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Exposure Factor and Toxicity Data for California Wildlife: Data Availability and Sources of Uncertainty for Ecological Risk Assessments

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Data needs for terrestrial ecological risk assessments are generally diverse, consisting of a large array of chemical- and wildlife species-specific information for exposure and effects evaluation. Normalizing factors (e.g., body weight and metabolic rate), contact rates (e.g., ingestion rates, dietary composition and inhalation rates), population dynamics information (e.g., home range size) and seasonal activity descriptions (e.g., migration patterns) for mammalian, avian, amphibian and reptile species of concern are often required for exposure estimation (U.S. EPA, 1993). Toxicity data needs for these species vary with the assessment endpoints of the ecological risk assessment but may include individual-, population- or community level endpoints (U.S. EPA, 1998). While new site-specific data may be collected for an ecological risk assessment, initial phases of the assessment are likely to utilize existing data from the scientific literature. Databases of ecological exposure and effects information are available but they generally address a limited range of information or number of species. For example, the U.S. Environmental Protection Agency has compiled exposure factor data for thirty-four mammals, birds, reptiles and amphibians (U.S. EPA, 1993). In order to address ecological risk assessment data needs in California, we developed Cal/Ecotox, a database of exposure factors and toxicity data for sixty-two species of California mammals, birds, reptiles and amphibians (see http://www.oehha.ca.gov). One of the key difficulties encountered in ecological risk assessments is the lack of exposure factor and toxicity data for many wildlife species (SETAC, 1987). Extrapolation of existing data provides an approach to overcome these data gaps but this method contributes uncertainty to the ecological risk assessment (Warren-Hicks and Moore, 1998). In this paper, we describe Cal/Ecotox and provide a survey of data currently in the database to assist in the identification of data gaps and potential sources of uncertainty for ecological risk assessment. Identification of these data gaps may contribute to prioritizing current research needs in ecological risk assessment.

MATERIALS AND METHODS

We selected a non-random sample of sixty-two species of mammals (Table 1), birds (Table 2), reptiles and amphibians (Table 3) found in California for inclusion in the database. The overall aim was to choose a range that might be

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useful as representative wildlife species in ecological risk assessments conducted in California. We compiled information on common species representing a breadth of taxonomic families, trophic groupings, habitats, and distribution within the state. The deer mouse, mallard, American kestrel and bullfrog, previously reviewed for exposure factors (U.S. EPA, 1993), were included because they were associated with relatively large datasets which permitted testing of Cal/Ecotox querying capabilities. Additionally, species were selected based on their status as a legally rare species, requiring special or priority consideration in ecological risk assessments in California. We selected twenty-two exposure factors, categorized as normalizing factors, contact factors, population dynamics and seasonal activities, based upon U.S. EPA (1993; Table 4). Eighteen toxicological endpoints represented five categories: exposure-related endpoints (e.g., biomarkers and accumulation), population-level endpoints (e.g., size or distribution), lethality, reproduction and other sublethal endpoints (Table 4).

We obtained primary source information by retrieving citations identified in species-specific searches in selected electronic databases; Aquatic Sciences and Fisheries Abstracts (Cambridge Scientific Abstracts, Bethesda, MD; 1978-1997), Medline (National Library of Medicine, Bethesda, MD; 1996-1997), Biosis Preview (Biosis, Philadelphia, PA;1988-1997), Zoological Record (Biosis UK, York, England; 1978-1997), Wildlife Worldwide (National Information Service Corporation, Baltimore, MD; 1935- 1997), and Current Contents (Institute for Scientific Information, Philadelphia, PA; 1994-1997). Searches identified citations containing either the common or scientific (genus and species) species name in the title, subject or abstract fields. Reference lists in retrieved citations and a number of secondary sources yielded additional citations. Data from citations were entered if the information met exposure factor and toxicological endpoint definitions and pertained to the selected wildlife species. Field and laboratory toxicological studies utilizing the selected species were included if data relating a defined chemical exposure to effects and/or tissue concentrations were included (e.g., studies reporting residues without defined exposure information were not included). Allometric equations or other extrapolation methods were not utilized to develop data for a particular species.

The basic unit of the database is the dataset, which contains an exposure factor or toxicological data point from a citation. Numbers of datasets and citations were tabulated for each species and data type. An estimate of exposure factor completeness for a particular species was obtained by summing the number of exposure factor categories containing at least one dataset and dividing it by the total number of exposure factor categories. A saturation growth rate model (DataFit, Oakdale Engineering, Oakdale, PA) was utilized to estimate the relationship between % completeness and exposure factor dataset number.

RESULTS AND DISCUSSION

Cal/Ecotox is currently organized into 4597 datasets, drawn from 1386 citations Tables l-3). Exposure factor datasets are most abundant for the selected

Table 1. Number of citations and exposure factor and toxicity datasets for mammals.

Mammals	Exposure Datasets	Toxicity Datasets	Total Citations
Insectivora			
Ornate shrew (*Sorex ornatus*)*	18	0	5
Broad-footed mole (*Scapanus latimanus*)	3	0	1
Chiroptera			
Pallid bat (*Antrozous pallidus*)	61	0	18
Carnivora			
Coyote (*Canis latrans*)	170	7	71
Kit fox (*Vulpes macrotis*)*	66	3	23
Long-tailed weasel (*Mustela frenata*)	36	0	9
Striped skunk (*Mephitis mephitis*)	77	3	25
Sea otter (*Enhydra lutris*)*	64	1	19
California sea lion (*Zalophus californianus*)	69	6	30
Rodentia			
San Joaquin antelope squirrel (*Ammospermophilus nelsoni*)*	10	0	5
California ground squirrel (*Spermophilus beecheyi*)	83	3	24
Merriam's kangaroo rat (*Dipodomys merriami*)	127	5	31
San Joaquin kangaroo rat (*Dipodomys nitratoides*)*	13	0	6
Stephens' kangaroo rat (*Dipodomys stephensi*)*	34	0	10
Little pocket mouse (*Perognathus longimembris*)*	29	0	15
Deer mouse (*Peromyscus maniculatus*)	365	64	123
Salt marsh harvest mouse (*Reithrodontomys raviventris*)*	17	0	8
California vole (*Microtus californicus*)	114	0	25
Lagomorpha			
Audubon's cottontail (*Sylvilagus audubonii*)	38	0	4
Brush rabbit (*Syvilagus bachmani*)*	41	0	11
TOTAL	1435	92	474

*Special status species or subspecies

mammals (41% of all exposure factor datasets; Table 1), followed by birds (3 1%; Table 2) and herpetiles (28%; Table 3). Data-rich species, defined as the upper quartile (76-100th percentile) of exposure factor dataset number, include the deer mouse, mallard, coyote, Merriam's kangaroo rat, side-blotched lizard, bullfrog, western fence lizard, California vole, mourning dove, American kestrel, desert tortoise, California ground squirrel, striped skunk and desert iguana (listed in descending rank order; Tables l-3). The percentage of selected special status species in the upper quartile is considerably lower (7%) than in other quartiles (56 - 67%). Among exposure factor categories, poorest overall coverage (1-25th percentile) for those factors applicable to all species is observed for inhalation rate, surface area, water ingestion rate and body fat measurements (Table 4). Data rich exposure factors (76- 100th percentile) include body weight, productivity estimates (e.g., clutch or litter size), dietary composition and home/foraging ranges. Within the mammal and herpetile groups, normalizing factors and population dynamic data are generally most available while population dynamic data is most available for birds (Table 4). Overall, average exposure factor dataset completeness is 54% (range = 0 - 89%; n = 62). Completeness increases with exposure factor dataset number but appears to reach saturation at about 85% (Figure 1).

Table 2. Number of citations and exposure factor and toxicity datasets for birds.

Birds	Exposure Datasets	Toxicity Datasets	Total Citations
Podicipediformes			
Western Grebe *(Aechmophorus occidentalis)*	12	8	9
Pelecaniformes			
Brown Pelican *(Pelecanus occidentalis)**	25	8	15
Double-crested cormorant *(Phalacrocorax auritus)**	33	39	26
Anseriformes			
Mallard *(Anas platyhrynchos)*	172	617	186[a]
Falconiformes			
Peregrine falcon *(Falco peregrinus)**	56	57	50
American kestrel *(Falco sparverius)*	103	125	74
Gruiformes			
Clapper rail *(Rallus longirostris)**	42	7	13
Charadriiformes			
Snowy plover *(Charadrius alexandrinus)**	48	0	14
Killdeer *(Charadrius vociferus)*	14	4	11
Least Tern *(Sterna antillarum)**	43	1	13
Columbiformes			
Mourning dove *(Zenaida macroura)*	107	61	58
Strigiformes			
Burrowing owl *(Speotyto cunicularia)**	62	7	19
Great horned owl *(Bubo virginianus)*	62	19	41
Piciformes			
Northern flicker *(Colaptes auratus)*	31	2	12
Passeriformes			
Willow flycatcher *(Empidonax traillii)**	34	0	12
Bushtit *(Psaltriparus minimus)*	15	0	6
Loggerhead shrike *(Lanius ludovicianus)**	68	7	20
Bell's vireo *(Vireo bellii)**	45	0	11
Song sparrow *(Melospiza melodia)*	69	5	23
Western meadowlark *(Sturnella neglecta)*	20	0	8
TOTAL	1061	967	607

*Special status species or subspecies

[a] Does not represent all the available data for this species

The considerable amount of existing exposure factor information for these species emphasizes the need to consult the scientific literature for species-specific exposure factor data before employing extrapolation methods which may contribute uncertainty to the risk assessment. Additionally, this evaluation demonstrates a number of gaps in exposure factor data for these species. Physiological exposure factors, except for body weight, tend to be underrepresented, possibly because they require invasive techniques or laboratory studies. Although population dynamics appeared to be relatively well studied, population trends in many of these wildlife species remain poorly understood, particularly the legally rare species, which, by their nature, may be difficult to sample.

Toxicity data represents 25% of the total number of datasets in Cal/Ecotox. Toxicity dataset abundance is greatest for the selected species of birds (85% of all toxicity datasets; Table 2), followed by mammals (8%; Table 1) and herpetiles (7%; Table 3). Eighty-two percent of all toxicity datasets are from studies on five species: mallard, American kestrel, bullfrog, deer mouse, mourning dove. (listed in descending order; Tables l-3). Pesticides and metals are the dominant chemical classes for which toxicity data existed (data not shown). By

Table 3. Number of citations and exposure factor and toxicity datasets for herpetiles.

Reptiles and Amphibians	Exposure Datasets	Toxicity Datasets	Total Citations
Testudines			
Western pond turtle *(Clemmys marmorata)**	22	0	7
Desert tortoise *(Gopherus agassizi)**	100	0	34
Squamata			
Blunt-nosed leopard lizard *(Gambelia silus)**	27	0	5
Desert iguana *(Dipsosaurus dorsalis)*	74	0	16
Western fence lizard *(Sceloporus occidentalis)*	116	0	27
Coachella Valley fringe-toed lizard	15	0	5
Sideblotched lizard *(Uta stansburiana)*	127	0	26
Island night lizard *(Xantusia riversiana)**	35	0	9
Western skink *(Eumeces skiltonianus)*	8	0	3
California whipsnake *(Masticophis lateralis)**	7	0	3
Gopher snake *(Pituophis melanoleucus)*	35	1	11
Giant garter snake *(Thamnophis gigas)**	1	0	1
Common garter snake *(Thamnophis sirtalis)*	70	0	27
Caudata			
California newt *(Taricha torosa)*	33	3	12
Long-toed salamander *(Ambystoma*	28	0	9
Pacific giant salamander *(Dicamptodon ensatus)**	19	0	10
Desert slender salamander *(Batrachoseps aridus)**	0	0	0
Ensatina *(Ensatina eschscholtzii)*	31	0	7
Anura			
Western toad *(Bufo boreas)*	34	6	15
Pacific treefrog *(Hyla regilla)*	21	5	10
Red-legged frog *(Rana aurora)**	32	2	11
Bullfrog *(Rana catesbeiana)*	124	66	57
TOTAL	959	83	305

*Special status species or subspecies

toxicological endpoint category, overall numbers of exposure-related, lethality, reproduction and other sublethal endpoints are similar but datasets addressing population-level endpoints are rare (Table 4). A similar relationship is seen within the three wildlife groups but population-level endpoints are relatively more common in mammals (Table 4). Six journals provided 50% of the toxicity data citations and the top-three ranked journals for each wildlife group were represented by these journals (Table 5). The combined top ranked journals, contributing 51% of the exposure factor and toxicity data citations are listed in Table 5.

Compared to exposure factors, toxicity data for the selected species are limited. Available wildlife toxicity data for these species tend to be clustered within a few common laboratory species, especially those species for which standardized toxicity tests have been developed (U.S. EPA, 1996). However, data for less traditional study species, especially among birds, are available and are potentially useful for ecological risk assessments. When undertaking a literature search, our results indicate that a wide variety of toxicological and ecological journals should be examined. Herpetile toxicity data for the species evaluated are very limited and represent an area needing further research, as noted by Sheffield et al. (1998). Systematic analysis of exposure factor and toxicity data abundance are critical to conducting and interpreting ecological risk assessments and in identifying gaps in wildlife exposure factors and toxicity data. The importance of linking risk

Table 4. Number of exposure factor and toxicity datasets, organized by categories, for mammals, birds and herpetiles.

Exposure Factors	Dataset Number			
	Mammals	Birds	Herpetiles	Total
Normalizing Factors Body Weight	321	98	165	584
Body Fat	21	17	4	42
Surface Area	4	5	3	12
Growth Rate	49	20	76	145
Metabolic Rate	95	26	102	223
SubTotal	**490**	**166**	**350**	**1006**
Contact Factors Dietary Composition	149	106	86	341
Food Ingestion Rate	71	26	23	120
Water Ingestion Rate	20	3	2	25
Inhalation Rate	5	4	2	11
SubTotal	**245**	**139**	**113**	**497**
Population Dynamics Age at Wean./Fledg./Metamor.	22	20	7	49
Age at Sexual Maturity	36	15	35	86
Incubation/Gestation Period	35	32	25	92
Productivity (litters/clutches)	153	277	120	550
Survival Rates	93	118	47	258
Population Density	103	104	57	264
Home or Foraging Range	164	71	70	305
SubTotal	**606**	**637**	**361**	**1604**
Seasonal Activities Time of Breeding	70	77	93	240
Time of Molting	8	15	NA	23
Time of Hibernation	7	NA	26	33
Time of Migration	NA	27	NA	27
Time of Dispersion	9	NA	NA	9
Time of Metamorphosis	NA	NA	16	16
SubTotal	**94**	**119**	**135**	**348**
Toxicological Endpoints				
Exposure-related	7	238	15	260
Population-level	10	1	0	11
Lethality	25	145	45	215
Reproduction	12	277	14	303
Other Sublethal	38	306	9	353

NA = Not Applicable

assessment to research to improve the use of scientific information in decision making has been emphasized by Vandenberg (1995) and Connolly et al. (1999).

Our analysis of a subset of wildlife species indicates that research has contributed a substantial amount of species-specific information that may be utilized in ecological risk assessment. However, our analysis of this broad group of wildlife species also suggests that many exposure factor and toxicity data gaps remain

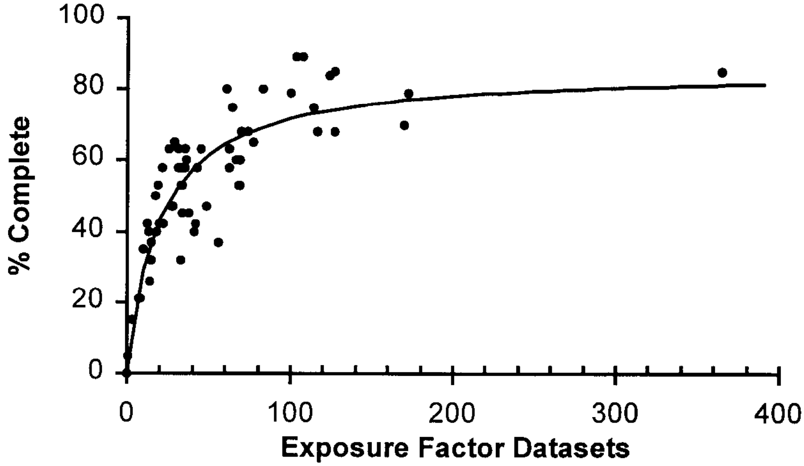

Figure 1. Relationship between number of exposure factor datasets and percent completeness of exposure factor data, measured as percent of data categories containing at least one dataset, for mammals, birds and herpetiles. The equation for the solid line is $y = 85.79\,x / (19.55+x)$ (correlation coefficient = 0.890; n = 60).

Table 5. Percentage of toxicology-related and total citations obtained from scientific journals.

Journal	Toxicology Citations (%)	Journal	Total Citations (%)
Arch. Environ. Contam. Toxicol.	16	J. Mammal.	8
Bull. Environ. Contam.	12	J. Wildlife Management	7
Environ. Toxicol. Chem.	7	Arch. Environ. Contam. Toxicol.	4
J. Wildlife Management	7	Canadian J. Zoology	4
J. Toxicol. Environ. Health	4	Condor	4
J. Wildlife Disease	4	Copeia	4
	50	Bull. Environ. Contam.	3
		Herpetologica	3
		Ecology	3
		Wilson Bulletin	3
		American Midland Naturalist	2
		J. Herpetology	2
		Auk	2
		Southwestern Naturalist	2
			51

which may contribute uncertainty to ecological risk assessments. By identifying these data gaps it is hoped that further collaborations between risk assessors and researchers will be undertaken to prioritize and address these data needs.

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