
QD	Habitat Trends	*ns*	70	0.31
All	Habitat Trends Pop	*ns*	62	0.56

Population and Genetics excluded from QB & QC analysis due to their small sample size which would severely limit the power of the test.

The following data are for section E (Mitigation) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: E49).

Variable	Question	P-value	N	R^2
Habitat data (SQ: E7)	QB	0.005	76	0.19
	QC	*ns*	75	0.03
	QD	0.01	84	0.14
	All	0.005	235	0.13
Trends in Habitat data (SQ: E11-E13)	QB	0.01	33	0.58
	QC	*ns*	37	0.36
	QD	0.05	68	0.35
	All	0.005	138	0.40
Population data (SQ: E14-E17)	QB	0.0001	11	1.0
	QC	0.0001	12	0.94
	QD	0.0005	61	0.59
	All	0.0001	85	0.68
Genetics (SQ: E18-E19)	QB	*ns*	6	0.50
	QC	*ns*	15	0.02
	QD	*ns*	69	0.09
	All	*ns*	90	0.08
Metapopulation (SQ: E20)	QB	*ns*	26	0.18
	QC	0.0005	28	0.52
	QD	*ns*	63	0.06
	All	0.01	117	0.22
Change (SQ: E21-E24, E30)	QB	-	1	-
	QC	-	1	-
	QD	0.05	48	0.54
	All	0.05	50	0.54
Catastrophes (SQ: E25-E29)	QB	-	-	-
	QC	*ns*	8	0.14
	QD	0.05	67	0.47
	All	0.05	76	0.46

The following models are assembled with all statistical significant data for that question.

Subquestion	Model Variables	P-Value	N	R^2
QB	Habitat Trends	*ns*	33	0.23
QC	Pop Meta	0.0001	12	1.00
QD	Habitat Trends Pop Change Catas	*ns*	47	0.73
All	All variables except Genetics	*ns*	49	0.74

Population excluded from QB analysis due to its small sample size which would severely limit the power of the test.

The following data are for section F, Part One (monitoring of take) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: F80).

Variable	Question	P-value	N	R^2
Individual data	QL	*ns*	54	0.11
(SQ: F7, F8)	QM	*ns*	7	0.68
	QN	*ns*	44	0.40
	All	0.05	105	0.25
Population data	QL	0.005	70	0.47
(SQ: F9-F12, F26)	QM	*ns*	10	0.88
	QN	0.05	54	0.65
	All	0.001	134	0.56
Individual Rate data	QL	0.05	63	0.22
(SQ: F13-F15)	QM	*ns*	6	0.59
	QN	0.0001	55	0.55
	All	0.0001	124	0.38
Genetics	QL	*ns*	70	-
(SQ: F16)	QM	*ns*	4	0.11
	QN	0.005	57	0.23
	All	0.05	131	0.10
Metapopulation	QL	*ns*	53	0.06
(SQ: F17, F18)	QM	*ns*	3	0.75
	QN	*ns*	28	0.22
	All	*ns*	95	0.13
Change data	QL	*ns*	57	0.17
(SQ: F19-F22, F25)	QM	0.001	4	1.00
	QN	0.05	44	0.64
	All	*ns*	105	0.36
Habitat data	QL	*ns*	67	0.20
(SQ: F23, F24)	QM	*ns*	30	0.12
	QN	0.05	54	0.28
	All	*ns*	151	0.23

The following models are assembled with all statistical significant data for that question.

Subquestion	Model Variables	P-Value	N	R^2
QL	Pop Indrate	0.05	63	0.42
QM	Change	0.0001	4	1.00
QN	Pop Indrate Gen Change Habitat	0.05	42	0.91
All	Ind Pop Indrate Gen	*ns*	91	0.53

The following data are for section F, Part Two (monitoring of population status) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: F80).

Variable	Question	P-value	N	R^2
Individual data	QL	*ns*	53	0.07
(SQ: F33, F34)	QM	0.05	8	0.62
	QN	*ns*	51	0.27
	All	*ns*	112	0.19
Population data	QL	0.05	71	0.43
(SQ: F35-F38, F52)	QM	0.05	11	0.84
	QN	0.001	62	0.72
	All	0.0001	144	0.58
Individual Rate data	QL	*ns*	64	0.08
(SQ: F39, F41)	QM	0.05	11	0.69
	QN	0.001	63	0.46
	All	0.005	138	0.29
Genetics	QL	NS	70	-
(SQ: F42)	QM	NS	9	0.27
	QN	0.001	63	0.27
	All	0.005	143	0.14
Metapopulation	QL	*ns*	53	0.15
(SQ: F43, F44)	QM	*ns*	11	0.12
	QN	0.05	46	0.47
	All	0.05	110	0.31
Change data	QL	*ns*	56	0.20
(SQ: F45-F48, F51)	QM	0.05	5	0.83
	QN	0.05	52	0.58
	All	*ns*	113	0.38
Habitat data	QL	*ns*	68	0.18
(SQ: F49, F50)	QM	*ns*	33	0.33
	QN	0.0001	67	0.44
	All	0.0005	168	0.32

The following models are assembled with all statistical significant data for that question.

Subquestion	Model Variables	P-Value	N	R^2
QL	Pop	0.05	71	0.43
QM	Ind Pop Indrate Change	*ns*	3	0.25
QN	Pop Indrate Gen Meta Change Habitat	*ns*	43	0.90
All	All variables except Ind and Change	*ns*	95	0.56

The following data are for section F, Part Three (monitoring for mitigation success) of the HCP data set - individual variables correlation with Overall adequacy rating (SQ: F80).

Variable	**Question**	**P-value**	**N**	$\mathbf{R^2}$
Individual data	QL	0.05	55	0.20
(SQ: F59, F60)	QM	0.05	8	0.62
	QN	*ns*	49	0.24
	All	0.05	112	0.23
Population data	QL	0.001	69	0.55
(SQ: F61-F64, F78)	QM	*ns*	8	0.91
	QN	0.001	57	0.67
	All	0.0001	134	0.62
Individual Rate data	QL	*ns*	62	0.15
(SQ: F65-F67)	QM	*ns*	7	0.76
	QN	0.01	56	0.46
	All	0.05	125	0.31
Genetics	QL	*ns*	69	-
(SQ: F68)	QM	*ns*	5	-
	QN	0.05	56	0.17
	All	*ns*	130	0.08
Metapopulation	QL	0.05	51	0.26
(SQ: F69, F70)	QM	*ns*	7	0.64
	QN	*ns*	45	0.40
	All	0.05	102	0.35
Change data	QL	*ns*	54	0.26
(SQ: F71-F74, F77)	QM	0.03	5	0.83
	QN	0.03	49	0.56
	All	0.05	108	0.40
Habitat data	QL	0.02	69	0.28
(SQ: F75, F76)	QM	0.02	35	0.39
	QN	0.0001	68	0.49
	All	0.0001	172	0.39

The following models are assembled with all statistical significant data for that question.

Subquestion	**Model Variables**	**P-Value**	**N**	$\mathbf{R^2}$
QL	Ind Pop Meta Habitat	*ns*	51	0.29
QM	Ind Change Habitat	*ns*	3	0.25
QN	Pop Indrate Change Habitat	0.05	45	0.88
All	All variables except Genetics	*ns*	91	0.69