11th Edition

Training Manual

California Wildlife Habitat Relationships System

CWHR Database Version 9.0

by

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PREFACE

This manual was prepared to support a training program on the California Wildlife Habitat Relationships System (CWHR). The CWHR system was designed in the early 1980's as a conservation planning and impact assessment tool for qualified wildlife biologists and natural resource managers. CWHR uses standardized wildlife-habitat relationships models and a habitat classification system as its foundation. An active training program was envisioned by the CWHR developers and managers as the primary method by which biologists and managers became familiar with the CWHR system so it would be used properly.

This training manual is the basis for the training session in which you will be participating over the next several days. It must be recognized, however, that this session will not cover every aspect of the system or every possible scenario that can be analyzed with CWHR. This manual along with the training session will provide you with a thorough understanding of the design, use, and assumptions behind the CWHR system. Other supporting CWHR publications should be consulted for additional information because they have greater detail on many areas discussed herein. Also, continued use of the system will increase your technical CWHR knowledge and ability.

INTRODUCTION TO THE CWHR SYSTEM

PURPOSE OF CWHR

The CWHR system is a comprehensive information system for California wildlife that describes, models, and predicts: (1) habitat relationships and requirements; (2) management status; (3) geographic distribution; (4) life history; and (5) responses to habitat changes of wildlife species in the system (Airola 1988).

Currently, the system has models for 712 species of regularly-occurring resident and migratory terrestrial and aquatic amphibians, birds, mammals, and reptiles in California. Regularly-occurring species are modeled in CWHR because these are the species that typically receive management emphasis by resource professionals in California. Well over 1000 terrestrial vertebrates are known from California and the CWHR system does have taxonomic information on all of these species. Species not in the CWHR system typically include vagrant and pelagic birds, and completely marine animals such as whales, dolphins, porpoises, and sea turtles.

All species in the database have the same general model structure and components, therefore, all species are treated equally in CWHR analyses. The benefit of this equality is that CWHR allows users to conduct community-level analyses that consider all potential members of the wildlife community, regardless of management status. Most impact assessments and management plans focus on several key species that have some special status, but CWHR gives all species equal treatment.

CWHR habitat-relationship models are known as "matrix" type models because habitat relationships are categorized using a matrix of habitats and vegetation size/cover stages (Morrison et al. 1992, Van Horne and Wiens 1991). A single habitat suitability rating (e.g., HIGH, MEDIUM, LOW, or UNSUITABLE) is given to each matrix cell. The habitat rating was developed from review of available scientific literature and professional judgment. A series of assumptions were made regarding the characteristics of the habitats in the matrix (see Specific Model Assumptions). At best, the habitat-relationships models and their habitat suitability ratings must be considered very coarse scale models, and they are one of the simplest types of models. Morrison et al. (1992) has a very thorough discussion on the different types of habitat-relationships models, including matrix models.

CWHR is a state-of-the-art tool with statewide applications for wildlife population, community, and habitat management and conservation, teaching and education, and research (Airola 1988). CWHR's standardized approach improves the consistency, reliability, accountability, efficiency, and credibility of wildlife analyses and resource management decisions.

The major goals of the CWHR program are (modified from Airola 1988):

1. Create a standardized information system on the geographic distribution, habitat relationships, management status, and natural history of California's wildlife that can be used by natural resource managers and scientists throughout California.

2. Create a dynamic system so that new information and technologies can be incorporated as needed.

3. Provide relatively easy access to published information and professional judgment about California's wildlife and their habitats in a standardized format through publications and a computer database.

4. Foster consistency, credibility, and accountability of analyses involving wildlife resources so that predicted impacts from various land uses can be readily compared in a standardized manner.

5. Provide a tool that predicts the potential of habitats to support wildlife and the effects of habitat changes.

6. Ensure a wildlife "community" and "ecosystem" orientation to these analyses by considering all regularly occurring wildlife that may occur in a given area and habitat.

7. Create a tool that makes analyses involving California's wildlife resources more understandable and credible to the general public and decision makers.

HISTORY OF CWHR'S DEVELOPMENT AND USE

A major impetus for California's CWHR program was the standardized wildlife information system developed by Thomas (1979) for the Blue Mountains of Oregon and Washington. This system modeled the habitat needs of wildlife by grouping them into guilds based on similarities in feeding and nesting.

California's CWHR system differs from that of Thomas (1979) by modeling the distribution, life history, and habitat relationships of each species individually instead as part of a guild. This allows more precise analyses of impacts to individual species and communities (Grenfell et al. 1982, Airola 1988).

The initial California CWHR efforts were conducted by the U.S. Forest Service (USFS) for five different geographic zones in the state during the late 1970's and early 1980's (Airola

1988): western Sierra Nevada (Verner and Boss 1980, Hurley and Asrow 1980); north coast/Cascades (Marcot 1979); northeast interior (Airola 1980a, 1980b, 1980c; Laudenslayer 1982; Laudenslayer et al. 1982; Shimamoto and Airola 1981); Lake Tahoe Basin (Osaki 1980); and southern California (Loe and Keeney unpubl. rept.).

Although there were many benefits to the USFS zone approach, certain deficiencies became evident when attempts were made to apply the systems statewide. These deficiencies included: (1) incomplete state geographic coverage; (2) inconsistencies in naming and classifying habitats; (3) an incomplete statewide habitat classification system; and (4) a primary focus on forested habitats and wildlife. These deficiencies limited the utility of the zone systems as land use planning tools in California.

The statewide CWHR system was initiated in 1981 to overcome the deficiencies and incorporate the strengths of the USFS zone systems. The major advances of the statewide system were a uniform statewide habitat classification system, complete coverage for the entire state, and a multi-agency organization to manage and operate the system known as the California Interagency Wildlife Task Group (CIWTG).

Initially, the CWHR database was primarily used to predict lists of species potentially occurring in given areas and habitats. This use continues today, along with other uses such as impact assessment, habitat suitability modeling, education, and research (Appendix C). The habitat classification system was used to describe, delineate, and quantify wildlife habitats in management and project areas. These uses continue today by long-time and new subscribers alike, and use of CWHR in California is increasing as the need for wildlife information increases.

On a regional and statewide basis, CWHR is associated with: (1) regulations under the California Forest Practice Act, which require use of the CWHR classification system to describe wildlife characteristics of late seral stage forest stands; (2) a Memorandum of Understanding (MOU) between state and federal natural resource agencies pledging to conserve California's biodiversity; (3) an MOU between state and federal natural resource agencies pledging to coordinate vegetation mapping throughout California; (4) Land Acquisition Evaluations to the Wildlife Conservation Board, which require use of the CWHR classification system in describing land for potential acquisition by the state; (5) the California GAP program, where the CWHR system is the foundation for mapping and quantifying wildlife species richness throughout California and identifying geographic gaps in biodiversity conservation areas (Davis et al. 1991); (6) the Forest Inventory and Analysis System developed by the California Timberland Task Force (1993), where forest types are mapped using the CWHR classification system and species models are used to predict changes in habitat suitability through time under different forest management scenarios; and (7) water rights applications to the State Water Resources Control Board, in which habitats must be typed using the CWHR system.

ORGANIZATIONAL STRUCTURE

Formed in 1981 to direct the CWHR program, the California Interagency Wildlife Task Group (CIWTG) consists of several state and federal natural resource agencies and academic institutions. The CIWTG has several major goals including: (1) increasing understanding of relationships between wildlife and their habitats; (2) guiding research and conservation efforts involving wildlife resources; (3) developing standardized information sources for California wildlife nomenclature, habitat relationships, habitat classification, and impact assessment; (4) developing and promoting a variety of analytical methods and tools for use in wildlife resource management, conservation, and research; and (5) providing guidance on the operation, management, and development of the CWHR system.

CIWTG holds quarterly meetings throughout California. A CIWTG Chairperson is elected by the group. That individual cannot be from the California Department of Fish and Game (CDFG) as CIWTG provides advice and guidance to CDFG on CWHR activities. From the outset, CDFG was placed as the manager of the daily operation and maintenance of the CWHR system.

In early 1993, a Memorandum of Understanding (MOU) was signed that outlined the relationships and responsibilities of the CIWTG and CDFG (Appendix E). Under the MOU, CDFG manages the daily operation, management, and maintenance of the system, while the CIWTG provides oversight and guidance on CWHR matters.

COMPONENTS OF THE CWHR SYSTEM

The CWHR system consists of: (1) wildlife-habitat relationships database software; (2) a series of supporting publications (Airola 1988; Mayer and Laudenslayer 1988; Zeiner et al. 1988, 1990a, and 1990b) which includes a standardized wildlife habitat classification system; and (3) Geographic Information System (GIS) data.

The wildlife-habitat relationships database software was developed to store and report most of the information provided by the CWHR System. Information for each modeled species includes a unique code, common and scientific name, taxonomic classification, management status, distribution, seasonal occurrence, habitats and stages used, relative value of each habitat stage for reproduction, feeding and cover, and the species' use of special habitat elements. The information is stored in several large database files with the relational component being the four-character alpha-numeric identification code (e.g. B001, M053, etc.). To date, the software produces nine types of reports (Appendix B). Bioview, an application added to the CWHR software beginning with Version 8.0, produces two additional types of output. This application takes habitat suitability ratings from the CWHR database for user-selected species and returns them to a user-provided habitat data file.

Major publications of the CWHR System include an explanatory guide (Airola 1988), a habitat guide (Mayer and Laudenslayer 1988) and a three-volume set of species notes (Zeiner et al., 1988-1990). The habitat guide, available electronically with updates, provides detailed descriptions of the wildlife habitats and stages recognized by the system. The three-volume set of species notes, now out of print but available electronically, contains a life history account, a range map, and an illustration for each species. Species have been added and life history notes updated since publication of these volumes. All of the accounts found in both the habitat guide and the species notes volumes are available on-line and in the database software.

GIS data includes species distribution maps as vector-based GIS shapefiles. All distribution maps were originally delineated at approximately 1:5,000,000 scale for the three-volume set of species notes. As maps are revised, they are delineated at a more precise 1:1,000,000 scale. Approximately 70% of the maps have undergone major or minor revision since publication of the original three-volume set. Species distribution maps are available as images in the database software, as *.pdf reports on-line, and as GIS shapefiles.

SYSTEM ASSUMPTIONS

GENERAL SYSTEM ASSUMPTIONS

The CWHR system was created and designed based on a set of well-defined assumptions. Several of these assumptions are unique to CWHR, while others are common to almost every type of wildlife-habitat relationships model. Assumptions must be acknowledged by CWHR users because they are the foundation of system use and interpretation of database outputs. The general assumptions for CWHR system include:

1. Wildlife species occurrence and abundance are strongly influenced by habitat conditions.

2. Wildlife habitat can be described by a set of environmental characteristics.

3. Relative suitability values (i.e., HIGH, MODERATE, LOW, UNSUITABLE) of habitats and the relative importance of special habitat elements may be determined for each species.

4. Habitat suitability value is uniform for a species throughout its range in California for the specified habitat.

SPECIFIC MODEL ASSUMPTIONS

Specific assumptions are needed for the models because of their defined structure. These specific assumptions include:

1. Habitat ratings reflect values only for that species.

2. Habitats for species that require juxtaposition of two or more habitats were individually rated as if the other habitats were available in the proper mix.

3. Ratings were developed assuming that all special habitat elements were present in adequate amounts if they are typical components of the habitat.

4. Habitats were rated assuming that adequate habitat amounts and patch sizes exist.

USING THE CWHR SYSTEM

The CWHR user is responsible for correct use of the CWHR system and correct interpretation of system output.

USER RESPONSIBILITY

Ultimately, the CWHR user is responsible for proper system use, while CDFG and CIWTG are responsible for improving the system and promoting proper use. The system is not perfect (see Accuracy of the CWHR Database), and users must acknowledge and accept these inaccuracies when using CWHR. If error-free predictions about wildlife habitat-relationships are needed for whatever reason, then CWHR should not be used. However, if relatively course-scale habitat-relationships models are needed for a variety of predictions about regularly-occurring California wildlife, then CWHR is an appropriate tool. CDFG and CIWTG are responsible for operation, maintenance, and improvement of the system, as well as training users in appropriate use. Yet, no one but the CWHR user is responsible for system use and output interpretation. The credibility of the CWHR system, its developers and managers, and wildlife biologists all suffer when the system is used inappropriately or inadequately.

CWHR DATABASE DEFINITIONS

Life Requisites. CWHR habitat-relationship models rate habitat value for three major life functions or life requisites: Reproduction, Feeding, and Cover. Water use is assumed to occur under each life requisite depending on the role of water in each species life history. Ratings for habitat suitability and habitat elements are given for all three life requisites (see respective Sections below). In many cases, habitats or elements will not have ratings for one or two life requisites, particularly for species that require special habitats or elements for a single life requisite, such as amphibians and many birds.

Habitat Suitability Ratings. All CWHR species models have suitability ratings for all habitats and stages in the system; this includes a rating of UNSUITABLE for those habitats which the species does not utilize. UNSUITABLE ratings occur when the species is not listed in the habitat relationships matrix. These ratings apply only to that species, and the ratings apply to habitats and stages throughout the species' California range. The ratings reflect the habitat's ability to support the species as measured by frequency of occurrence or population density. However, the rating definitions do not explicitly assess habitat suitability in terms of reproduction and survivorship, which ultimately are more valid measures of habitat quality than population density (Van Horne 1983). The four suitability ratings are as follows (modified from Airola 1988):

1. HIGH: Habitat is optimal for species occurrence; can support relatively high population densities at high frequencies.

2. MODERATE: Habitat is suitable for species occurrence; can support relatively moderate population densities at moderate frequencies.

3. LOW: Habitat is marginal for species occurrence; can support relatively low population densities at low frequencies.

4. UNSUITABLE: Habitat is unsuitable for species occurrence; species is not expected to occur in the habitat. The database allows users to specify habitat ratings for searches. Different ratings can be specified for any or all life requisites (Reproduction, Feeding, Cover). Unless user-specified, the database defaults to the lowest rating for suitable habitat (LOW). If specified, the database includes those species that have a life requisite suitability at or above the specified level. For example, specifying MEDIUM for Reproduction, Feeding, and Cover will result in output for species with MEDIUM and HIGH ratings. The greater the habitat rating, (i.e., HIGH > MEDIUM), the fewer the total number of species predicted for a given habitat because species with lower habitat ratings are eliminated.

Geographic Location. Database searches can be done using several different geographic location categories. These categories include: Counties, USDA Ecoregions (CIWTG Endorsed), Cal Water Hydrologic Regions, US Forest Service National Forests. Counties are the smallest geographic area to search for most of California's 58 counties. Exceptions would be large counties such as Inyo, San Bernardino, Kern, Riverside, Lassen, and Siskiyou.

Species predictions for each county are drawn from a variety of sources, including the CWHR distribution maps, published county bird lists and observations by field biologists and other users of CWHR. Some discrepancies will exist between the database models and the distribution maps as maps are not updated as often as the database. However, the distribution of a species, as represented in the database model, will always be inclusive of the area covered by the published map. When discrepancies exist -- particularly in the case of birds, where published county bird lists based on actual observations were reconciled with predictions based on distribution maps -- users should trust the database output. In the case of amphibians, reptiles and mammals, database output more closely resembles distribution maps.

Users should also note that a species in the database is predicted to occur in a county if any source of data regarding that species refers to even a small portion of the county. This holds true for other location categories as well. For example, the long-toed salamander (*Ambystoma macrodactylum*) occurs in extreme northeastern Del Norte County (Zeiner et al. 1988). The database would predict its occurrence in Montane Hardwood-Conifer habitat in Del Norte County even if a user's project area were in the southwest corner of the county. Here is a case where the user might denote species from the CWHR output that do not occur in the project area based on published distribution maps. (Users are cautioned against doing this for bird species, however; see paragraph above.)

Habitat Elements. There are 124 habitat elements used in the CWHR system to describe special habitat components that could not be readily addressed with the habitat matrix. Elements provide a finer scale of habitat description than is possible simply with matrix habitat suitability ratings. In fact, suitability ratings were made assuming the presence of all elements expected in a given habitat. It is the knowledge of broad habitat relationships and geographic distribution, not habitat elements, keeps spurious predictions from occurring, such as woodpeckers from being predicted for Marine habitats.

The database allows users to exclude elements that are absent from the project area. The elements function only to delete species from the list of predicted species; they do not drive presence predictions. They also do not modify the habitat ratings except to make habitat unsuitable by deleting species requiring the absent element. Therefore, the elements can be used to fine-tune species list predictions.

The database assumes all elements are present if they are typical components of the habitat. Model users often ask for explicitness on which special elements they may assume are typical in any given habitat, so they know which elements to exclude in a query. Users may be confident in the following standard assumptions regarding elements:

1. If a habitat can be found next to another habitat that contains an element, that element is assumed to be present. For example, large logs in various states of decay may be assumed present in the shore zone of marine habitat because of the adjacency of other habitats.

2. An element is assumed to be present unless it is never present, either in the habitat being evaluated or any other habitat that might occur nearby.

As a result of these assumptions, most habitats possess virtually all of the elements. The exceptions are listed below.

Table 1. Elements Assumed Absent in CWHR Habitats.

CWHR Habitat	**Dominant Species or Dominant Associates**	**Elements Assumed Absent** (CWHR users do not have to delete these elements during queries.)
Tree-Dominated Habitats (27)		
Aspen (ASP)	Willow, Alder, Black Cottonwood	kelp, salt ponds, tidepools
Blue Oak Woodland (BOW)	Interior Live Oak, Valley Oak, Juniper	kelp; salt ponds; sand dunes; tidepools; trees, fir
Blue Oak-Foothill Pine (BOP)	Interior Live Oak, Valley Oak, California Buckeye	kelp; salt ponds; sand dunes; tidepools; trees, fir
Closed-Cone Pine-Cypress (CPC)	Tecate, Cuyamaca, Foothill Pine	none
Coastal Oak Woodland (C0W)	White Oak, California Black Oak, Engelmann Oak	none
Eucalyptus (EUC)	Blue Gum, Red Gum	none
Desert Riparian (DRI)	Tamarisk, Velvet Ash, Mesquite	kelp; tidepools; trees, fir
Douglas-Fir (DFR)	Live Oaks, Tanoak, Ponderosa Pine	none
Eastside Pine (EPN)	Ponderosa Pine, Jeffrey Pine, White Fir	kelp, salt ponds, sand dunes, tidepools
Jeffrey Pine (JPN)	Ponderosa Pine, Coulter Pine, Sugar Pine	kelp, salt ponds, sand dunes, tidepools
Joshua Tree (JST)	Juniper, Singleleaf Pinyon, Mojave Yucca	kelp; log, large rotten; log, large sound; log, large hollow; snag, large rotten; snag, large sound; tidepools
Juniper (JUN)	White Fir, Jeffrey Pine, Ponderosa Pine	kelp, tidepools
Klamath Mixed-Conifer (KMC)	White Fir, Douglas-Fir, Ponderosa Pine	kelp, salt ponds, tidepools
Lodgepole Pine (LPN)	Aspen, Mountain Hemlock, Red Fir	kelp, salt ponds, sand dunes, tidepools
Montane Hardwood (MHW)	Canyon Live Oak, Douglas Fir, Knobcone Pine	kelp, salt ponds, tidepools
Montane Hardwood-Conifer (MHC)	Ponderosa Pine, Douglas Fir, Incense Cedar	kelp, salt ponds, tidepools
Montane Riparian (MRI)	Black Cottonwood, White Alder, Bigleaf Maple	kelp, salt ponds, tidepools
Palm Oasis (POS)	Coyote Willow, Velvet Ash, Sycamore	acorns; cones; kelp; tidepools; trees, fir

CWHR Habitat	**Dominant Species or Dominant Associates**	**Elements Assumed Absent** (CWHR users do <u>not</u> have to delete these elements during queries.)
Pinyon-Juniper (PJN)	Oaks, Mojave Yucca, Ponderosa Pine	kelp, tidepools
Ponderosa Pine (PPN)	White Fir, Incense Cedar, Coulter Pine	kelp, salt ponds, tidepools
Red Fir (RFR)	Noble Fir, White Fir, Lodgepole Pine	kelp, salt ponds, sand dunes, tidepools
Redwood (RDW)	Sitka Spruce, Grand Fir, Douglas Fir	none
Sierran Mixed-Conifer (SMC)	White Fir, Douglas Fir, Ponderosa Pine	kelp, salt ponds, tidepools
Subalpine Conifer (SCN)	Engelmann Spruce, Subalpine Fir, Mountain Hemlock	kelp, salt ponds, sand dunes, tidepools
Valley-Foothill Riparian (VRI)	Cottonwood, Sycamore, Valley Oak	kelp; trees, fir
Valley Oak Woodland (VOW)	Sycamore, Black Walnut, Foothill Pine	kelp; sand dunes; tidepools; trees, fir
White Fir (WFR)	Live Oak, Jeffrey Pine, Sugar Pine	kelp, salt ponds, tidepools
Shrub-Dominated Habitats (12)		
Alkali Desert Scrub (ASC)	Saltbush, Sagebrush, Creasotebush	kelp, tidepools
Alpine Dwarf-Shrub (ADS)	Creambush Oceanspray, Greene Goldenweed, Mountain White Heather	kelp, tidepools
Bitterbrush (BBR)	Big Sagebrush, Rabbitbrush, Mormon Tea	kelp, tidepools
Chamise-Redshank Chaparral (CRC)	Toyon, Ceanothus, Sugar Sumac	kelp, tidepools
Coastal Scrub (CSC)	Lupine, Coyotebush, Sagebrush	none
Desert Scrub (DSC)	Creasotebush, Catclaw Acacia, Desert Agave	kelp, tidepools
Desert Succulent Shrub (DSS)	Octillo, Mojave Yucca, Desert Agave	acorns; kelp; tidepools; trees, fir; trees, pine
Desert Wash (DSW)	Paloverde, Desert Ironwood, Mesquite	kelp; log, large rotten; log, large sound; log, large hollow; snag, large rotten; snag, large sound; tidepools; trees, fir
Low Sage (LSG)	Rabbitbrush, Bitterbrush, Winter Fat	kelp, tidepools
Mixed Chaparral (MCH)	Oaks, Ceanothus, Manzanita	kelp, tidepools
Montane Chaparral (MCP)	Ceanothus, Manzanita, Bitter Cherry	kelp, salt ponds, sand dunes, tidepools
Sagebrush (SGB)	Rabbitbrush, Sagebrush, Gooseberry	kelp, tidepools

CWHR Habitat	Dominant Species or Dominant Associates	Elements Assumed Absent (CWHR users do not have to delete these elements during queries.)
Herbaceous-Dominated Habitats (6)		
Annual Grassland (AGS)	Wild Oats, Soft Chess, Brome	none
Freshwater Emergent Wetland (FEW)	Big Leaf Sedge, Bulrush, Redroot Nut Grass	none
Saline Emergent Wetland (SEW)	Cordgrass, Pickleweed, Bulrush	trees, fir
Pasture (PAS)	Bermuda Grass, Ryegrass, Tall Fescue	none
Perennial Grassland (PGS)	California Oatgrass, Hairgrass, Sweet Vernalgrass	none
Wet Meadow (WTM)	Thingrass, Sedge, Spikerush	kelp, tidepools
Agricultural and Developed Habitats (9)		
Dryland Grain Crops (DGR)	Cereal Rye, Barley, Wheat	none
Deciduous Orchard (DOR)	Almonds, Walnuts, Peaches	none
Evergreen Orchard (EOR)	Oranges, Avocados, Lemons	none
Irrigated Hayfield (IRH)	Alfalfa, Hay	none
Irrigated Grain and Seed Crops (IGR)	Corn, Dry Beans, Safflower	none
Irrigated Row and Field Crops (IRF)	Tomatoes, Cotton, Lettuce	none
Rice (RIC)	Rice	none
Urban (URB)	Grass Lawns, Trees, Hedges	none
Vineyard (VIN)	Grapes, Kiwi Fruit, Boysenberries	none
Aquatic Habitats (4)		
Estuarine (EST)	Plankton, Algae, Eel Grass	none
Lacustrine (LAC)	Plankton, Duckweed, Water Willies	none
Marine (MAR)	Plankton, Algae, Kelp	Stage 1 (pelagic) – acorns, amphibians, aquatics, bogs, brush pile, buildings, burrow, campground, cave, cliff, cones, duff, dump, eggs, fences, fern, flowers, forbs, fruits, fungi, grain, graminoids and grass interfaces, insects, lakes, layers, lichens, lithic, litter, mammals – medium and small, moss, mud flats, nectar, nest box, nest island, nuts, pack stations, ponds, riparian, rivers, rock, roots, salt ponds, sand dune, sap, seeds, shrubs and shrub interfaces, soils, springs, steep slopes, streams, stumps, talus, transmission lines, tree leaves,

CWHR Habitat	Dominant Species or Dominant Associates	Elements Assumed Absent (CWHR users do not have to delete these elements during queries.)
		trees and tree interfaces, vernal pools, water – fast, slow and man created, water/agriculture
		Stages 2-4 (subtidal, intertidal, shore, respectively) – none
Riverine (RIV)	Water Moss, Algae, Duckweed	none
Non-Vegetated Habitats (1)		
Barren (BAR)	Rock, Pavement, Sand	none

It must be acknowledged that the database has no explicit way of fully accounting for element distribution, abundance, and quality. When elements are excluded, they are assumed to be absent or present in unsuitable quality or insufficient amounts and distribution. The user must determine the quality and sufficiency of the elements with field inventories of the project area.

The elements were given the following suitability ratings in the models for Reproduction, Feeding, and Cover life requisites (Airola 1988):

1. ESSENTIAL: Required for the species to exist; must be present in habitat if species is to be present.

2. SECONDARILY ESSENTIAL: Required but may be replaced by other secondarily essential elements; must be present unless compensated by presence of other secondarily essential elements in the same life requisite category.

3. PREFERRED: Used but marginally helpful for survival; enhances habitat suitability, but is not essential for species to be present; element used more than would be expected based on availability.

4. NOT RATED: May or may not be used; if used, element does not enhance habitat suitability; element used less than expected based on availability.

As with Habitat Suitability Ratings, the database allows the user to select an element suitability rating for queries. This decision is one of the most critical in producing species lists. If no rating level is selected, the database defaults to the highest suitability level for element use (ESSENTIAL). When elements are excluded, fewer species are deleted at the higher requisite levels because species are excluded based on element suitability. CWHR has a default of excluding elements at the ESSENTIAL level because it is not desired or biologically correct to eliminate species that can fulfill their life requisites with other habitat elements that were not excluded. Unnecessary or incorrect species deletions increase the likelihood of omission errors, which, in this case, are due to improper database use and not model error. The effect of different element suitability ratings on a hypothetical CWHR species list is illustrated in Table 2.

Table 2. Matrix illustrating the effect of element suitability rating selection on individual species model results with CWHR queries that exclude species.

Hypothetical Species	Life Requisites and Suitability Levels			Element Excluded at		
				Essential[a]	Sec. Essential[b]	Preferred[c]
	Reproducti on	Cover	Feed	Result	Result	Result
A001	E	E	E	DROP	DROP	DROP
A045				RETAIN	RETAIN	RETAIN
B005	S	P	P	RETAIN	DROP	DROP
B510	E	S		DROP	DROP	DROP
M018	P	P		RETAIN	RETAIN	DROP
M052	S	S		RETAIN	DROP	DROP
R023	S	P	P	RETAIN	DROP	DROP
No. spp. retained				5 SPP.	2 SPP.	1 SPP.

[a]Excluding at "ESSENTIAL" level drops those spp. with ≥ 1 suitability level for the excluded elements at the "ESSENTIAL" level; retained spp. will be those that have a suitability level at "SECONDARILY ESSENTIAL" or "PREFERRED" for any life requisite for the elements.

[b]Excluding at "SECONDARILY ESSENTIAL" level drops those spp. with ≥ 1 suitability level for the excluded elements at the "SECONDARILY ESSENTIAL" or "ESSENTIAL" levels; retained spp. will be those that have a suitability level at "PREFERRED" or unsuitable for all life requisites.

[c]Excluding at "PREFERRED" level drops those spp. with ≥ 1 suitability level for the excluded elements at the "PREFERRED", "SECONDARILY ESSENTIAL", or "ESSENTIAL" levels; retained spp. will be those that do not have a rating for the excluded elements.

The results in Table 2 are fairly obvious. Excluding at the "Essential" level retained five of the seven species, while excluding at the "Secondarily Essential" and "Preferred" levels resulted in retention of two and one species, respectively. Therefore, the more restrictive suitability rating of "Essential" resulted in a larger number of predicted species, and, a presumably reduced number of omission errors. The amount of commission errors with different suitability ratings would likely vary in proportion to the number of species predicted by CWHR.

Seasonality. Two options exist to define queries based on seasonality: Season in Location or Season in Habitat. These options restrict predictions to those wildlife species with a given seasonal status in the selected geographic locations or habitats. Season in Location and Season in Habitat may be different for a given species depending on its residency status and movements throughout California. If a user selects nothing or selects "All Season Categories", species predictions will not be restricted based on this parameter.

The seasons used in CWHR are defined based on those used in *American Birds* for seasonal bird reports. While the seasons are based on migration and residency patterns of California birds, these seasons correspond fairly well with life history patterns of many California wildlife species. The seasons are defined as follows:

Winter:	December 1 - February 28
Spring:	March 1 - May 31
Summer:	June 1 - July 31
Fall:	August 1 - November 30

Table 3 illustrates what seasons are included under a particular CWHR season category, and the seasonal occurrence status of wildlife in the appropriate CWHR category.

Table 3. CWHR season categories, seasons included in the categories, and appropriate animal seasonality patterns.

CWHR Season Choices	Seasons				Animal Seasonality Pattern
	Winter (Dec. 1 to Feb. 28)	Spring (Mar. 1 to May 31)	Summer (Jun. 1 to Jul. 31)	Fall (Aug. 1 to Nov. 30)	
Only Species Present Yearlong	X	X	X	X	seen in all seasons, mostly residents
Only Winter Visitors	X				winter only
	X			X	fall through winter
	X	X		X	fall through spring
	X	X			winter through spring
Only Summer Visitors and Breeders			X		summer only
		X	X		spring through summer
		X	X	X	spring through fall
			X	X	summer through fall
Only Migrants				X	fall only
		X			spring only
		X		X	spring and fall

Arithmetic and Geometric Means. Two Condition queries can produce either *Habitat Value Comparison Reports* or *Weighted Habitat Value Reports*. These reports require the selection of formula to integrate habitat suitability ratings for Reproduction, Feeding, and Cover, and calculate a mean habitat suitability rating. Users must select either Arithmetic or Geometric means.

In both reports, the habitat stage life requisite ratings of HIGH, MEDIUM, LOW, or UNSUITABLE are converted to numeric values of 1.00, 0.66, 0.33, and 0.00, respectively. These values for Reproduction, Feeding, and Cover are averaged for each size/cover stage. Each formula has its advantages and disadvantages, and users should be aware of these when selecting a formula. Arithmetic means treat each life requisite rating equally, regardless of value, while

Geometric means give greater weight to extreme values (i.e., 1.00 or 0.00). Arithmetic means will always result in a numeric value, even with UNSUITABLE ratings for one or more life requisites. Geometric means will result in values of 0.00 with one or more UNSUITABLE ratings. Both means give lower values to poorer quality habitat, but Geometric means tend to give lower values than Arithmetic. Queries using arithmetic means generally result in fewer omission errors than queries using geometric means when some CWHR species models predict the habitat to be unsuitable for a life requisite because an Arithmetic mean always returns an average suitability value > 0.00 for species that use the habitat for at least one life requisite.

The formulae used to calculate arithmetic and geometric means for the various types of CWHR reports are as follows:

Habitat Value Comparison Report:

Arithmetic mean: $$SI = \frac{1}{N} \sum_{i=1}^{N} \frac{(R_i + C_i + F_i)}{3}$$

Geometric mean: $$SI = \frac{1}{N} \sum_{i=1}^{N} \sqrt[3]{(R_i * C_i * F_i)}$$

Weighted Habitat Value Comparison Report:

Arithmetic Mean: $$SI = \sum_{i=1}^{N} \left(\left(\frac{(R_i + C_i + F_i)}{3}\right)*(weight_i)\right)$$

Geometric Mean: $$SI = \sum_{i=1}^{N} \left(\sqrt[3]{R_i * C_i * F_i} * weight_i\right)$$

Where:

R = suitability value for Reproduction
C = suitability value for Cover
F = suitability value for Feeding
SI = mean habitat suitability index
N = number of habitat/stage combinations within a single study area
weight = weight (i.e., acres, percent of area, etc.) of individual habitats in query

Several examples of the effect of selecting arithmetic or geometric mean using the same life requisite levels are illustrated in Tables 4 and 5. Using the geometric mean results in habitat suitability values = 0.00 for single habitats when at least one life requisite is unsuitable (Table 3). Habitats with suitability values = 0.00 will greatly reduce mean habitat suitability values for multiple habitats (Table 4).

Table 4. Examples of CWHR mean (average) habitat suitability index value calculations using arithmetic and geometric means for a single habitat. The first example illustrates the effect of habitat that is unsuitable (value = 0.00) for one life requisite (Reproduction), while the second example illustrates habitat that is suitable (values = 0.33, 0.66, or 1.00) for all life requisites.

Examples	Suitability Value for Life Requisite			Mean Habitat Suitability Index
	Reproduction	Cover	Feeding	
Arithmetic Mean	0.00	0.33	0.66	0.33
Geometric Mean	0.00	0.33	0.66	0.00
Arithmetic Mean	1.00	0.66	0.33	0.66
Geometric Mean	1.00	0.66	0.33	0.60

Table 5. Examples of the effect of arithmetic and geometric mean (average) calculations for CWHR Habitat Value Comparison Reports using three different habitats. Suitability ratings for each life requisite are equal within a habitat for the arithmetic and geometric mean calculations. In the first example (One Unsuitable Value), Habitat 3 is unsuitable (value = 0.00) for one life requisite. In the second example (All Suitable), all habitats are suitable (values = 0.33, 0.66, or 1.00) for all life requisites.

One Unsuitable Value	Habitat 1	Habitat 2	Habitat 3	Mean Habitat Suitability Index
Arithmetic Mean	0.33	0.55	0.67	0.52
Geometric Mean	0.33	0.52	0.00	0.28
All Suitable				
Arithmetic Mean	0.55	0.77	0.89	0.74
Geometric Mean	0.52	0.76	0.87	0.72

Table 6 illustrates the calculation of weighted habitat values for three different habitats. Calculation of habitat units is the same regardless of whether the arithmetic or geometric mean are used (see previous equations), but the geometric mean formula will result in 0.0 habitat units for a habitat if it has at least one unsuitable (value = 0.00) life requisite. Therefore, geometric means have the potential to result in substantially fewer habitat units in a CWHR query (Table

Table 6. Example of weighted habitat values calculated using arithmetic and geometric means (averages) for CWHR Weighted Habitat Value Comparison Reports using three different habitats. Suitability ratings for each life requisite are equal within each habitat for the arithmetic and geometric mean calculations. Habitat 2 is unsuitable (value = 0.00) for one life requisite.

	Habitat 1		Habitat 2		Habitat 3		Arithmetic Mean Totals Across Habitats	Geometric Mean Totals Across Habitats
	Arithmetic Mean	Geometric Mean	Arithmetic Mean	Geometric Mean	Arithmetic Mean	Geometric Mean		
Suitability Value	0.55	0.52	0.22	0.00	0.89	0.87		
Weight (acres)	50	50	50	50	50	50	150	150
Habitat Units	28	26	11	0	45	44	84	70

<u>Legal</u> <u>Status</u>. Queries can be conducted for species in one or more legal status categories. These categories include: Federally Endangered, Federally Threatened, California Endangered, California Threatened, California Fully-Protected, California Protected, California Species of Special Concern, Federally-Proposed Endangered, Federally-Proposed Threatened, Federal Candidate, BLM Sensitive, USFS Sensitive, CDF Sensitive. If no status category is selected, queries include all species that do and do not have any special status. If a category is chosen, queries will include species with that status only, and all other species will be omitted.

<u>Species</u> <u>Selections</u>. Queries can be conducted for any species list developed by the user. The default setting is a query for all species in CWHR. Individual species can be added or deleted from the query list, and the database has several taxonomic groups, such as passerine birds and plethodontid salamanders, that can be retrieved and used in queries. Furthermore, users can develop their own species lists, which can be saved and retrieved.

CONSIDERATIONS WHEN USING THE SYSTEM

Because of CWHR's flexibility, users must consider several issues when designing queries. These issues primarily involve temporal and spatial scales of the project or scenario analyzed with CWHR. Temporal and spatial scales should be realistic from biological and logistical standpoints. Inadequate choices will affect database outputs. Common sense and professional judgment should be applied to all CWHR queries so that temporal and spatial issues are not overlooked or biased.

Temporal Considerations. The CWHR habitat classification system and habitat-relationships models can be used to classify wildlife habitats as well as predict species composition and habitat suitability at any time period chosen by the user. Current and future habitat conditions must be correctly determined by the user for database predictions to be accurate. Determining current or baseline habitat conditions is difficult enough, but predicting future habitat conditions represents another possible source of error. Predicting future habitat conditions is extremely tenuous, particularly with longer time frames, dynamic habitats, or poorly understood habitats.

Two Condition queries can be done if comparisons between two different points in time are desired. The user can define any time period for analysis. However, when Two Condition queries are done to predict the impacts of a particular land use, determining the time periods for analysis becomes critical. In most cases, comparing the baseline condition against habitat conditions shortly after the land use is completed will suffice for assessments of immediate impacts. However, wildlife habitats are dynamic and quickly change, particularly with the younger seral stages. Therefore, queries may be done comparing habitat conditions at several time periods. It is critical that the two habitat conditions in the query be comparable in time if differences are to be meaningful. This is especially true when impacts are being assessed and mitigation recommendations are being made. Typically, the appropriate period to fully assess impacts and recommend mitigation would be the life of the project. This may be 50-150 years or longer for commercial timber operations. However, impacts can be amortized over the life of the project using techniques such as the Habitat Evaluation Procedures developed by the U.S. Fish and Wildlife Service.

Garrison (1992) compared the results of CWHR Two Condition comparisons between baseline, future-with-project, and future-without-project scenarios for an analysis of wildlife biodiversity changes over a 10-year period in coast redwood (*Sequoia sempevirens*) habitat. This habitat was subjected to hypothetical intensive timber management over the 10-year period, and there was considerable growth and recruitment occurring in many of the harvested stands. He found that comparing future-with-project against future-without-project scenarios gave the most realistic comparison of habitat conditions because both scenarios were assessed over the same time period. Baseline compared to future-with-project scenarios were not considered realistic because of the 10-year difference in habitat conditions between the two scenarios. Garrison and Standiford (1997) used habitat suitability ratings from CWHR models for 21 wildlife species combined with a single tree growth model in an analysis of the effects of firewood cutting in blue oak (*Quercus douglasii*) woodlands over a 50-year period. Assessing firewood cutting impacts over a 50-year period was felt to be a realistic assessment because trees grow after the harvest and habitat conditions do not remain static.

Spatial Considerations. Study area size plays a key role in the apparent accuracy and biological reality of CWHR predictions. If the study area is too small, CWHR assumptions on patch size adequacy and juxtaposition may be violated and the number of commission errors (see Accuracy of the CWHR Database) may be unrealistically great. Also, CWHR essentially treats habitats as single, isolated units without considering surrounding habitats and landscape heterogeneity, although model assumptions address this. As we all know, habitats seldom occur as single, isolated units in wildland situations. In addition, surrounding habitats play a substantial role in the species composition of individual habitat patches. Therefore, the user must seriously consider what habitats to include in the query.

Habitat suitability ratings were developed on spatial scales on the order of 40 acres (Mayer and Laudenslayer 1988). Typically, CWHR runs should be done for a study area that is at least 40 acres, but queries probably are more accurate with much larger areas. Larger study areas would be necessary for larger projects and cumulative effects assessments. Queries involving areas < 40 acres should be evaluated closely, and species whose home ranges exceed the size of the study area may have to be eliminated from the output. Also, the large number of commission errors with smaller areas may substantially reduce biological accuracy thereby negating the value of CWHR queries.

Surrounding habitats should be included in the query if they influence the species composition of the study area or will be affected by the project. All habitats within the assessment area must be included in the query. In some cases, habitats may have to be aggregated if the number of habitats exceeds the number of habitats that can be analyzed by the computer (currently 200 with laser printers and the Two Condition Comparison). Habitats with similar characteristics and wildlife habitat relationships should be combined. However, it is also possible that large project areas could be subdivided and analyzed using multiple queries.

Biological Significance of Predicted Changes. CWHR's Two Condition comparison calculates differences in predicted habitat values between two situations that may represent assessments of land use impacts or habitat suitability differences with temporal and spatial changes. Species are categorized as negatively or positively affected or unaffected based on the predicted differences, regardless of magnitude. For example, two wildlife species would be categorized by CWHR as negatively affected if differences in predicted habitat values were -1.0% and -100.0%, respectively. Consequently, the biological significance of the list of affected species may be difficult to interpret if predicted habitat differences are not critically evaluated.

Garrison (1994) compared CWHR-predicted habitat differences under a hypothetical scenario among five different biological significance categories. The categories included: (1) habitat predicted as unsuitable for one of the two situations; (2) CWHR's predicted effects categories; (3) a difference of one or more CWHR habitat rating classes for overall average habitat suitability between the two situations; (4) a difference in average habitat values of 25% or more; and (5) a difference of 50% or more. (Appendix G)

Based on these comparisons, he felt that the habitat unsuitable and rating class difference categories were the most biologically realistic when using CWHR Two Condition comparisons as an assessment tool. However, users were cautioned to individually evaluate the biological significance of predicted differences for each species. Individual life requisite suitability ratings and element presence also should be critically evaluated. The difficulty in extrapolating CWHR habitat ratings to meaningful biological parameters, such as population density or productivity, with management utility complicates this evaluation. Also, model errors and lack of field validation further complicate the biological significance of predicted changes.

FIELD WORK

Field work is essential for correctly using the CWHR system. The system was designed as a tool that requires as well as supports field work. The degree of field effort required to use the system correctly will vary with many factors including logistic and financial constraints, significance of the project, desired accuracy, and complexity of the project area and associated database query. Certainly, controversial and complex projects or applications will require considerably more field effort than relatively simple applications.

At a minimum, wildlife habitats and stages must be accurately determined. Inaccurate habitat determinations will ultimately result in inaccurate database predictions, and habitat determination is one component of CWHR use for which the user is totally responsible. The existing habitat classification system is broad enough that a trained, knowledgeable individual probably could accurately determine habitats in the project area from visual estimates while walking or driving through the project area. However, good quality aerial photographs or other remote sensing imagery are still needed to determine size of habitat patches. And, field work is necessary to identify habitat stages and determine the presence of special habitat elements.

Wildlife field inventory data can be used to refine and validate CWHR predictions. As with habitat sampling, the level of inventory data can vary. In fact, CWHR outputs can be used in the absence of wildlife field data because of CWHR's predictive nature. These outputs can be the initial basis for designing appropriate field inventories. Verified field sightings of wildlife from project areas will greatly strengthen CWHR output because they validate the predictions. In fact, a highly accurate CWHR system can be developed for land areas that have received extensive field inventories of CWHR habitats.

The level of field inventory will be dictated by the same factors as habitat sampling. The CWHR user must also recognize that projects involving special status wildlife species will likely require some level of field surveys per accepted protocols. While these protocols likely will provide data on the several species of interest, they can be expanded to inventory more wildlife species if desired. Other sources of information on wildlife field inventories include Hayes et al. (1981), Cooperrider et al. (1986), Morrison et al. (1992), and Bookhout (1994).

Field inventories can provide data on wildlife presence/absence, abundance, and frequency. CWHR predictions can be verified with these data, but the tested predictions depend on the type of data available. Predicted species lists can be verified with data on observed species. However, users should expect many predicted species to be absent from the study area because CWHR predicts more species to occur in an area than will likely be found with relatively intense field inventories (see section on Errors in Database Predictions). Data on abundance or frequency of occurrence can be used to test predictions on presence and habitat suitability. These data require greater inventory effort than species presence because of the required methods and statistical considerations. Some predictions about species presence can be verified with relatively coarse field surveys, particularly those involving common or conspicuous species and species observed in field but not in CWHR predictions. Rare or secretive species will certainly require more effort.

ACCURACY OF THE CWHR DATABASE

ERRORS IN DATABASE PREDICTIONS

The CWHR system is not perfect, and a variety of errors occur (see Summary of Accuracy Assessment). In fact, the system was designed with some errors built into the database predictions. Errors typically occur with almost every type of wildlife-habitat relationship model (see Morrison al. 1992 for a more thorough discussion of model validation and error). The purpose of this section is not to discount or excuse CWHR's errors, but to fully explain what types of errors exist and their ramifications when CWHR is used in a predictive manner.

The CWHR users have direct control over accuracy at two steps in the query process: habitat determination and query design. If these two steps are done correctly, subsequent errors in CWHR predictions are due to biological factors, CWHR modeling error, or field methodology. Model error is primarily responsible for prediction accuracy when validation information is lacking.

Because of CWHR's dynamic nature, errors can be rectified when empirical evidence or revised professional judgment exists that justifies a change. CDFG evaluates CWHR validation studies as they become available, and CDFG makes changes to the models and database based on these studies (Appendix F). As the database manager, CDFG is responsible for making changes to the models and database.

CWHR predictions can produce at least three general types of errors: (1) species list errors; (2) habitat relationship errors; and (3) natural history errors. These errors are not necessarily mutually exclusive; in fact, habitat relationship or natural history errors produce species list errors. Deficiencies in information about habitat relationships, geographic distribution, seasonality, and legal status can all produce species list errors. The interrelationship between the errors is due to the relational design of the CWHR database, as well as the structure of the models.

Species List Errors. These errors occur when differences exist between lists of wildlife species produced by CWHR and those from field inventories. Commission errors occur when species predicted by CWHR are not observed in the field, while omission errors occur when species are observed in the field that were not predicted by CWHR. Commission errors are built into CWHR because of its predictive nature, and they should be expected in database outputs and validation studies. However, omission errors were not designed into the system, but they should be expected for several reasons (see Ramification of Errors).

Commission errors may be due to:

1. Inaccurate models that overstate the habitat relationships, distribution, or seasonality.

2. Improper or inadequate field methods that cannot detect a given species.

3. Biological factors such as cyclic populations, transitory populations, populations not at carrying capacity, and predation and other interspecific factors.

4. Stochastic environmental factors such as epidemic diseases, fires, drought, landslides, etc. that either decimate populations or substantially alter habitat.

Omission errors may be due to:

1. Inaccurate model information on habitat relationships, distribution, seasonality, or natural history.

2. Incorrect use of the database, models, or habitat classification system.

3. Biological factors such as range extensions or vagrancy.

4. Models do not exist for a species. For example, CWHR currently has models for 712 of the over 1000 species of amphibians, birds, mammals, and reptiles currently known to occur in California, leaving many species without models.

Habitat Relationship Errors. This type of error is due to a deficiency in any component of the habitat relationship information. This information may include habitats and stages for which the species is expected to occur, habitat/stage suitability and element preference ratings, and habitat elements influencing species' presence. Overstating habitat use patterns may result in commission errors, while understating use patterns may result in omission errors. Relationship errors, in addition to producing commission and omission errors, affect CWHR predictions when predicted habitat suitability ratings differ from those documented with field studies.

Natural History Errors. This generic type of error occurs from deficiencies in any non-habitat component of the species models. Inaccurate or deficient information about geographic distribution, legal status, and seasonality can produce commission and omission errors as well as inaccuracies for those species predicted by CWHR and found in the field.

SUMMARY OF ACCURACY ASSESSMENT

In 1992, the Department undertook an effort to gather and review all known validation studies conducted to date of different CWHR versions (Garrison 1993). Validation is defined (Marcot et al. 1983) as the determination of the usefulness and accuracy of model predictions and of model implementation in planning, monitoring, and impact assessment.

These studies were used to correct, modify, and update CWHR models for Version 5.2. A total of 18 validation studies were available for Version 5.2 updates (Appendix F), and these were community-level studies where data were gathered on relatively large numbers of wildlife species of one or more broad taxa (i.e., amphibians, birds, etc.). These validation studies resulted in 1,387 record changes to the CWHR database with Version 5.2. Only 15 studies were detailed enough to be used for an evaluation of CWHR validation studies and accuracy assessment using CWHR Version 5.0. These studies tested field data against a variety of CWHR model predictions including species occurrence by geographic location, habitat and stage, or season.

Eleven of the 15 studies (73%) evaluated Version 5.0 of the statewide CWHR system, while the remaining four studies involved various USFS CWHR progenitors (Garrison 1993). Of the 11 statewide CWHR studies, only six (55%) were initially designed to validate CWHR. Birds were the most studied (14 of 15 studies [93%]), while amphibians, mammals, and reptiles were evaluated in seven studies (47%). Five studies involved all four taxa. A total of 14 of CWHR's 53 (26%) habitats were studied. Valley-Foothill Riparian and Mixed-Conifer with four and three studies, respectively, were the most studied. Two validation efforts were conducted in five habitats: Valley-Foothill Conifer, Montane Hardwood, Douglas-fir, Mixed Chaparral, and Chamise-Redshank Chaparral. One study each was conducted in seven habitats. Therefore, most of the studies were done in hardwood and coniferous forest habitats.

In an effort to summarize accuracy and errors of earlier CWHR versions (Version 5.0 and earlier), levels of correct predictions and commission and omission errors from the validation studies were quantified (Garrison 1993). Errors were calculated for a single habitat and stage for each validation study. A formula that yielded a conservative estimate of accuracy was chosen, and it did not include correct absence predictions which would have increased the percentage correct predictions.

Bird models had the highest level for correct predictions averaging 50% (N=19), while amphibian models had the lowest accuracy (25%, N=4). Mammals (N=4) and reptiles (N=4) had intermediate accuracy levels (36% and 35%, respectively). Amphibians had the highest commission error level (73%) and lowest omission error level (2%), while birds had the lowest commission error level (37%) and highest omission error level (13%). Mammals and reptiles had similar commission errors (56% and 55%, respectively) and omission errors (8% and 10%, respectively). There is an obvious inverse relationship between commission and omission errors. Building models to minimize commission errors increases levels of omission errors and vice versa.

The accuracy results are not surprising. Birds are the most mobile group capable of occurring in atypical habitats and locations, often as rarities or vagrants. Therefore, omission errors are expected to be greatest for birds. In addition, distribution and habitat relationships of birds are relatively well known compared to amphibians, mammals, and reptiles. Also, survey methods for birds are generally the most well defined and efficient. Amphibians remain one of the least known taxa, and they are difficult to survey. In addition, amphibians tend to respond to finer grain habitat features such as clean, cool water, rather than coarser grain features such as dominant plant species, canopy cover, or average tree diameter. Mammals are probably better known than reptiles and amphibians as evidenced by their lower omission and commission errors, but reptiles and mammals may have similarities in habitat relationships and field survey limitations as evidenced by their equivalent accuracy and error levels.

The validation studies yielded important insights into the information and assumptions behind the CWHR models for each species and taxa. Only through validation can systems such as CWHR be updated so that the information foundation is as biologically accurate as possible. These validation studies were used to improve the models in Version 5.2, therefore, accuracy levels likely have improved and should be considerably greater with Versions 5.2 and above.

RAMIFICATIONS OF ERRORS

The significance of errors in CWHR predictions is extremely variable depending on type and magnitude of the error. When assessing error significance, several factors must be acknowledged including:

1. Errors reduce accuracy of CWHR predictions. Therefore, any management decisions made using inaccurate predictions are affected. Ultimately, wildlife resources may be affected by decisions made with inaccurate predictions.

2. CWHR's credibility is reduced, and decisions made using CWHR are second guessed or dismissed outright.

3. Errors must be rectified if the database is to be improved.

4. Not every error is due to deficiencies in the system; correct system use can substantially reduce the number of errors.

5. Omission errors, once identified, represent known species which can be accounted for, while commission errors cannot be easily accounted for without supporting

field data.

6. Known and unknown errors will always exist because of the limited knowledge upon which CWHR is based and the dynamics of natural biological systems.

Error significance varies with use of database predictions and each species. At face value, omission errors appear the most onerous to CWHR users and decision makers. Omission errors can be particularly problematic and significant for special status species (e.g., threatened and endangered, candidates, species of special concern, harvest, etc.) when CWHR is used to determine if a species occurs in a given area or habitat and stage. However, as mentioned earlier, identified omission errors can be dealt with rather easily because the omitted species is known to be present. However, unknown omission errors (e.g., those species occurring but not detected in the field or predicted by CWHR) may also occur. It must be acknowledged that not all omission errors are due to model inaccuracies. Many omission errors identified in several validation studies were actually due to inaccurate or less than complete use of the database. Also, CWHR models do not exist for over one-fourth of all wildlife in California, so omission errors must be expected and accepted.

Commission errors, although built into the system, are due to more factors than omission errors. Therefore, their ramifications are more varied. In some cases, they may actually be more significant than omission errors, particularly when predicted species lists are compared between two or more habitat situations in a biodiversity type assessment. However, commission errors may also be due to improper field methods that do not detect certain species. Compared to omission errors, commission errors can be due to a wider variety of biological and environmental factors that affect populations and communities and habitat conditions. Commission errors are more likely to occur with rarer, less common species that require greater search efforts. Also, poorly known species are likely candidates for both commission and omission errors because relatively little information exists on their habitat requirements and distribution.

IMPROVING ACCURACY

Accuracy of CWHR outputs can be improved in several ways. The CWHR user can improve accuracy by using all system components, while accuracy improvement in some cases requires changes to the database. Errors will always exist with CWHR predictions, and users must acknowledge this when using the system. Resource professionals who require perfection in their work probably should not utilize the CWHR system.

Despite its imperfection, CWHR accuracy can be substantially improved with several simple techniques. Accuracy cannot be improved for omission errors from species without models unless the user removes the omitted species from CWHR accuracy calculations or utilizes other tools for those species, or unless models are developed.

Commission errors can reduced by eliminating species from CWHR outputs for the following reasons: (1) they do not occur in the project area based on range maps in *California's*

Wildlife or local knowledge; (2) they do not occur because the habitat patches are too small, habitat juxtapositions do not exist, or habitat elements do not occur; (3) field survey techniques were inadequate for the species; and (4) the project area is in a species' known range but they are absent due to biological or managerial decisions (e.g., California condor [*Gymnogyps califorianus*], brown-headed cowbirds [*Molothrus ater*], etc.). For example, Stoms (1991) increased overall CWHR accuracy from 71% to 90% and reduced commission error from 27% to 9% by using species range maps to refine predicted species lists.

Many omission errors can be eliminated with proper CWHR use. For example, specifying too low a level for excluding habitat elements (e.g., PREFERRED) may eliminate a relatively large number of species thereby causing high omission error levels. To rectify this problem, excluding species based on absent habitat elements should be done at the ESSENTIAL level. Also, habitats and elements surrounding the project area may cause omission errors unless the user includes those habitats in the analysis. This problem can be especially prevalent when terrestrial habitats interface with aquatic habitats (e.g., Valley-Foothill Riparian with Riverine). Also, users must be fairly strict in their observations of habitat use. For example, it is questionable whether a flock of Canada goose (*Branta canadensis*) flying 150 m over Klamath Mixed-Conifer 5M are really using that habitat at a level that constitutes an omission error.

HABITAT CLASSIFICATION SYSTEM

DESIGN AND INTENT

The terrestrial vegetation and aquatic wildlife habitats in Mayer and Laudenslayer (1988) are the foundation of the CWHR system. Two agricultural types in the original publication were later replaced with eight, resulting in 59 habitats for Version 7.0 and later versions.

The classification system was not designed or intended to be an extensive classification system for vegetation in California; it is a wildlife habitat classification system. On one hand, the habitat system provides resource professionals with a standardized approach to naming and describing wildlife habitats in California. On the other, the system is the foundation of the habitat-relationships models. A standardized habitat system allows: (1) the models to be developed using the same general structure; and (2) community level predictions where all species are treated equally.

Terrestrial vegetation habitats are classified using even-structure size/cover stages, and the system classifies existing or current vegetation. The habitats themselves are based on dominant vegetation species, while the size/cover stages are based on two major structural components: vegetation cover and vegetation size. Cover and size are combined to determine habitat stage. Wildlife habitat use is known to be influenced by both floristics and structure (Morrison et al. 1992). Habitats and stages are the backbone of model habitat suitability ratings and database predictions.

Stand age, although not explicitly used to define size/cover stages, is indirectly accounted for because trees and shrubs, in particular, get larger and older as they grow. The size/age relationship is particularly strong with the shrub habitats such as Mixed Chaparral where shrub size is defined using crown decadence.

The four aquatic habitats (Marine, Estuarine, Lacustrine, Riverine) are classified using zones and substrates. The zones are categorized by relative amounts of open water and shoreline, while the substrates are categorized by differing bottom materials (e.g., organic, mud, etc.).

Habitats are further described using a standardized list of elements, which define habitat micro-features that influence species presence. There are 124 elements in the system that can be used to describe habitat micro-features. The elements work to retain or delete species from CWHR-predicted species lists.

A standardized approach allows for easy communication and common identification of California wildlife habitats. In addition, the system was designed to recognize and logically categorize major vegetation complexes at a scale sufficient to predict wildlife-habitat relationships (Mayer and Laudenslayer 1988). The classification system is not fine enough to meet the needs of most statewide vegetation classification efforts, yet crosswalks exist for most statewide vegetation schemes. A system using a finer vegetation classification scale would likely infer a greater degree of precision and understanding about California wildlife-habitat relationships than is warranted with the available information.

ASSUMPTIONS WITH HABITAT CLASSIFICATION SYSTEM

As with any classification system, assumptions are needed for clarity and utility. The importance of these assumptions with regard to CWHR's habitat classification system and database predictions cannot be over-emphasized because the habitat system is the foundation of the habitat-relationships models. Several of these assumptions also apply to the models. These assumptions are:

1. Minimum mapping units using the classification system generally should be no greater than 40 acres. Minimum mapping units should be considerably less with habitats that are rare or restricted (e.g., riparian, wetland, etc.), or when home ranges of wildlife species of particular concern are of a considerably smaller scale than that represented by 40 acre mapping units.

2. All habitat elements are assumed present in selected habitats and stages. This assumption is especially critical when making database predictions, therefore, elements must be identified to ensure proper CWHR use.

3. It is assumed that the appropriate habitats are arranged in proper juxtaposition for those wildlife species that require this juxtaposition.

4. It is assumed that the required habitat patch size is present for those wildlife species that require minimum patch sizes.

Some of these assumptions are often violated in field applications. Therefore, the CWHR user should consult the species notes to refine the species list and habitat classification. Assumption violations often occur with elements, habitat juxtaposition, and patch size. Refining the predicted list will minimize the effect of assumption violations, reduce errors with CWHR predictions, and improve the credibility of the CWHR analysis.

CLASSIFYING CWHR HABITATS

The habitat system was designed so that classification would be done using some combination of remote sensing and field data. Remote sensing information (e.g., aerial photographs, LANDSAT imagery, etc.) is needed to delineate habitat patches, quantify amounts, and evaluate assumptions regarding juxtaposition and patch size. Field data is needed to accurately determine habitat and stage, occurrence of habitat elements, and, perhaps, some degree of field validation of CWHR predictions. At a minimum, field work should be done at a level that ensures accurate determination of CWHR habitat and stage and occurrence of habitat elements. Any CWHR analyses done without this minimum level of field work are deficient.

CWHR habitats are classified using dominant existing vegetation. Dominance is based on (1) amount of live vegetation crown closure by plant species in the overstory, or (2) a unique indicator of specific environmental conditions (i.e., Closed-Cone Pine Cypress). Mayer and Laudenslayer (1988, pg. 11) developed a flow chart that outlines the decision rules for determining major habitat subdivisions using the CWHR classification system, but this flowchart as been updated by the CWHR Program (Appendix H). The major CWHR habitat subdivisions are:

1. Tree-dominated: Tree canopy ≥ 10.0% cover

2. Shrub-dominated: Shrub canopy ≥ 10.0% cover, but tree canopy < 10.0% cover

3. Herbaceous-dominated: Herbaceous ≥ 2.0% cover, but < 10.0% tree or shrub cover

4. Barren: Does not have canopy cover to meet Tree-, Shrub-, or Herbaceous-dominated

5. Aquatic: Open water ≥ 98.0% of surface

For tree-dominated habitats, three structural variables are used to determine habitat stage: (1) crown diameter; (2) stem diameter measured at breast height (4.5 ft); and (3) canopy closure. Diameter at breast height is calculated using quadratic mean diameter (see below). Crown diameter and stem diameter are both used to determine tree size, but users traditionally have used only one variable. Stem diameter is used on habitat determinations primarily based on ground data, while crown diameter is often used with remote sensing imagery. The consistency of the relationship between the two variables has not been fully tested to our knowledge for all tree-dominated CWHR habitats. It may be prudent to measure both diameter variables to most accurately determine tree size. For most applications, however, one diameter variable will suffice, and stem diameter is the most often used. Stem diameter is preferred, especially for ground surveys, because it is relatively simple to measure and is widely recognized as an important component influencing habitat relationships.

Other structural attributes are used to determine habitat stages for shrub, herbaceous, desert, and aquatic habitats. For vegetated habitats, stage is still determined using a combination of vegetative cover and size. Aquatic habitat stages are determined using both bottom substrate type and aquatic/terrestrial zones. See Mayer and Laudenslayer (1988) for more detail on these habitats.

Crown Diameter. Crown diameter is one of two variables used to determine CWHR size class; stem diameter is the other. When ground information is collected, stem diameter should be used to determine tree size. When remotely sensed information is used, crown diameter may be adequate. Crown diameters are taken for coniferous (softwoods) and deciduous (hardwoods) trees, and means are determined separately for each group to determine tree size class.

The stand crown diameter mean is calculated using quadratic mean diameter (see Stem Diameter for formula), while crown diameters of individual trees are calculated using arithmetic means of at least two cross-sectional (diameter) measurements. With ground information, crown diameters should be taken from a representative sample or all stems in the sample plot > 5 inches diameter at breast height (dbh). Crown diameter of an individual tree is determined by taking two cross-sectional (diameter) length measurements more or less perpendicular to each other through the narrowest and widest diameters of the tree (Hays et al. 1981) (Appendix H). In practice, however, the narrowest and widest diameters are rarely perpendicular to each other.

Stem Diameter. Stem diameter is the primary attribute used to determine tree size with the CWHR system. Although not stated in the CWHR habitat guide (Mayer and Laudenslayer 1988), stem diameter was intended to be determined using the quadratic mean diameter of all woody stems in the sample plot or measurement unit >= 5 inches in diameter at breast height (4.5 ft). Quadratic mean diameter is a relatively common method used by the forestry profession to determine the mean stem diameter of forest stands. Quadratic mean diameter is favored over arithmetic and geometric means because larger diameter trees are given greater weight in the mean calculation because of the diameter squaring. The formula for quadratic mean diameter is (Davis and Johnson 1987):

$$\overline{d_q} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} d_i^2}$$

Where d is the diameter of the woody stems and N is the number of stems in the sample. Quadratic mean diameter is calculated by pooling stem diameters of all stems in the sample, including conifers and hardwoods. Mean stem diameter of the stand is determined using the arithmetic mean if the number of stems per sample plot is relatively equal among sample plots. However, the weighted arithmetic mean (where numbers of stems per plot are the weights) should be used to calculate mean stand stem diameter when the number of stems per sample plot varies greatly among sample plots.

Canopy Cover. Canopy cover or crown closure is another structural attribute used to classify CWHR habitat stages. For tree-dominated habitats, the % cover by overstory trees contributing to the canopy is measured. This can be done from the ground or from remotely sensed information.

Because the existing CWHR habitat classification system is an even-structure, even-sized, or even-aged system, the majority of trees in even-structure stands probably will contribute to the overstory canopy. However, in uneven-structure stands with ≥ 2 canopy layers, this may present a problem. In most cases, canopy cover should be measured from those trees that contribute most to the size class determination. In practice, these will be the larger trees which themselves contribute to the overstory. However, there may be cases where canopy cover may have to be measured for each canopy layer and a composite CWHR stage identified (e.g., Klamath Mixed Conifer 5S/2M). Arithmetic or geometric mean habitat suitabilities can be calculated to "average" habitat values of these uneven-structure stands when stages are treated together as a single situation.

Other Stage Attributes. Canopy closure is an attribute used for shrub-dominated, herbaceous-dominated, and desert habitats. Percent closure is determined using vegetation that determines the habitat. For example, annual grasses and other ground vegetation should be measured to determine canopy cover in Annual Grasslands rather than trees or shrubs that may occur in the sample area. Again, representative samples should be taken to ensure accuracy in CWHR stage determination. Trees and shrubs may be components of non-tree habitats, but they are not to be used to determine canopy cover. The habitat models for non-tree habitats include assumptions regarding presence of tree and shrub elements.

Shrub size classes in shrub-dominated habitats are determined using the amount of crown decadence in the sample. Decadent shrubs are those that are dead or dying. Generally, if current habitat values are desired, size class of herbaceous habitats is determined using height of the plants at the time of sampling. However, herbaceous plant heights may be projected if sampling occurs when annual plants have died back or starting their growth cycle. Furthermore, vegetation conditions could be projected over the course of the year, and an "average" condition could be determined and used in the CWHR query if yearlong suitability values are desired. Ideally, sampling should occur during the time when habitat suitabilities are desired. Again, measurements are height of the dominant vegetation that determines the habitat.

In desert habitats, several size attributes are measured depending on the dominant vegetation. In Palm Oasis and Joshua Tree habitats, size class is determined using stem diameter measured at the plant's base above the bulge near the ground. Stems of all sizes must be measured to determine size class. In Desert Riparian habitat, size class is determined using stem height. Quadratic mean should be calculated for these measurements from a representative sample.

Aquatic zones are determined using a variety of data. Direct field observation will suffice in most cases, and hydrological data can be used to supplement field observations. Aquatic substrates require direct field observation, which may be difficult in water that is too deep and dark to allow easy observation. Bottom substrate samples can be taken with conventional field methods if necessary. Also, aquatic systems often have several different bottom substrates, so multiple substrate types may have to be selected.

CONCLUSIONS

Several broad conclusions can be drawn about the CWHR system and its use for wildlife conservation in California. These conclusions are detailed throughout this training manual and supporting CWHR publications and they should be thought of as "rules of the road" when using CWHR. These conclusions are summarized as follows:

1. The CWHR system is a tool intended for use by trained, knowledgeable biologists and natural resource managers for wildlife resource issues in California.

2. The user is responsible for using the CWHR system and interpreting and using the output.

3. Users must acknowledge that CWHR is a predictive tool that has a variety of assumptions, inaccuracies, and inconsistencies.

4. The accuracy, utility, and credibility of the CWHR system depend greatly on accurate use and feedback from users on model errors and inconsistencies. CWHR managers must continually make improvements and provide regular updates.

5. The CWHR system is intended to be used with some level of field work. At a minimum, habitats, stages, and elements must be accurately identified through field surveys.

6. The habitat classification system was designed to identify and classify wildlife habitats, and it is not a vegetation classification system per se.

7. The habitat classification system is an even-structure or even-aged system. However, uneven-structure stands can be described and analyzed using the CWHR system.

8. Accuracy can be substantially improved through correct use of all system components and acknowledgment of assumptions.

9. For individual habitats and stages, the number of predicted species generally declines with increasing number of query parameters.

10. The special habitat elements only retain or delete species from the predicted species list; elements do not explicitly modify habitat suitability ratings except making habitat unsuitable by deleting a species.

11. Habitat elements are generally the most critical parameter for queries because species will be unnecessarily deleted if elements and element ratings are used incorrectly.

12. All species in the CWHR system are treated equally because the models are more or less structurally equal. This equality allows for a wildlife community prediction where all species meeting the query parameters are included in the output.

13. Because of its predictive nature and original design and intent, commission errors (predicted species not observed in the field) are built into database predictions.

CDFG and CIWTG hope that these conclusions and other information in this training manual and CWHR publications results in the best possible use of the CWHR system by knowledgeable users. Anyone employing CWHR should use it correctly, and everyone involved must recognize its imperfections. Diligent work is continually being done to improve it and rectify its errors. Ultimately, everyone involved with CWHR must take responsibility and credit for whatever successes and failures occur.

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