RECENT ADVANCES AND APPLICATIONS OF THE CALIFORNIA WILDLIFE HABITAT RELATIONSHIPS SYSTEM

KEVIN W. HUNTING, California Department of Fish and Game, Bird and Mammal Conservation Program, 1416 Ninth Street, Sacramento, CA 95814, USA

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The California Wildlife Habitat Relationship System (CWHR) consists of a series of publications and a computer database program which function as a wildlife information and modeling system for predicting California wildlife species occurrence under a set of prescribed environmental conditions. The system is managed by the California Department of Fish and Game (CDFG) with the assistance of the California Interagency Wildlife Task Group (CIWTG) which is comprised of experienced system users, academic researchers, natural resource agency representatives, and system developers. The system is used by forestry and wildlife professionals as a tool to help assess wildlife community impacts from a given landscape treatment, management or land use action, and is frequently used as a general reference for wildlife information.

In this paper, I describe current system structure, usage and limitations, and recent advances and improvements to the CWHR system as well as current and potential future applications.

BACKGROUND

CWHR is a community-level matrix model system which can be applied over a broad spectrum of geographic scales and habitat conditions. The system supports models for 655 regularly occurring California terrestrial vertebrate species including mammals, birds, reptiles, and amphibians. Fully marine mammals (Cetaceans), some pelagic birds (Procellarids, Hydrobatids, Fregatids), many eastern wood warblers (family Parulidae), and other vagrant birds are not supported in the current system.

System components include a computerized database program, the *California's Wildlife* publications (Zeiner et. al. 1988, 1990a, b), a *Guide to the Wildlife Habitats of California* (Mayer and Laudenslayer 1988), a *Guide to the California Wildlife Habitat Relationship System* (Airola 1988), the *User's Manual for the California Wildlife Habitat Relationship System Microcomputer Database* (Garrison and Sernka 1997), and the *CWHR Training Manual* (Garrison et al 1997). See Airola (1988) and Garrison et al (1997) for a thorough discussion of system components.

The series of computer database files consist of matrices relating species to habitats, locations, and element use and are based on published wildlife habitat relationship information such as validation or autecological studies or, in their absence, professional judgement by "species experts"; scientists who conducted recent primary research or status reviews for the subject, or closely related, species. Relational data is also derived from county bird lists (observed bird species in location matrices) and other direct observational data. Selected queries allow for calculation of average habitat suitability values which provide for between-habitat comparisons. See Garrison and Sernka (1997) for a detailed discussion of habitat value comparison and weighted habitat value comparison queries.

The computer database program was developed in the DOS environment and written using the DBase III Plus computer software program (Borland Corp., Scotts Valley, CA.). Although the DOS version of the CWHR program allows rapid retrieval of model information, access to all database information and query combinations is limited.

The system is capable of generating a list of predicted species under a given location, habitat type, seral stage, and seasonal regime as modified by the presence or absence of one or more special habitat elements (i.e., relatively fine scale habitat features such as snags and burrows). The system can also generate species lists reflecting model predictions for two sets of environmental conditions to provide a tool for comparing and evaluating differences between conditions.

System Accuracy and Validation

The CWHR system has been subjected to extensive validation, or error testing, to evaluate both model accuracy and scope of application. Data from validation studies and other reliable data sets present the opportunity to compare accuracy between model versions and assess the relative effectiveness of system improvements. Model accuracy can be calculated in many different ways. However, most accuracy calculation formulas analyze both Type I, or commission errors, and Type II, or omission errors (Morrison et al 1992). In general, commission error rates are a measure of the number of species predicted by the model but not observed in the field, while omission error rates measure the number of species observed but not predicted.

Garrison (1993) summarized 15 community-level CWHR validation studies and analyzed the results for consideration of system improvement. Using a conservative calculation method to express system accuracy by taxonomic group, Garrison (1993) found birds had the highest level of correct predictions (50%, *n*=19) whereas amphibians had the lowest (25%, *n*=4). Omission error rates ranged from 13% in birds to 2% in amphibians, while commission ranged from 73% in amphibians to 37% in birds. Garrison (1993) noted that (1) species distribution was not considered in most validation study analysis and (2) special habitat elements were misused in some cases; both contributing to reduced accuracy.

Since impact assessment is a primary use of the CWHR system, an understanding of the significance of model output is essential to proper results interpretation. Garrison (1994) analyzed the sensitivity of 5 different categories of change significance under a hypothetical 2-condition scenario and found that a change from a suitable habitat rating to an unsuitable rating or a difference between the 2 scenarios of at least 1 rating class (e.g., high to medium or medium to low) were likely to be the most biologically meaningful. He recommended using these 2 categories because they rely less on the CWHR-programmed percent change in average suitability values and are less sensitive to minor suitability value differences which could be misinterpreted as biologically significant or insignificant.

The CWHR model operates under a set of broad ecological assumptions and requires a basic understanding of California wildlife and wildlife habitats to properly interpret results. Model assumptions include:

- Wildlife respond to habitat features and this relationship can be modeled.
- Habitat is present in sufficient quantity and quality to support a species population.
- Habitat suitability ratings were assigned assuming known habitat patch size and configuration requirements are present.
- Habitat ratings assume special habitat elements are present in adequate quantity and quality if they are typical components of the habitat.

These assumptions, which strongly influence system accuracy, are often violated during the query design process. This problem can be minimized with continued user training and by developing more sophisticated, "smart" CWHR software products.

Limitations and Biases

The CWHR system is intended to be a tool to predict regularly occurring California terrestrial vertebrates within 1 or more coarse-scale wildlife habitat types. As such, the model is limited to large, structurally homogeneous habitat patches that can be accurately typed to a corresponding CWHR habitat type. System accuracy will decrease with a decrease in patch size and increase in structural diversity. In addition, the model does not account for species distribution patterns within CWHR habitat types. For example, the CWHR blue oak (*Quercus douglasii*) woodland habitat type is rated high for all life requisites for the yellow-billed magpie (*Pica nuttalli*) despite the fact that this species distribution differs from the distribution of the blue oak woodland type in California.

Another weakness of the model is the coarse scale at which habitat suitability ratings are assigned. Species such as the tailed frog (*Ascaphus truei*), indeed most amphibians, respond to fine scale habitat features, or special habitat elements, and not generalized wildlife habitat types. Despite partial compensation for this problem with the use of special habitat elements, accuracy for amphibians and ecologically similar species is diminished.

Because the current CWHR system evolved from a habitat-relationships model for Sierra Nevada species in commercially valuable wooded types, the data for these species is often more complete. Habitat suitability ratings in non-wooded types (ie., grassland, urban, and agricultural) are more frequently based on professional judgement than field data and model accuracy is consequently decreased in these types. This weakness points to the need to focus validation studies on CWHR habitat types with comparatively fewer empirical data.

Finally, the CWHR model is only as good as the data upon which habitat relationships are based. Little information is available for many species considered in the CWHR model. Continued financial commitment to the program by CDFG and CIWTG will result in improved model capabilities.

RECENT ADVANCES

Data from the 15 validation studies reviewed by Garrison (1993), combined with published and unpublished data from autecological studies, county bird lists, and a complete review of reptile and amphibian models were the basis for approximately 25,200 individual model matrix changes between version 5.0 and version 5.2 (the 1995 DOS version release of the database program). The effect of these improvements on system accuracy was tested on data from a study by Keil (1993) in which she tallied bird species in 30 wet meadow habitat patches in Sierra National Forest, California. I compared her pooled observations (*n*=41) against bird species predicted by CWHR version 5.0 and version 5.2 for the wet meadow habitat type alone and for the wet meadow and montane riparian habitat types combined (Table 1). The montane riparian habitat type was added because it is a typical component of sierran wet meadow habitats (Mayer and Laudenslayer 1988).

Data changes incorporated in version 5.2 reduced omission and increased commission error rates when applied to the Keil (1993) data; the only suitable data set submitted to the CWHR program which was not used as a basis for version 5.2 improvements. Because omission errors are generally considered far more serious than commission errors (Avery and Van Riper 1990) and omission errors reflect directly on the quality of the data (Block et al. 1994), it appears accuracy was improved by selectively incorporating validation and autecological study results. Accuracy was also significantly improved by considering the range of habitat types which influence the wildlife community in a study area.

One goal of the CWHR program is to create a dynamic system so that new information and technologies can be incorporated as needed (Hunting 1995). In meeting this goal, the CDFG and CIWTG identified using today's computer hardware and software technologies to make the computer database available in all standard platforms and operating systems. Hence, in 1995 the CDFG embarked on an effort to rewrite the computer database program in the Windows (Microsoft Corp., Redland, WA) operating environment. Visual Dbase 5.5 (Borland Corp., Scotts Valley, CA) was selected as the programming language to maximize compatibility with the existing DOS version.

Version 6.0, a full-featured Windows-based version of the CWHR program, became available to users in May 1997. This version incorporates the flexibility of the Windows environment and offers several features not available in earlier DOS versions. Species life history notes and generalized wildlife habitat distribution maps, previously available only in print form, are now part of the software program. Version 6.0 also includes crosswalks between CWHR habitat types and two commonly used vegetation classification systems (Cheatham and Haller 1975, Holland 1986). Much of the system use

Table 1. Comparison of error rates (%) between CWHR versions 5.0 and 5.2 using bird observation data (n=41) from wet meadow (WTM) and montane riparian (MRI) CWHR habitat types. Data from Keil (1993).

Error Measure	Ver. 5.0	Ver. 5.2
Omission (WTM)	56	51
Commission (WTM)	15	14
Omission (WTM&MRI)	5	0
Commission (WTM&MRI)	28	28

and query definition information in the CWHR supporting documents is now available in the computer program. Species information has been expanded to include the unique CWHR species identification code, AOU number (for birds), and the nationwide alpha-numeric taxa identification system adopted by The Nature Conservancy.

Other improvements over the DOS versions address query definition and the use of special habitat elements. Flexibility in query design has been improved to allow storage and retrieval of query parameters from different query types and the ability to apply query parameters to a subset of species. Users can apply habitat type and stage, location, and special habitat element information to a predetermined set of species which may represent, for example, those of greatest management concern. Modeled relationships between species and special habitat elements can be evaluated prior to completing the query to aid in proper use of special habitat elements.

Concurrent with development of Version 6.0, Department CWHR and GIS staff are improving other system components and developing new components and applications. The *California's Wildlife* publications (Zeiner et al 1988, 1990a, b) contain coarse range maps for all 655 CWHR species. Each map was digitized and projected against a base California map, direct observation data and, in some cases, vegetation data and plotted for review at 1:1,000,000 scale. The resulting 850 maps (all yearlong species and summer and winter range for some birds) are currently undergoing a rigorous review and revision process by CDFG and California Academy of Science biologists. Ultimately, the final maps will be incorporated into the distribution matrix of the model and perhaps the next generation of CWHR spatially-explicit models.

System advances have been coupled with the addition of new components. Spatially-explicit Habitat Suitability Index (HSI) models, which calculate a habitat suitability index from 3 environmental variables for a given species, are being developed which are capable of modifying CWHR habitat suitability values based on species life history and landscape characteristics. These models consider factors including home range size, distance to important foraging or reproduction resources, patch size, and distance between patches to modify base habitat suitability values and, when combined with user-supplied geographic information, can populate a GIS vegetation coverage with habitat suitability information. Currently, 37 HSI models, which include individual programs for use in ARC-INFO (ESRI, Redlands, CA), are available as part of the CWHR system.

APPLICATIONS

The most common applications of the CWHR system are (1) evaluating impacts on wildlife communities as a result of proposed timber harvest and forest management practices, and (2) assessing impacts from proposed land use changes such as urban, commercial, and industrial development. Because CWHR was originally developed as an assessment tool for the forestry profession, habitat type and stage specificity, and model sensitivity favor conifer and hardwood habitat types. As a result, CWHR can capture a wide variety of possible forest treatment and management scenarios. A recent increase in it's use for evaluating impacts to non-forest related projects under the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA) has focused attention on the previously discussed need for validation, and subsequent model improvement, in grassland, agricultural, urban, and non-forest habitat types.

The CWHR system can be a valuable tool in wildlife habitat monitoring. The system has been used by CDFG biologists to approximate baseline species diversity for establishing monitoring goals for riparian habitat enhancement projects. The model has been used to evaluate alpha and beta diversity in large scale (>200 ha) biodiversity and land use planning efforts in coastal scrub and grassland dominated landscapes in Alameda County; grassland, agricultural and coastal oak woodland dominated landscapes in Sonoma County; and hardwood and conifer dominated landscapes in Shasta County. A rather unique application of the CWHR system was it's use by the California Department of Health Services to predict potential mammalian disease vector focus areas.

Combining the data from the model matrices with geo-referenced vegetation data has allowed CDFG biologists to determine habitat suitability patterns for a given species across the entire state. For example, by selecting the most frequent stage rating (high, medium or low) within a given habitat and applying this rating to the entire type, Torres (1996) depicted mountain lion (*Felis concolor*) habitat suitability across California using a Geographic Information System (GIS). This approach relies on an accurate vegetation map and a thorough knowledge of statewide wildlife-habitat relationship information for the species. The resulting map allowed estimation of total acres of suitable habitat, by CWHR habitat type, within California and identified areas of management and research focus.

CONCLUSIONS

Through operating system and data improvements, the CWHR program has emerged as a comprehensive source of information about the habitat relationships, life history, and distribution of California's wildlife. Armed with an understanding of the system's limitations, assumptions, and proper use, CWHR users can develop queries that yield wildlife occurrence and habitat suitability predictions within acceptable accuracy limits. As community-level vegetation data is refined and tested, spatially-explicit models can be developed and may be used for modeling more complex wildlife community interactions at landscape, watershed, and ecosystem scales.

The recent improvements and advances in the use of current technologies and information support the CWHR goal of providing a flexible, continually evolving wildlife information and habitat relationships modeling system. As validation efforts become focused on key data need areas, and funding levels for improving and maintaining the system are increased, the CWHR system will be capable of meeting the growing need for predictive modeling and accommodate the wide array of applications which now stretch CWHR's limitations.

As wildlife conservation, commercial and recreational use, and urbanization continue to put demands on a limited land resource, the need for reliable evaluation of the effects of land use proposals on wildlife communities increases. Wildlife managers, ecologists, and natural resource professionals are often called upon to evaluate these effects in the absence of sufficient empirical data. Thus, the CWHR system plays an important role as an impact assessment tool and wildlife information source for California's terrestrial vertebrate fauna.

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