

Areas of Conservation Emphasis (ACE-II)

Project Report

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Executive Summary

The mission of the Department of Fish and Game (Department) is unique in its broad responsibility to conserve California's natural resources for both ecological and recreational values. To meet its responsibilities and comply with specific laws and mandates, the Department must establish programs and processes that will guide and inform its priorities for species and habitat conservation. The goal of the Areas of Conservation Emphasis project (ACE-II) was to build a spatial model that would incorporate Department priorities and mandates, be transparent and repeatable, use the best available science, and be flexible and responsive to specific management questions or funding opportunities. ACE-II is a compilation of statewide, spatial data addressing specific biological values, stressors, and landscape considerations analyzed at a consistent scale of 2.5 square mile hexagons that can be used in a flexible manner to identify areas of biological or conservation interest.

The ACE-II project team developed spatial data layers that depict California's biological diversity. The primary focus of ACE-II was to collect and summarize the best available statewide, spatial data on biological richness, including species diversity, rarity, and sensitive habitats.

To depict biological richness, four indices relevant to conservation value were produced: native species richness, rare species richness, "irreplaceability" (i.e., rarity-weighted richness), and the presence of sensitive habitats. Native richness and rarity layers were developed for each of six taxonomic groups: birds, fish, amphibians, plants, mammals, and reptiles. The data were then combined across taxonomic groups to produce total native species richness, total rare species richness, and total rarity-weighted richness maps. These maps are normalized to give each taxonomic group equal weight, to remove any bias caused by the variation in the total number of taxa per taxonomic group. The layers produced can be used to view the distribution of richness and rarity, by individual taxonomic group and overall, throughout the state and within each USDA ecoregion section. Information on the location of four sensitive habitat types, wetlands, riparian, rare upland natural communities, and high value salmonid habitat, was also assembled. The sensitive habitat layers can be used to view the distribution of these habitat types throughout the state based on the best currently available data.

The four indices of richness and rarity were combined in a weighted additive model to produce the ACE-II biological index surface. See Figure 1 for further details on the biological index calculation. Hexagons with a high biological index score represent those areas with high species richness, high levels of rarity and irreplaceability, and/or sensitive habitats. The biological index was calculated separately by USDA Ecoregion section, to identify the areas of highest richness and rarity within each ecoregion of the state. Because each ecoregion was analyzed separately, the biological index surface is meant to be viewed only one ecoregion at a time; biological index scores are not directly comparable between ecoregions.

Areas with a high biological index score would be expected to have high conservation value and meet multiple conservation goals. However, data included in ACE-II are subject to certain assumptions and limitations (summarized in Table 1) that must be considered in any use or application of the data. The biological index surface is limited by the accuracy and scale of the

input data, and does not represent all areas of high biological value throughout the state. The ACE-II biological index model is a broad-scale analysis and does not incorporate all biological considerations that should be addressed during comprehensive conservation planning. Therefore, it should not be interpreted as a map of the Department's conservation priorities. Current level of protection, level of habitat conversion (i.e., urbanization), intactness and connectivity, and stressors to natural habitats, all important considerations when determining conservation value, were not considered when developing the biological index. For example, urban areas containing small habitat fragments that support rare species may have a high biological index score even though much of the hexagon has low conservation value. The biological index surface is not a delineation of the reserve configuration needed to ensure adequate protection of individual species or habitats. The biological index does not replace site-specific evaluation of biological resources and should not be used as the sole measure of conservation priority during planning.

The biological index layer was reviewed by Department staff with local expertise on the distribution of biodiversity and conservation value in the landscape throughout the state. Many areas of high conservation value as identified by local experts received high biological index scores. Areas of high conservation value that received low biological index scores generally fell into the following categories: habitats important for a single focal species, habitats with population-level importance (e.g., largest population, southernmost population), wildlife linkages and corridors, intact wildland areas or areas adjacent to conserved lands, specific upland habitat types such as oak woodland and coastal sage scrub, aquatic reaches and fish habitat, habitats with high invertebrate diversity or rarity, large game important habitat (e.g., deer winter range), and habitats with limited public data such as large tracts of private lands.

Products of the ACE-II project include a set of tools for displaying biological data that can be used to identify areas of potential biological or conservation interest and may be useful during conservation prioritization. The data are available for viewing in an interactive, on-line ACE-II viewer. The viewer allows the ACE-II biological richness maps, stressors, protected status of lands, and connectivity and corridors to be overlaid. This viewer tool allows the user to display and contrast the arrangement and relative value of California's unique biological resources, providing a first step toward setting conservation priorities statewide. The viewer also provides a weighted-additive model interface that allows for custom calculation of a biological index using user-defined weights, which is a preliminary step in developing a flexible framework to address specific land acquisition or management questions.

September 2015 update

In 2015, the Conservation Analysis Unit updated the Areas of Conservation Emphasis (ACE-II) data layers. The goal of this effort was to (1) re-run the ACE-II calculations with updated species ranges, species occurrence data and vegetation maps based on data from July 2015; and, (2) fully automate the process with Python scripts. All assumptions and calculations were kept the same as had been decided on by the ACE-II Technical Team in 2009, except as described below.

Datasets used in the development of ACE-II:

Layer	ACE-II v1	ACE-II v2
Native species richness	Total number of native taxa (full species only) based on species range maps. Data used: CWHR ranges, 1998 Moyle fish ranges, plants by Jepson ecoregion based on Hickman (1993)	Total number of native taxa (full species only) based on species range maps. Data used: CWHR ranges, Pisces fish ranges (2014), plants by Jepson ecoregion based on Jepson Database (2015)
Rare species richness	<u>Rare species</u> : listed species, species of special concern, and fully protected species. <u>Datasets used</u> : CNDDDB data (extant occurrences except 5 mile radius non-specific points); UCB Museum of Vertebrate Zoology (MVZ) data; Jepson Herbarium records post 1990; CDFW Wildlife Branch GIS data. All occurrences were buffered by 1 mile in order to standardize accuracy.	<u>Rare species included</u> : listed species, species of special concern, and fully protected species, based on the species designation in CNDDDB <u>Datasets used</u> : CNDDDB data (extant occurrences except 5 mile radius nonspecific points); UCB Museum of Vertebrate Zoology (MVZ) data; Jepson Herbarium records post 1990; CDFW Wildlife Branch GIS data; additional museum data and breeding bird survey data compiled for CHAT; select BIOS datasets. All occurrences were buffered by 1 mile in order to standardize accuracy.
RWI	Inverse of number of hexagons occupied by a rare species based on occurrences used in rare species richness calculation	No change
Sensitive Habitats	National Wetland Inventory, DWR Land Cover, Ducks Unlimited; California Lakes; FVEG 2009, Holland vernal pools 2005; CNDDDB rare natural communities	National Wetland Inventory, DWR Land Cover, Ducks Unlimited; California Lakes; FVEG 2015, Holland vernal pools 2010; CNDDDB rare natural communities; sensitive habitat data from 40 fine-scale VegCAMP vegetation maps.

Summary of changes in processing made in ACE-II v2:

Issue	ACE-II v1	ACE-II v2
In order to avoid double-counting of species ranges along ecoregion boundaries, only those ranges intersecting the hex centerpoint were counted. However, a different method must be developed to calculate richness values for edge hexes whose centerpoint falls outside the state boundary.	Hex centerpoint was used except as follows: When the centerpoint fell outside the state boundary, the mean value of adjacent hexes was used to populate the native species richness values.	Hex centerpoint was used to calculate the value for each hex cell or partial hex. Centerpoints falling outside a partial hex were manually forced to the center of the partial hex cell based on visual estimation.
When intersecting two datasets in ArcGIS, some datasets will overlap by just a sliver.	Slivers were removed by deleting any rare species occurrences overlapping the ACE-II hexagon by <5%.	Slivers were not removed due to scripting issues. This should make little difference in the final output; the decision to use a 5% or no threshold for inclusion is arbitrary.

Background

The mission of the Department of Fish and Game (Department) is unique in its broad responsibility to conserve California's natural resources for both ecological and recreational values. To meet its responsibilities and comply with specific laws and mandates, the Department must establish programs and processes that will guide and inform its priorities for species and habitat conservation. A number of other conservation organizations (e.g., The Nature Conservancy, Trust for Public Land) have developed conservation prioritization models that spatially address their priorities. The goal of ACE-II was to build a spatial model that would incorporate Department priorities and mandates, be transparent and repeatable, use the best available science, and be flexible and responsive to specific management questions or funding opportunities. The ACE-II technical team was assembled in April 2009.

ACE-II is a compilation of statewide spatial data addressing specific biological values, stressors, and landscape considerations analyzed at a consistent scale of 2.5 square mile hexagons. ACE-II is a tool for use in land acquisition and conservation decision-making. Appropriate use of ACE-II will consider data assumptions and limitations outlined in this report. *The purpose of ACE-II was to develop a tool that can be used in a flexible manner to identify areas of biological or conservation interest. It should not be interpreted as a map of conservation priorities.*

The Role of ACE-II in Conservation Prioritization

One purpose of ACE-II was to develop a tool for displaying biological data that could be used to identify areas of potential biological or conservation interest. This tool may provide information that would be useful during a conservation prioritization, but is not intended for use as a stand-alone tool to delineate conservation priority areas. The process for delineating conservation priority areas is reviewed below.

Conservation priority areas can be defined as those areas that should be scheduled for conservation action first, and are generally designed to represent the biodiversity of the region they are situated in (Margules et al. 2002). To date, a number of conservation prioritization efforts have been undertaken across the globe, and have been implemented at varying spatial scale, spatial extent, and in a variety of habitat types (Malczewski et al. 2003, Geneletti 2004, Phua and Minowa 2005, Ricketts and Imhoff 2003, Reyers et al. 2007, Geneletti 2008, Gorokhovich and Voustianiouk 2009). The methods used may vary depending on project goals and resources, but should typically be explicit, efficient, flexible, cost-effective, and make the most of available data.

Conservation priority areas generally have the following attributes (adapted from Margules et al. 2002):

- Are necessary in combination with other areas to achieve conservation targets;
- Rarely constitute all remaining natural or semi-natural habitat in a region;
- Will never encompass all biodiversity, but rather work toward the goal of encompassing a representation of important biodiversity;

- Will not sustain their biodiversity over time if managed in isolation;
- Protection of some areas may be "non-negotiable" if they contain unique components of diversity that cannot be substituted in other areas;
- Are based on the best current available data, which always have limitations and are never complete. The model can and should be modified later as more data become available.

Margules et al. (2002) described the process needed to identify priority areas for conservation as follows:

- 1) measure diversity or conservation value (using surrogates)
- 2) set goals, including determining sufficient levels of representation if applicable
- 3) develop methods to implement goals
- 4) product should represent each level of biodiversity or conservation value identified
- 5) prioritize areas using
 - a) complementarity
 - b) irreplaceability
 - c) threat
 - d) sustainability

The ACE-II tool provides data for use in step 1 of the above process.

Project Goals and Assumptions

Department Planning and Conservation Prioritization Goals

Based on reviews of the Fish and Game code and acquisition and funding priorities developed by the Wildlife program and the Lands program, the ACE-II technical team developed a list of Department mandates and conservation priorities (Appendix A). High priority conservation areas in California that are needed to fulfill the Department's mission and meet Department mandates include those areas that:

- a) Best conserve fish and wildlife presence, use and diversity;
- b) Conserve functional ecosystems;
- c) Avoid extinctions, extirpations, and the need to list species;
- d) Provide hunting, fishing, and wildlife observation opportunities for the public; and
- e) Support climate change adaptation planning.

Assumptions

The ACE-II technical team developed a list of additional biological and spatial assumptions relevant to the identification of high priority conservation areas in California. Many of these assumptions were not addressed in the data layers developed for ACE-II, but should be considered in a comprehensive conservation prioritization.

- Long-term conservation potential should consider the overall viability of a target occurrence, status of stressors affecting the occurrence, predicted changes in the environment over time, and the conservation management status of the habitat supporting the occurrence.
- Areas that support multiple species are generally more valuable than those that support single species.
- Conserving adequate areas of all habitat types in the state will capture the conservation of many species.
- Large, well-connected preserves provide opportunities for species movement between current and future suitable habitats, accommodate range shifts, and provide habitat and refuge areas to help species persist in a changing climate.
- Large, well-connected preserves will help maintain and increase ecological integrity and offer increased protection from catastrophic events such as fire or flood.
- Areas that are intact and less fragmented from housing and roads have higher biological value.
- Conservation areas that provide connectivity along elevational or latitudinal gradients will improve the ability of species to persist in a changing climate.
- Conservation of functional ecosystems will improve hunting, fishing, and wildlife observation on and adjacent to conserved lands.
- Conservation prioritization is limited by the spatial extent and scale of available data. The spatial extent of data layers used must encompass the entire study area. For example, a statewide prioritization will be limited to only those data layers with a statewide or greater spatial extent. The scale chosen should be coarse enough to maximize use of available data but must be fine enough to be meaningful for local planning.

ACE-II Objectives

The first project objective was to identify and compile currently available data that may be considered in a conservation prioritization model. This was done through a Department-wide call for data, and additional effort by the ACE-II technical team to obtain specific data layers. The inventory and assessment of current data also resulted in the identification of future data needs (Appendix B).

To begin addressing the Department's conservation prioritization goals, the ACE-II technical team was tasked with developing the following product(s):

- A tool for use in identifying areas of the state that may meet broad conservation goals such as areas that have high biodiversity, or high value for meeting DFG mandates.

- A tool that is meant to complement other efforts, such as ACE I (identification of areas based on local expert knowledge), the California Essential Habitat Connectivity project (Spencer et al. 2010), and local conservation plans.
- A modeling process for spatial assessment of biological richness that is transparent, repeatable, can be modified and used for different purposes using the best currently available biological information, and can be updated and repeated as new data are available.
- A tool to share the Department's biological data that may be relevant to conservation prioritization with all levels of government, non-profits, and private environmental endeavors.
- A tool that can be used to create maps of biological richness based on the best current scientific knowledge, to provide guidance to:
 - DFG and WCB, for use in identifying areas of biological or conservation interest when determining high priority areas for land acquisitions
 - Other planning efforts (e.g., climate change adaptation planning)
- A process that can identify future modeling and data needs.

ACE-II Data Layer Descriptions, Uses and Limitations

ACE-II is a compilation of statewide, spatial data addressing specific biological values, stressors, and landscape considerations. ACE-II is a tool for use in land acquisition and conservation decision-making. The data included in ACE-II are subject to certain assumptions and limitations, which must be considered in any use or application of the data. The uses and limitations of ACE-II are described below and are summarized in Table 1.

Hexagons

All ACE-II datasets were applied to a statewide, 2.5 square-mile hexagon grid. The hexagons were clipped to the 24k state boundary, and represent terrestrial California. All marine species and habitats, as well as islands, were excluded from the analysis.

Data precision

All ACE-II data values are generalized across 2.5 square mile hexagons, and therefore cannot be used to pinpoint specific parcels with high biological richness in the landscape. The ACE-II data values are applied to hexagons that have a consistent size (2.5 square miles) and shape. Hexagon borders do not correspond with political or land ownership boundaries. ACE-II does not identify specific parcels with high conservation value. ACE-II incorporates datasets that vary in accuracy and scale. The precision of ACE-II values is limited by the accuracy and scale of the source data.

Table 1. Uses and Limitations of ACE-II.

ACE-II IS...	ACE-II IS NOT...
an analysis tool that shows broad-scale patterns of biological richness (defined by biodiversity, rarity, irreplaceability, and presence of sensitive habitats) across the landscape.	a map of the California Department of Fish and Game’s conservation priorities .
a continuous surface of biological richness based on data and assumptions outlined in this report.	a hard-line map delineating the reserve configuration needed to meet specific conservation or management goals, such as ensuring adequate protection of individual focal species or habitats.
a tool that includes biological layers showing patterns of richness and rarity based on numbers of species potentially present per hexagon.	a comprehensive analysis of species-specific habitat needs or critical conservation areas for individual species.
a broad-scale analysis of biological richness based on currently available, statewide data, upon which future analyses can be built. All data were applied to 2.5 square mile (1600 acres) hexagons.	a tool that can be used to assess the biological or conservation value of specific parcels . The precision of ACE-II values is limited by the accuracy and scale of source data. The value of any single hexagon should be interpreted with caution.
a tool displaying biological metrics of biodiversity, rarity, irreplaceability, and the presence of sensitive habitats within a hexagon.	a prioritization tool that incorporates all four facets of a conservation prioritization: complementarity (e.g., current level of protection), irreplaceability, threat, and sustainability (e.g., landscape configuration).
a dynamic analysis tool to inform conservation and land acquisition decisions based on specific management questions or project goals. A tool comprised of datasets that will be revised over time as new data become available.	a definitive, final map .
an analysis tool to facilitate the identification of areas of biological and conservation interest.	a regulation or a plan that dictates land use or land acquisition decisions for any public or private entity, nor is it a California Department of Fish and Game response to potential impacts to a habitat or species from a project subject to the California Environmental Quality Act (CEQA), California Endangered Species Act (CESA), National Environmental Policy Act (NEPA) or federal Endangered Species Act (ESA).

Data Disclaimer

The ACE-II maps display biological values based on available data and constrained by the limitations of the data. These values do not represent critical conservation areas for individual species or habitats. The values may be influenced by level of survey effort and do not consider current levels of protection for species or habitats. Some areas showing low biological values may have high conservation value. The ACE-II data represent broad-scale patterns of biological richness, and the value of any single hexagon should be interpreted with caution. ACE-II is a decision-support tool to be used in conjunction with species-specific information and local-scale conservation prioritization analyses. The user accepts sole responsibility for the correct interpretation and use of the ACE-II datasets and report. The ACE-II maps do not replace the need for site-specific evaluation of biological resources and should not be used as the sole measure of conservation priority during planning. No statement or data set shall by itself be considered an official response from a state agency regarding impacts to wildlife resulting from a management action subject to the California Environmental Quality Act (CEQA).

ACE-II is a compilation of the best available scientific information. However, many of these datasets are not comprehensive across the landscape, may change over time, and should be revised and improved as new data become available.

Biological Datasets

Native Species Richness

Native species richness represents the total number of native taxa potentially present per hexagon based on species range maps, and can be used to view patterns of diversity statewide and ecoregionally. Richness counts for all six taxonomic groups (amphibians, birds, fish, mammals, plants, reptiles) were based on full species only; counts did not consider subspecies or varieties because range maps were generally not available at the subspecific level. See Appendix D for the list of species included in richness counts. Range data are coarse-scale (i.e., the actual distribution of the species may be limited to certain habitat types within the range), which would be expected to result in an *overestimate* of species richness in some hexagons. Therefore, the native richness values per hexagon represent generalizations of the distribution of diversity throughout the state, but are not meant to represent actual number of species present per hexagon.

Native Species Richness was derived from the Department's CWHR native species range maps for amphibians, birds, mammals¹ and reptiles; from the 1998 University of California, Davis fish distribution coverages produced for The Nature Conservancy by Peter Moyle and Paul Randall for fish; and from the Jepson ecoregions designations in Hickman (1993) for plants. Of the 694 species ranges that have been mapped to date in CWHR, 664 are native species, with 660 included in this project (excludes offshore island species). Of the 112 inland fish species ranges by Moyle and Randall, 58 are native. Plant richness was calculated based Jepson ecoregion designations for 4960 native species (excludes subspecies and varieties).

For animals except fish, native species richness was calculated per hexagon as the total number of all native species ranges overlapping each hexagon's center point, with separate totals for each taxonomic group: amphibians, birds, mammals, and reptiles. Calculations of richness were based on the hexagon center point rather than by simple presence or absence in the hexagon in order to reduce error along the edges of ecoregional boundaries: Because CWHR species ranges are often snapped to ecoregional boundaries, hexagons along the border between two ecoregions show artificially high richness (i.e., species in both ecoregions overlapping the hexagon are counted, resulting in stripes of high richness along ecoregional boundaries). Using the center-point method eliminated this error. When the center point of a hexagon fell outside the state boundary (i.e., in the ocean or a neighboring state), the richness value was calculated by averaging the values from all adjacent hexagons. Native inland fish species richness was calculated per hexagon as the total number of fish whose ranges overlap >5% of the hexagon area. The center point method was not used for fish due to the linear nature of many aquatic systems; linear habitats may be less likely to intersect a hexagon center point. Native plant species richness was calculated by Jepson Ecoregion. Jepson ecoregion designations of all subspecies were merged,

¹ Updated ranges provided by the CDFG Wildlife branch were used for bear, elk and deer instead of CWHR ranges.

and species counts per ecoregion were based on full species only. To assign plant richness, each hexagon was given the plant richness value of the Jepson ecoregion covering the greatest area within that hexagon.

Data for each taxonomic group were normalized separately to give each taxonomic group equal weight (maximum value of 1) in the analysis (see section on data normalization for a detailed description of this process). Statewide normalized values for the six taxonomic groups were summed to determine statewide total native species richness. Ecoregionally normalized values for five taxonomic groups (excluding plants) were summed to determine ecoregional total native richness. Because native plant ranges were available at the ecoregion level only, native plant richness was not normalized ecoregionally, and native plant richness was excluded from the total species richness values normalized by ecoregion.

Total native species richness is the sum of richness normalized by taxonomic group². Areas with high ACE-II total native species richness represent not only areas with the greatest total count of species, but also areas with high relative richness per taxonomic group. For example, although amphibians may contribute only a small number to the total count of species in a hexagon, areas with high relative amphibian richness would contribute a large relative richness value in the normalized richness calculation.

Native species richness by taxonomic group displays the count of native species per hexagon, and can be used to view the distribution of diversity in each taxonomic group by ecoregion or statewide. The list of species potentially present in any hexagon in the state based on species range maps can be obtained using a database query.

Rare Species Richness

Rare species richness represents the total number of special status³ taxa present per hexagon based on documented species occurrences, and can be used to view patterns of rarity. Rare species richness counts were conducted for all six taxonomic groups (amphibians, birds, fish, mammals, plants, reptiles) at the taxonomic level treated as special status. See Appendix E for the list of taxa included in rare species richness counts.

Rare species occurrence locations were derived from “presumed extant” California Natural Diversity Database records (excluding extirpated and possibly extirpated records); additional museum records from the California Academy of Sciences, the Museum of Vertebrate Zoology at UC Berkeley, and the Consortium of California Herbaria (from years 1999-2009); and additional Department datasets (BIOS, other regional or branch data). All documented occurrences with accuracy ± 1 mile or better were included in order to incorporate as many known occurrences as possible. No cut-off date of observation was used, based on the assumption that occurrences still may be present if the habitat has not been modified and the

² The richness values for each taxonomic group were normalized from 0 to 1 before summing to give each taxonomic group equal weight in the analysis (see section on data normalization for detailed description).

³ Special status taxa included all State- and Federally-listed or Candidate species, DFG species of special concern, DFG fully-protected species, and CNPS List 1B and List 2 plants

occurrences have not been documented as extirpated. Further supporting this assumption are the results of recent survey efforts that successfully relocated decades-old historical occurrences of several species. A 1 mile buffer was added to all occurrence points and polygons to standardize accuracy. All hexagons with >5% area covered by a buffered documented occurrence were considered presences.

The total number of rare species was counted per hexagon for each taxonomic group: amphibians, birds, fish, mammals, plants, and reptiles. Data for each taxonomic group were normalized separately to give each taxonomic group equal weight (maximum value of 1) in the analysis (see section on data normalization for a detailed description of this process). Statewide normalized values for the six taxonomic groups were summed to determine statewide total rare species richness. Ecoregionally normalized values for the six taxonomic groups were summed to determine ecoregional total native richness.

Verified species occurrences mapped by CNDDDB and museum data tend to be spatially biased toward areas with high levels of survey effort, which may result in particularly high rare species richness values in well-surveyed areas. Conversely, surveys have not been conducted in a comprehensive and consistent manner across the entire landscape, and current maps of verified rare species occurrences are expected to have high rates of omission. For this reason, counts of rare species richness would be expected to be *underestimates* in some hexagons, particularly those for which no survey data are available. A data layer showing those hexagons for which no rare species data are available has been produced and can be used to identify the most poorly surveyed areas.

Total rare species richness is the sum of rare species richness normalized by taxonomic group. Data were normalized per taxonomic group to remain consistent with the methods used for total native species richness. Areas with high ACE-II rare species richness represent not only areas with the greatest total count of rare species, but also areas with high relative rare species richness per taxonomic group.

Rare species richness by taxonomic group displays the count of rare species per hexagon based on documented occurrences, and can be used to view the distribution of rarity in each taxonomic group by ecoregion or statewide.

Rarity-weighted Richness

Rarity-weighted richness represents the “irreplaceability” of an area based on the presence of special status species⁴ weighted by their degree of rarity. Areas with a high rarity-weighted richness index (RWI) support rare species with few documented occurrences; these areas would be expected to support unique habitats or suites of species that are limited in distribution and likely of high conservation concern. The RWI was calculated by taking the inverse of the number of hexagons occupied by each rare taxon [$RWI = \sum 1/(\# \text{ occupied hexagons per taxon})$], so that taxa with the smallest distributions have the largest values. All RWI values were then summed per hexagon by taxonomic group. Data for each taxonomic group were normalized separately to

⁴ List of species status species used for rarity-weighted richness was the same as that used for rare species richness.

give each taxonomic group equal weight (maximum value of 1). Statewide normalized values for the six taxonomic groups were summed to determine statewide total RWI. Ecoregionally normalized values for the six taxonomic groups were summed to determine ecoregional total RWI.

Because verified species occurrences were used to determine species distributions for the purposes of this calculation, the RWI may be biased by the level of survey effort for certain species or within certain areas of the state, or by the level of reporting to CNDDDB. Rarity-weighted richness best represents the “irreplaceability” of areas supporting narrow-ranging species and habitats. Wide-ranging species that are rare within their range would have low RWI values although they may be of high conservation concern. A separate metric should be used to identify the areas of highest concern for wide-ranging species.

Total rarity-weighted richness is the sum of RWI normalized by taxonomic group. Data were normalized per taxonomic group to remain consistent with the methods used for total native species richness and rare species richness. Areas with high ACE-II rarity-weighted richness represent not only areas with the greatest RWI, but also areas with high relative RWI per taxonomic group.

Rarity-weighted richness by taxonomic group displays the total RWI per hexagon by taxonomic group, and can be used to view the level of “irreplaceability” among hexagons by ecoregion or statewide.

Sensitive Habitats

The ACE-II sensitive habitat layers represent those hexagons where wetlands, riparian, rare natural communities, and/or high value salmonid habitat are present. If a sensitive habitat of any size was mapped as present in a hexagon, the hexagon was designated a presence for that habitat type regardless of habitat size or quality. Sensitive habitats were designated as present or absent only and hexagons were not ranked by any measure of sensitive habitat conservation value. The sensitive habitat layers are therefore very broad-scale representations of the distribution of these habitat types throughout the state.

Riparian

The riparian habitat layer represents those hexagons in which riparian habitat is present. Most generally, habitats classified as riparian represent streamside vegetation. This includes riparian forest, riparian woodland, riparian scrub and other streamside vegetation types.

Riparian data for the state are inconsistent in geographic area coverage and resolution. Various sources therefore contributed to the creation of a statewide riparian coverage for the use of this project. It should be noted that a consistent methodology was not used by the source datasets to identify and classify habitat termed “riparian”. GIS data input into the riparian statewide layer originated from the following sources: the most current Ca. Dept. of Forestry and Fire Protection’s Multi-Source Land Cover Data covering the entire state (30 meter pixel); Ca. Dept. of Water Resources Land Use Survey data for agricultural areas

(1:24,000 polygons); DFG's Calif. Natural Diversity Database (CNDDDB) riparian habitats and associated species occurrences (1:24,000 polygons); and Central Valley wetlands raster grid from Pacific Meridian Resources/Duck's Unlimited (30 meter pixel). Taken together, these sources identify many but not all riparian zones in the state. Therefore the ACE-II statewide riparian layer includes the best available information on riparian habitat statewide, but is not expected to represent all riparian zones in the state.

Wetland

The wetland habitat layer represents those hexagons in which wetland habitat, generally defined as habitat where the soil is saturated with water either permanently or seasonally, is present. This includes habitats such as estuarine and coastal marshes, tidal flats, freshwater marshes, lakes and ponds, desert springs, seeps, fens, and vernal pools. Permanently and seasonally flooded agricultural lands were denoted but were not classified as wetlands for purposes of the analysis.

Wetland data for the state is inconsistent in geographic area coverage and resolution. Various sources contributed to the creation of a statewide wetlands coverage for the use in this project. GIS data input into the wetland statewide layer originated from the following sources: the most current Ca. Dept. of Forestry and Fire Protection's Multi-Source Land Cover Data covering the entire state (30 meter pixel); Ca. Dept. of Water Resources Land Use Survey data for agricultural areas (1:24,000 polygons); US Fish and Wildlife Service National Wetland Inventory maps (1:24,000 polygons); California lakes mapped by DFG (1:24,000 polygons); DFG's Calif. Natural Diversity Database (CNDDDB) wetland habitats and associated species occurrences (1:24,000 polygons); Central Valley wetlands raster grid from Pacific Meridian Resources/Duck's Unlimited (30 meter pixel); various county vernal pool coverages; USFS mapped fens and fen meadows in the Sierra Nevada; and local vegetation maps of Marin County and the western Mojave showing wetland vegetation types. Taken together, these sources identify many but not all wetland areas in the state. Therefore the ACE-II statewide wetland layer includes the best available information on wetland habitat statewide, but is not expected to represent all wetland habitats in the state.

Rare Natural Communities

Rare natural communities included for the purposes of this project were those communities designated as rare by Holland (1986) and mapped in CNDDDB (1:24,000 polygons). It should be noted that not all rare natural communities are well-represented in CNDDDB. Therefore, the rare natural communities coverage represents areas where rare natural communities are known to occur, but is not a comprehensive representation of rare natural communities across the state. Riparian and wetland rare natural communities were excluded from this coverage since they were included in the riparian and wetland sensitive habitat layers. Additional occurrences of some rare natural communities were added from local vegetation maps.

High Value Salmonid Habitat

High value salmonid habitat included all COHO, steelhead, and heritage native trout watersheds as mapped by the Department.

Biological Index

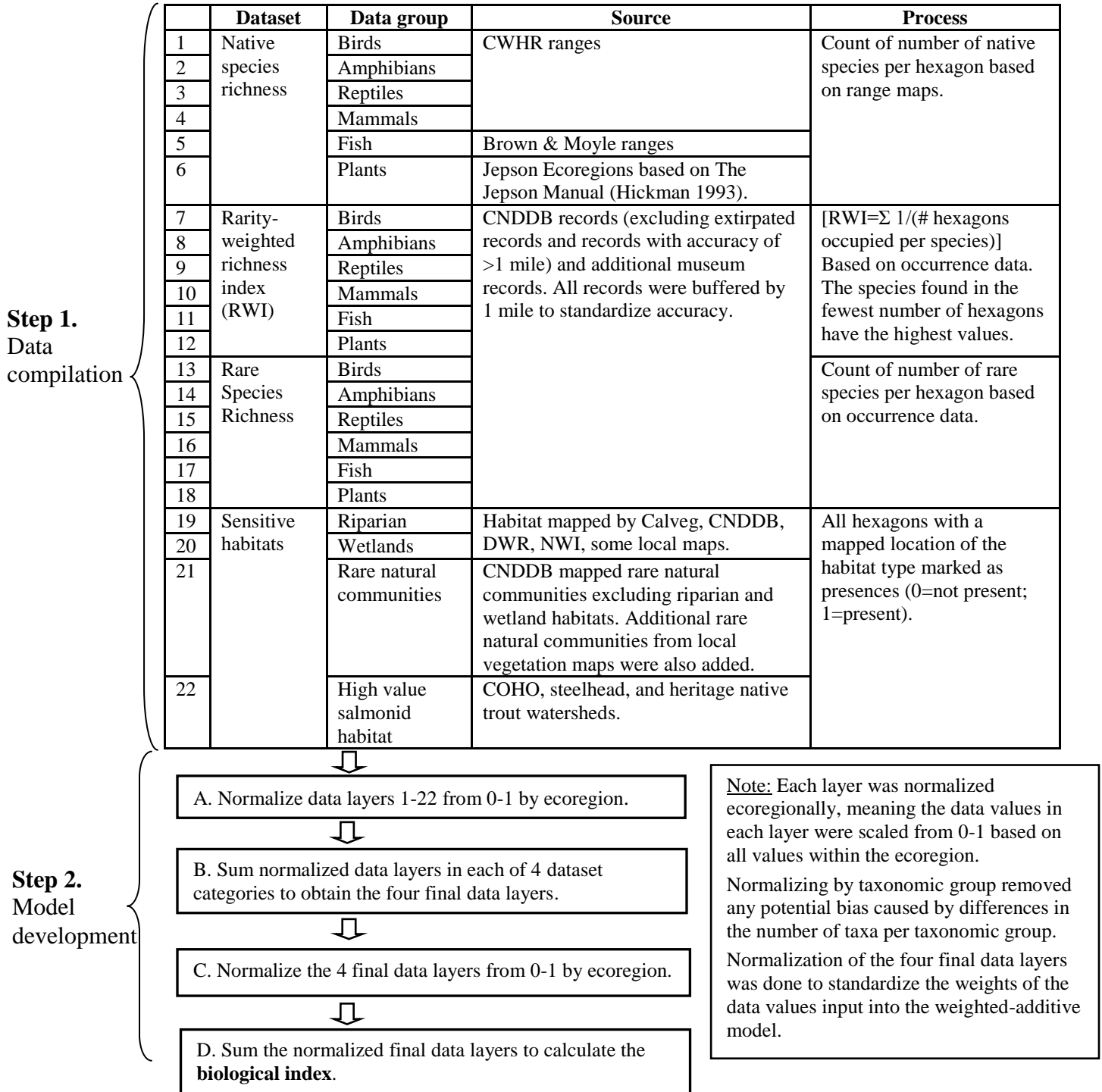
The *ACE-II biological index surface* is a composite of four indices relevant to conservation value: native species richness, rare species richness, “irreplaceability” (i.e., rarity-weighted richness), and the presence of sensitive habitats (see Figure 1 for further details on biological index calculation). The four indices were summed using a weighted-additive model framework (see the weighted-additive model section for further detail), with all four layers given equal weight in the model. Hexagons with a high biological index score represent those areas with high species richness, high levels of rarity and irreplaceability, and/or sensitive habitats.

The statewide layers were summed to produce a Statewide Biological Richness Overview map. This map can be used for comparisons of biological richness between any two areas of the state; however, it does not account for the large ecological differences across different regions of the state and has very limited use for regional or local-scale planning. The Ecoregional Biological Index was calculated separately by USDA Ecoregion section, to identify the areas of highest richness and rarity within each ecoregion of the state. This index accounts for ecological differences across different areas of the state and would be more appropriate for use during regional planning. However, because the index was calculated separately by ecoregion, the biological index scores are not directly comparable between ecoregions.

Areas with a high biological index score would be expected to have high conservation value and meet multiple conservation goals. However, data included in ACE-II are subject to certain assumptions and limitations (summarized in Table 1) that must be considered in any use or application of the data. The biological index surface is limited by the accuracy and scale of the input data, and does not represent all areas of high biological value throughout the state. It is a broad-scale analysis and does not incorporate all biological considerations that should be addressed during comprehensive conservation planning. Therefore, it should not be interpreted as a map of the Department’s conservation priorities. Current level of protection, level of habitat conversion (i.e., urbanization), intactness and connectivity, and stressors to natural habitats, all important considerations when determining conservation value, were not considered when developing the biological index. For example, urban areas may have a high biological index score even though they have low conservation value, because urbanization was not a component of the biological index score. The biological index surface is not a delineation of the reserve configuration needed to ensure adequate protection of individual species or habitats. The biological index does not replace site-specific evaluation of biological resources and should not be used as the sole measure of conservation priority during planning.

Figure 1. ACE-II Biological Index Model Flow Chart.

The **Biological Index** is based on four indices relevant to conservation value, native species richness, rare species richness, irreplaceability, and the presence of sensitive habitats, summed in a weighted-additive model framework. Data were normalized to give each taxonomic group and each of the four indices equal weight in the analysis. The analysis was done by ecoregion, to identify areas of high biological richness within each ecoregion of the state. The analysis unit used was 2.5 square mile hexagons.



Landscape Considerations

Current level of protection

The ACE-II biological index surface was developed independent of the current protected status of any given area, and the number of currently protected occurrences of any species or habitat was not considered in the analysis. A public lands layer is available as an overlay in the ACE-II Viewer to view the biological index with respect to the configuration of public lands.

Current level of protection of species and habitats is often considered when setting priorities for conservation goals. For example, a species or habitat with no protected populations would be given a higher conservation priority (i.e., would be scheduled for conservation first) than a species or habitat with many populations in already protected areas. Incorporating level of protection addresses *representation*, that is, ensuring that each focal species and habitat is adequately represented within protected areas. This can be done using *thresholds*, which target the representation of a threshold number of populations of each focal species or a threshold percentage of area of each habitat type for protection. Representation and thresholds are most often used when determining the optimum reserve configuration to meet specific conservation goals. ACE-II does not address reserve design, representation or thresholds.

There are a number of problems with incorporating current protected status into a statewide conservation prioritization model in California. Oftentimes, public lands are used as a surrogate for protected status. However, the management and uses of public lands across the landscape varies, and lands under conservation easement may not be represented on maps of public lands. GAP designations⁵ for public lands in California are available, but further refinement of land management status designations across the state should be completed to fully incorporate current level of protection into conservation prioritization models in California.

Using thresholds to address representation requires not only an understanding of protected status and management across the landscape, but also a comprehensive understanding of the distribution of species and habitats. For example, ensuring the representation of habitat types

⁵ Land protected status definitions from the California GAP Analysis project (Davis et al. 1998):

GAP 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency and intensity) are allowed to proceed without interference or are mimicked through management.

GAP 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive use of management practices that degrade the quality of existing natural communities.

GAP 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type or localized intense type. It also confers protection to federally listed endangered and threatened species throughout the area.

GAP 4: Lack of irrevocable easement or mandate to prevent conversion of natural habitat types to anthropogenic habitat types (arrested succession, dominance by exotics) and allow for intensive use throughout the tract, or existence of such restriction is unknown.

within protected areas requires a habitat or vegetation map accurately showing the distribution of habitats across the landscape. This map would be used to determine the current representation of habitats within protected areas, and to identify areas of underrepresented habitats or vegetation types that should be prioritized for conservation. Unfortunately, the accuracy and scale of current statewide habitat or vegetation maps do not allow for a fine-scale analysis of representation within currently protected areas (i.e., at the parcel level) without a high degree of error. A fine-scale vegetation map would be necessary for such an analysis. At this time fine-scale vegetation maps are available for certain sections of the state, but a statewide map has not yet been completed.

Using thresholds to address representation of individual species also requires an understanding of their distributions across the landscape. Range maps are available for many species, but are coarse-scale representations of species distributions. Actual species distributions generally occupy only a portion of the area of a species range, often in specific habitat types within the range. Further refinement of range maps would be necessary if they are to be used to address representation. Mapped species occurrences (i.e., CNDDDB and museum records) represent locations in the landscape where species occurrences have been verified. Although CNDDDB data are not comprehensive across the landscape and are biased by areas where surveys have been conducted, these are the best data available and may allow for an analysis of the representation of rare species on protected lands. An analysis of representation of key focal species within protected areas was outside the scope of ACE-II but would be an important component of a comprehensive conservation prioritization.

Habitat Connectivity

The ACE-II process developed the biological index surface across the state independent of landscape configuration or habitat connectivity. Reserve configuration and habitat connectivity are important considerations for conservation prioritization. As stated in the ACE-II biological assumptions; large, well-connected preserves will help maintain and increase ecological integrity and offer increased protection from catastrophic events such as fire or flood. Large, well-connected preserves provide opportunities for species movement between current and future suitable habitats, accommodate range shifts, and provide habitat and refuge areas to help species persist in a changing climate. Conservation areas that provide connectivity along elevational or latitudinal gradients may also improve the ability of species to persist in a changing climate. Movement corridors are particularly important for the conservation of migratory species and species with large home ranges.

Habitat connectivity and reserve configuration may be addressed in a conservation prioritization by focusing on areas that provide connectivity or expand current reserves. Broad-scale connectivity areas have been identified by the *California Essential Habitat Connectivity* analysis (Spencer et al. 2010), which used a least cost path method based on an index of ecological integrity to identify *Essential Connectivity Areas*, areas essential for maintaining ecological connectivity between large, natural habitat blocks. Potential *Riparian Connections* based on routed hydrography and *Interstate Connections*, potential linkages into other states, were also identified. Key movement corridors could be identified at a local level using species-specific

monitoring and modeling. In addition, the *California Essential Habitat Connectivity* analysis delineated *Natural Landscape Blocks*, which represent large, intact areas of habitat that may or may not be in conservation ownership. These models are complementary to the ACE-II biological layers and can be used to address intactness and connectivity during a conservation prioritization. The *California Essential Habitat Connectivity* data layers are available for overlay in the ACE-II viewer.

Stressors

The ACE-II biological index surface was developed across the state independent of the presence of stressors in the landscape. An analysis of potential stressors, sometimes referred to as threats, is an important component of conservation value and should be considered during a conservation prioritization. Stressors may increase the urgency of conservation action (e.g., securing conservation status before an area is permanently altered by anthropogenic habitat conversion). Conversely, certain types of stressors may decrease the long-term conservation value of an area (e.g., coastal marshlands expected to be fully inundated by sea level rise). Because stressors may increase or decrease the conservation priority of an area, stressors were not incorporated into the ACE-II biological scores and should be considered individually at the local level during conservation planning.

Urban Footprint

Level of urbanization was not considered in the calculation of the ACE-II biological index surface; therefore, urbanized areas that would generally be thought to have low conservation value may receive a high biological index score. High levels of survey effort near population centers often lead to large numbers of rare species occurrence records in urbanized areas, which may amplify the biological index score in these areas. A current urban footprint layer and a year 2050 projected urbanization layer are available for overlay in the ACE-II viewer to provide an indication of the level of urbanization in an area.

The current urban footprint layer was not used to refine the ACE-II biological index (i.e., lower the biological index score in urban areas with little or no remaining natural habitat) due to scale-related issues. There are some potentially important habitat fragments within urbanized areas that would not be picked up if the biological index score was lowered in all mapped urban areas. Furthermore, many hexagons are partially covered by urbanized areas making it difficult to classify them as urbanized or not.

Other conservation prioritization efforts have manually refined current urbanization layers within their project area using aerial photographs, but this was not possible to do statewide within the scope of the ACE-II project. The Essential Habitat Connectivity Project identified small Natural Landscape Blocks (<2000 acres), some of which lie completely within mapped urban or semi-urban areas. The small Natural Landscape Blocks are available as an overlay in the ACE-II viewer, and can be used to view some intact habitat fragments that fall within urban boundaries. The ACE-II biological index and other biological richness measures should be viewed with the consideration that these scores were not adjusted for level of urbanization

ACE-II Development

Data Sources

Call for Data

A call for data was sent out by Director McCammon in March, 2009. All regions and branches were requested to submit a list of spatial datasets they have developed. A final list of all data layers was compiled, which included a total of 1024 separate data layers from 6 regions and 4 branches. Many of these datasets were region-specific, and a number of them were not yet digitized.

Criteria for Inclusion of Data Layers

The following criteria were used to determine which data to include:

- Digital spatial data available OR spatial data available and can be easily digitized (for high priority layers only);
- Extent is appropriate (statewide) or data could be merged with layer at larger extent;
- Data are not already captured elsewhere (e.g., in CNDDDB);
- Includes data on biological richness, stressors, or landscape configuration
- Captures location or range of species/habitats of priority interest (native or rare, or species for which DFG has special regulatory mandate);
- Captures location of landscape configuration such as ownership, land access, and corridors (e.g., DFG facilities, protected lands);
- Captures location of stressors (e.g., polluted lands, transmission corridors, high-speed rail corridors, areas with high vulnerability to climate change).

Unit of Analysis, Scale and Extent

Choosing a Unit of Analysis

Three types of analysis units were considered: hexagon, grid and ecoregional unit. Hexagons and grids are “artificial” units that are consistent in size and shape across the landscape, while ecoregional units are biologically based and vary in size and shape. Although ecoregional units have natural boundaries that are likely more biologically relevant than artificial units, the variation in area and edge length is problematic for modeling. For example, richness calculations within analysis units of varying size are unreliable due to species-area effects (i.e., the number of species counted in a large ecoregion may be greater than that in a small ecoregion because of differences in the amount of area available for surveys rather than intrinsic differences in the actual diversity levels). Because one goal of the analysis was to create standardized maps of biological attributes that could be used for modeling, such as species richness and rarity-weighted richness, an analysis unit with a consistent size and shape was chosen.

Data can be applied to hexagons or grid cells of any size, allowing for a flexible choice of scale when using either type of units. Raster grids have the advantage of being a series of squares that easily nest into larger squares, making it easy to convert data between scales, while hexagons do not nest. However, hexagons have been shown to reduce the distortion of data when applied across the landscape (White et al. 1992). For this reason, hexagons were chosen as the unit of analysis.

Scale

Scale was one of the most important considerations in the analysis. To define scale, we considered the following questions:

- At what extent and scale are data layers available?
- What scale best captures focal species habitat occupancy and/or biodiversity?
- What scale is most applicable for conservation planning?

We sought to define a scale that would be coarser than the level of individual parcels but fine enough to adequately capture the distributions of species or habitats with narrow distributions (e.g., riparian areas, streams, narrow-endemic species). The desired hexagon size would reduce spatial errors perpetuated by larger hexagon sizes (i.e., a data point is transferred to an entire hexagon even when the point falls on the edge of the hexagon), would allow the integration of data layers with high spatial accuracy while minimizing loss of information, but would also limit a false sense of precision.

We used the mean area of rare natural communities mapped in CNDDDB, the mean area of Department Lands Units, and the scale used in the 2003 DFG Atlas of Biodiversity of California as frames of reference for determining an appropriate hexagon size. The Atlas of Biodiversity of California used 250.4 square mile (160,256 acres) hexagons as the analysis unit to calculate and display rarity-weighted richness statewide. Using a large unit to summarize rare species occurrence data has the advantage that nearby suitable habitat will likely be captured in the same unit. However, although the scale used in the Atlas is suitable for showing broad statewide patterns, it would be of limited usefulness for local conservation planning because significant local-scale variation in habitats would be expected within a 250 square mile area. Precise data on species occurrence and habitat locations would be lost when generalized across these coarse-scale units. For example, the mean size of a rare natural community mapped in CNDDDB is 0.8 mile² (513 acres), which would represent less than 0.5% of the area of a 250 mile² hexagon. The mean area of a Department Lands Unit is approximately 2-3 square miles (~1280-1960 acres). Because one goal of the ACE-II project was to provide data to inform land acquisition decisions, a hexagon size similar in size to the average DFG lands unit was chosen: 2.5 square miles (1600 acres).

Extent of Analysis

Spatial extent is an important consideration of any spatial analysis because it influences the number of and spread of values included in the analysis, thereby affecting the final results. In addition to analyzing data statewide, the ACE-II Technical Team considered analysis by smaller units including by county, by ecoregion, and by the Department's regional boundaries. We reviewed the distribution of data values across the state and assessed the implications of using different data extents for analysis and data viewing. For example, when comparing species richness across the state, the cool, wet forests of northwestern California have very high richness values, while the hot, dry deserts in southeastern California have very low values (for all taxonomic groups except reptiles). When analyzing and viewing the data at a statewide extent, the lowest richness areas in the northwest have a higher relative richness value than the highest richness areas in the southeast. Because the number and type of species and habitats in these two regions of the state are very different, identifying areas of highest richness within each region would likely be more meaningful for conservation than evaluating relative richness between the two areas. Assessing the highest richness areas within each region would also address *complementarity*, that is, representation of multiple highly rich areas distributed across the landscape.

Three types of regional divisions were considered for the purposes of the analysis: 6 Fish and Game regions, 19 USDA ecoregions (ecological sections), or 58 counties. Fish and Game regions and counties are politically-determined boundaries, while ecoregions represent "ecological sections" based on climate, geology and ecosystems. Relative biological richness likely has the most meaning when comparisons are made between areas that are generally ecologically similar. Therefore we chose to conduct the regional analysis based on USDA ecoregion sections. The Great Valley ecoregion, which spans the entire California central valley from Tehama County to Kern County was split into two sections for the purposes of this analysis due to large ecological differences between the northern and southern portion of this ecoregion. The ecoregion was split along the Merced River and Merced County line, and the ecoregions are designated as Great Valley North and Great Valley South.

Statewide Extent

In the statewide analysis, all biological richness values were assessed relative to values within the entire state. These data can be used for comparisons of biological richness between any two areas of the state; however, these data do not account for the large ecological differences across different regions of the state.

Ecoregional Extent

In the ecoregional analysis, all biological richness values were assessed relative to other values within that ecoregion. The biological index was built on the ecoregionally normalized values only. This analysis allows the identification of the areas of greatest richness and rarity within an ecoregion. Biological richness indices calculated separately by ecoregion, including the biological index, are not directly comparable between two different ecoregions.

Species and Habitat Data

Species Occurrence Data and Range Maps

To define which species data to include, we considered the following questions:

- Should habitat requirements of focal species be considered individually or generalized with species richness calculations?
- Should diversity measures be based on species range or species occurrence data?
- At what taxonomic level should species be viewed, at the species or subspecific level?

Two types of data are often available to map species distributions:

Species occurrence data, which represent confirmed occurrence locations mapped in CNDDDB or museum records, are specific and spatially accurate. Occurrence data have the advantage of representing habitat *known* to be occupied by a species. However, occurrence data are only available for areas where surveys have been completed and reported, resulting in a high rate of omission. In addition, occurrence data tend to be spatially biased toward areas with high levels of survey effort. For wide-ranging species, occurrence data may not be particularly useful for determining conservation priorities unless specific locations critical to a species survival are identified (e.g., wintering areas, breeding areas). Conversely, occurrence data may be highly relevant for determining conservation priorities for relatively immobile species that are restricted to specific locations in the landscape.

Range maps generally represent a coarse view of species distributions. Range maps are likely to be inclusive; they are generally meant to represent all potential occurrences within the limits of distribution for a species. Range map data have low spatial accuracy and high commission error (i.e., habitat areas included in the species range where the species is not found). Range maps may be limited in their usefulness for conservation prioritization because not all areas within range may be critical to conservation of a species. In addition, range maps are not available for all species. Of the 757 rare focal species identified for ACE-II, range maps are available for only 213 (28%). Many rare vertebrates are subspecies, and at this time CWHR range maps are only available for full species, not subspecies. Subspecies usually only occupy a portion of the full species range. There are currently no range maps for rare plants.

The ACE-II technical team considered several approaches for use of occurrence data and range maps to represent the distributions of the 757 rare focal species. Calculations of rarity-weighted richness, based on the area occupied by a species, are sensitive to the level of precision of species distribution data. For reliable calculations of rarity-weighted richness, the type and precision of the data must be consistent for each species. Species with less precise or coarser-scale distribution data show occupancy over a larger area than they actually occupy, which influences any area-based measures. If the precision of the species distribution data used to calculate such measures varies across species, species with less precise distributions will receive a lower rarity-weighted richness score as an artifact of data accuracy. Rarity-weighted richness then becomes a measure of data accuracy rather than a true representation of rarity. Similarly,

using distribution data that vary in precision for calculations of rare species richness would result in a bias toward the less precise data. In this case, richness would appear to be higher in areas of low data precision. A consistent approach that standardized the accuracy of the distribution data was necessary to ensure that the rarity measures were not highly skewed by the precision of the data. Three approaches were considered:

1. Intersect approach: Represents rare species distributions by occupied hexagons, in which any hexagon that intersects a known occurrence point or polygon is designated a species presence.
2. Buffer approach: Represents rare species distributions by occupied hexagons, in which any hexagon that intersects a known occurrence point or polygon, buffered by a specific distance, is designated a species presence. The buffer would serve to standardize the accuracy of all data points and polygons, and in addition, may capture potentially suitable habitat near known occurrences.
3. Pseudo-range approach: Creates “pseudo-ranges” for each species based on occupied ecoregions, or an intersection of USDA ecoregions and watersheds. Ecoregional boundaries are biologically based, so if a species occurs in one part of the ecoregion, it is likely there will be other areas of suitable habitat within that ecoregion. In addition, the resulting maps would be more comparable with the total species richness maps based on CWHR range maps, because CWHR range maps often use ecoregional boundaries to represent the edges of species ranges.

Ultimately, the preferred approach would be one that would estimate species distributions in the landscape. Use of species distributions would correct for biases caused by varying levels of survey effort, reporting, and access for surveys for different species and in different areas of the state. The pseudo-range approach was first considered to address this problem; however, this approach would introduce another type of imprecision, so in effect would trade one type of error for another. Modeled species ranges based on ecological drivers of species distributions would better predict ranges than assignment of species ranges to ecoregions or watersheds. Development of species distribution models for all 757 focal species was outside the scope of ACE-II, but future efforts should consider using species distribution models to correct for biases in species occurrence data. The buffer approach was chosen as the final method for use in ACE-II because it allowed for the incorporation of the greatest number of data points while maintaining precision of information at a scale appropriate for the hexagon size chosen.

Final protocol for occurrence data (CNDDDB, museum records, additional Department occurrence point datasets):

1. use only presumed extant CNDDDB occurrences (exclude extirpated and possibly extirpated)
2. use all records (no date cut-off)
3. exclude non-specific points with 5 mile buffer
4. buffer all non-specific points with 1 mile buffer

5. buffer all specific and non-specific polygons with 1 mile buffer
6. Count hexagons as occupied only if >5% overlap of hexagon by buffered species occurrence

Choosing Which Habitats to Address

In choosing which habitats to address, the ACE-II technical team considered what statewide habitat or vegetation maps were available, and the level of their accuracy. Vegetation or habitat mapping can be used to ensure representation of species and habitat types in a conservation prioritization as stated in the ACE-II biological assumption, “Conserving adequate areas of all habitat types in the state will capture the conservation of many species.” Habitat data may be a more appropriate vehicle for determining conservation priorities than individual species, because it captures the conservation of multiple species including those for which we have little information, such as invertebrates. However, use of habitat data to determine conservation priorities requires accurate, fine-scale habitat or vegetation maps, which are not currently available statewide in California. The lack of availability of appropriate datasets limited the incorporation of habitat data into ACE-II.

Certain habitat types such as wetlands and riparian habitats are of special concern because they are critical to maintaining ecosystem function and are protected by state and federal mandates. Habitats designated as rare natural communities are of conservation concern and may also be afforded special protections. These sensitive habitats were chosen for inclusion in ACE-II based on their high conservation value and legal mandate for protection. High value salmonid watersheds were also included.

Weighted-Additive Model

A weighted-additive model was used to combine the biological richness data layers into a single index. See Figure 1 for a flow chart depicting the modeling process. Additional explanation on the modeling process is provided below. The weighted-additive model steps were as follows:

- 1) Normalize all data layers to standardize all values from zero to one. This was done to remove any bias caused by variations in the range of values in different layers.
- 2) Combine data across taxonomic groups and habitat types. Sum species richness across taxonomic groups to produce an overall native species richness dataset. Repeat this process for rarity-weighted richness and rare species richness. Sum data from four sensitive habitat types into a single sensitive habitats layer.
- 3) Re-normalize the overall native species richness, rarity-weighted richness, rare species richness, and sensitive habitats datasets to standardize the weight of each data layer in the final model.
- 4) Various weights can be given to the normalized data layers at this point based on project goals or priorities. For example, a project that focuses on rare species may choose to increase the weight of the rare species layer. The weighted-additive model feature in the

ACE-II viewer allows the user to adjust the weights of the ecoregional layers and view the resulting maps.

- 5) For the ACE-II biological index model, no specific priorities among layers were defined; therefore, all data layers were given equal weight. The normalized native species richness, rarity-weighted richness, rare species richness, and sensitive habitat data layers were summed to produce the biological index surface.

Data Normalization

Data normalization was done to standardize the values of each layer in the final model, to ensure that results would not be artificially biased by variations in the range of values in the different data layers. Each layer was normalized by scaling the data values from zero to one, so that the each dataset would have the same range of values and the same maximum value. For each data layer, the data values in all hexagons were divided by the maximum data value in that dataset, so that the maximum value would be one, and all other values would be <1.

Normalizing by taxonomic group removed any potential bias caused by differences in the number of taxa per taxonomic group. Due to large differences in total numbers of species between taxonomic groups (e.g., 59 total native amphibians, 4960 total native plants), the sum of total species richness based on raw values resulted in richness maps highly skewed toward the taxonomic group(s) with the largest numbers of species. Data were normalized from zero to one by dividing the hexagon values for each taxonomic group in each data layer by the largest value for that taxonomic group in that layer, giving the highest value hexagon in each layer a normalized value of one. For example, the hexagon with the largest plant richness value would have a normalized value of one, and the hexagon with the largest amphibian richness value would have a normalized value of one. The normalized values were then summed across the six taxonomic groups to obtain total native species richness. This method was repeated to obtain total rare species richness and total rarity-weighted richness maps. The four final data layers were also normalized before input into the weighted-additive model to give each layer equal weight in the final model.

For statewide maps, data were normalized on a statewide basis. For ecoregional maps, each layer was normalized ecoregionally, meaning the data for each layer were normalized from zero to one based on the values within the ecoregion. This allows for the identification of the highest value areas within each ecoregion.

Ranking

All final data layers were ranked by quintiles. Quintiles represent a percentile ranking with 5 classes. This allows the user to see an easily interpretable rank-score for each hexagon. The statewide ranking shows the rank-score of the hexagon on a statewide basis, while the ecoregional ranking shows the rank-score of the hexagon within the ecoregion. Rank 5 represents the top scoring fifth (81st–100th percentile) of hexagons for the index represented; rank 1

represents the lowest scoring fifth (1st-20th percentile) of hexagons; and ranks 2, 3 and 4 represent the 21st-40th, 41st-60th, and 61st-80th percentiles, respectively.

Weighted-Additive Model Viewer Application

The weighted-additive model application in the ACE-II viewer provides an on-line, interactive interface that allows the user to define weights for the four biological richness indices to create customized biological index model maps. This is a preliminary step in developing a flexible framework to address specific land acquisition or management questions.

ACE-II Evaluation

In July 2010 meetings were conducted at Department regional offices throughout the state to review the ACE-II biological index layer. The biological index layer was reviewed by Department staff with local expertise on the distribution of biodiversity and conservation value in the landscape in different areas of the state. Many areas of high conservation value as identified by local experts received high biological index scores. Areas of high conservation value that received low biological index scores generally fell into the following categories: habitats important for a single focal species, habitats with population-level importance (e.g., largest population, southernmost population), wildlife linkages and corridors, intact wildland areas or areas adjacent to conserved lands, specific upland habitat types such as oak woodland and coastal sage scrub, aquatic reaches and fish habitat, habitats with high invertebrate diversity or rarity, large game important habitat (e.g., deer winter range), and habitats with limited public data such as large tracts of private lands. The identification of these types of areas was outside the scope of ACE-II due primarily to the limitations of available statewide data (see Appendix A). However, additional datasets may be available to help identify these types of areas during a local conservation prioritization (Table 3).

Table 3. Types of areas of high conservation value not addressed in ACE-II, and datasets available to identify these areas.

Type of conservation value	Datasets that may address this conservation value during local conservation prioritization
Habitats important for a single focal species	Local data or individual species records to highlight areas important for focal species. For terrestrial vertebrates, some areas have been identified by using detailed vegetation data with habitat suitability models from CWHR.
Population-level importance (i.e., largest population or southernmost population of a species)	Local data or individual species records to highlight areas important for focal species.
Wildlife linkages and corridors	Natural Landscape Blocks and Essential Connectivity Areas and/or local data to identify linkages and corridors.
Intact wildland areas or areas adjacent to protected lands	Natural Landscape Blocks and Essential Connectivity Areas and maps of protected status to identify intact habitats and juxtaposition to protected lands.
Specific upland habitat types such as oak woodland, coastal sage scrub, bunchgrass prairie	Vegetation maps or local data to identify specific focal habitat types of concern.
Aquatic reaches and fish habitat	Routed hydrology layer and species-specific or local data from Cal-FISH or other sources
Areas with acquisition opportunity	Local-level data regarding willing sellers
Habitats with high invertebrate diversity or rarity	Species data and local datasets to highlight areas of high invertebrate diversity. In some cases habitat can be used as a surrogate (i.e., vernal pools).
Large game important habitat (i.e., deer winter range)	Species specific or local datasets such as winter range and fawning grounds. High value areas could be identified within specific habitat types or elevation ranges. Natural Landscape Blocks and Essential Connectivity Areas may also identify areas of intact habitat important to large game.
Habitats with limited data, such as large tracts of private land	Natural Landscape Blocks and Essential Connectivity Areas may identify areas of intact habitat with limited data.

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