

Few-Shot Learning with Localization in Realistic Settings (Supplementary Materials)

1. Additional Results

1.1. Ablation Study

Top-1 and top-5 mean and per-class accuracies are given below. Three-digit model names indicate the presence or absence of batch folding, localization, and covariance pooling, in that order. For example, ‘101’ indicates a model with batch folding and covariance pooling, but no localization. Because two versions of localization exist, we use ‘0’ to indicate no localization, ‘1’ for few-shot localization, and ‘2’ for unsupervised localization. A ‘*’ indicates a model presented in the main paper.

Model	Top-1 Accuracy		Top-5 Accuracy	
	Mean	Per-Class	Mean	Per-Class
000*	16.07 ± .19	17.55 ± .19	42.10 ± .21	41.98 ± .18
100*	20.04 ± .04	20.81 ± .08	47.86 ± .31	46.57 ± .23
010	21.55 ± .09	22.37 ± .08	50.20 ± .08	48.70 ± .08
001	24.31 ± .48	24.64 ± .39	53.29 ± .76	51.09 ± .63
020	24.32 ± .15	24.68 ± .81	53.16 ± .89	51.44 ± .94
021	25.60 ± 1.02	25.51 ± .90	54.66 ± 1.07	52.04 ± .91
110*	26.25 ± .05	26.29 ± .04	55.43 ± .09	53.01 ± .08
011	27.46 ± .15	26.39 ± .14	56.37 ± .17	52.37 ± .17
120*	28.75 ± .13	28.39 ± .15	57.90 ± .24	55.27 ± .37
101	31.06 ± .61	29.07 ± .53	60.41 ± .67	55.50 ± .62
121*	32.74 ± .13	30.52 ± .13	61.32 ± .14	56.62 ± .16
111*	35.52 ± .05	31.69 ± .06	63.76 ± .09	57.33 ± .10

Between any two models with different numbers of features, the one with more always outperforms the one with less, regardless of combination. Thus batch folding, localization, and covariance pooling consistently and independently improve performance on meta-iNat.

1.2. Learning Without Forgetting

We evaluate the ability of our prototype-styled classifiers to adapt to new concepts without forgetting old ones. We combine the evaluation and representation sets of meta-iNat into a single, larger dataset and provide accuracy numbers for prototype-styled classifiers. Softmax classifiers are ignored, as they cannot handle old and new concepts simultaneously without completely replacing the topmost fully-connected layer. While accuracy decreases overall (we are now distinguishing between 1135 categories rather than 227), batch folding, few-shot localization, and covariance pooling still lead to significant improvements. For logistical reasons, we run only one trial in all settings, though we still evaluate four independently trained models for each.

Model	Top-1 Accuracy		Top-5 Accuracy	
	Mean	Per-Class	Mean	Per-Class
Baseline	6.64 ± .06	7.37 ± .08	21.08 ± .13	21.08 ± .19
Batch Folding	8.87 ± .13	9.35 ± .14	25.92 ± .20	25.13 ± .16
BF + few-shot localization	13.22 ± .04	13.11 ± .07	33.54 ± .12	31.60 ± .12
BF + fsL + covariance pooling	20.69 ± .16	17.44 ± .13	43.70 ± .23	37.17 ± .33

2. Network Architectures

Our learner architectures mimic the original prototypical networks. Networks contain four 64-channel 3×3 convolutional layers, with Batchnorm, ReLU, and 2×2 max-pooling in between. This is followed by Batchnorm and 10×10 global average-pooling, for a 64-dimensional feature vector. Unlike prototypical networks, which flatten the feature map to a

6400-dimensional vector, we use average pooling to eliminate spatial priors on uncentered, uncropped images. Softmax classifier models use a fully-connected layer on top of the feature vector; prototype classifiers use the feature vector directly. Localization and covariance pooling models replace average-pooling layers with the appropriate algorithm(s).

Models based on ResNet50 use the first two stages of a ResNet50 model, pretrained on ImageNet, to produce 28×28 feature maps with 512 channels. Learned layers consist of 2×2 max-pooling, followed by 3×3 convolution with 128 channels, Batchnorm, ReLU, a second 3×3 convolution with 64 channels, and Batchnorm. The resulting 14×14 feature maps are localized, average pooled, or covariance pooled as appropriate. As in the original setting, softmax classifiers use an additional fully-connected layer, while prototype architectures use the pooled embeddings directly.

3. Training and Implementation Details

3.1. Training

We train meta-iNat models via SGD with Adam, using an initial learning rate of 10^{-3} and dividing by two every epoch. Each epoch consists of 10 passes over the representation set, with five epochs in total. For mini-ImageNet, we lengthen each epoch to 28 passes, to account for the smaller representation set.

In both settings we unit-normalize input color channels. We use random horizontal flipping but no other data augmentation. Because bounding boxes are downsized to very small resolutions (e.g. 10×10), we use 4×4 average-pooling before downsampling, as a fast approximation for anti-aliasing.

3.2. Batch Sampling

While mini-ImageNet uses random batch sampling with replacement during training and testing, meta-iNat uses a different sampling procedure for each. During each training iteration, classes are sampled without replacement: so long as classes have sufficient remaining images to create a batch, they are sampled proportionately to the number of available images they contain. This ensures that differently-sized classes occur at constant, representative rates throughout the entire sampling process. Images are then selected from the sampled classes, and those images are subsequently unavailable for further training until the next pass over the dataset.

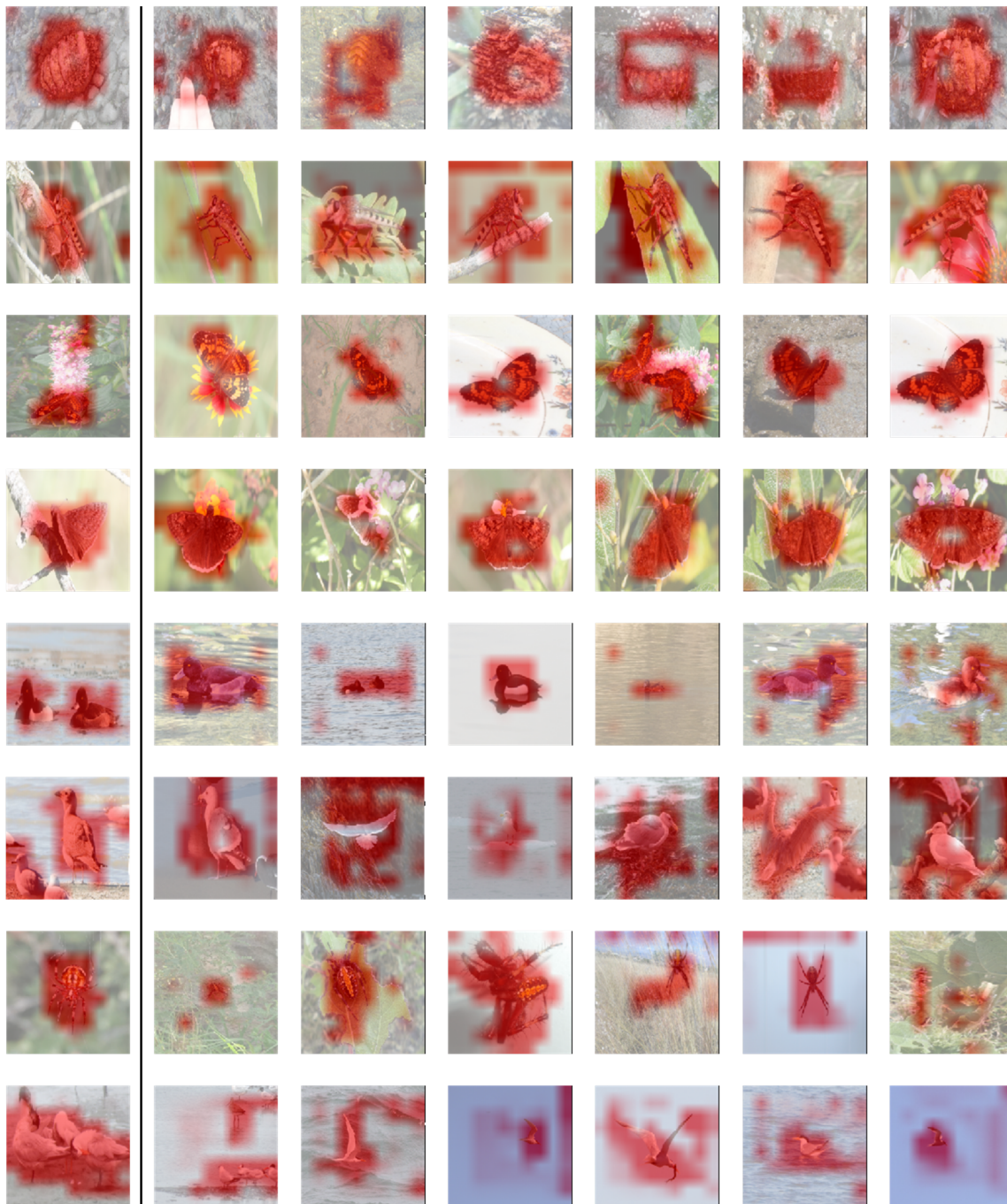
During testing, we wish to evaluate classification accuracy for relatively large numbers of classes and images. For sufficiently high values, it becomes impossible to process the sampled datasets as single batches in computer memory. Category sizes also vary so widely that it no longer makes sense to use constant sample sizes. Rather than attempt to evaluate a given network on a large number of large and complicated datasets, we instead impose a single reference/query split over the evaluation set.

Evaluation consists of one pass over the reference images followed by one pass over the query images. During the reference pass, each category is split into manageable batches, and the class centroid is computed from a running total of the embedding vectors. The query pass is divided the same way, and the pre-computed centroids are used to make class predictions. When localization is used, we run 10 trials where different 10% subsets of the reference images are randomly selected to receive bounding box annotations.

The above applies to prototype-styled classifiers, which require representation and query sets for a limited selection of classes in every batch. For straightforward softmax classifiers, we instead use random sampling without replacement, and a batch size of 128. Annealing schedule is as above.

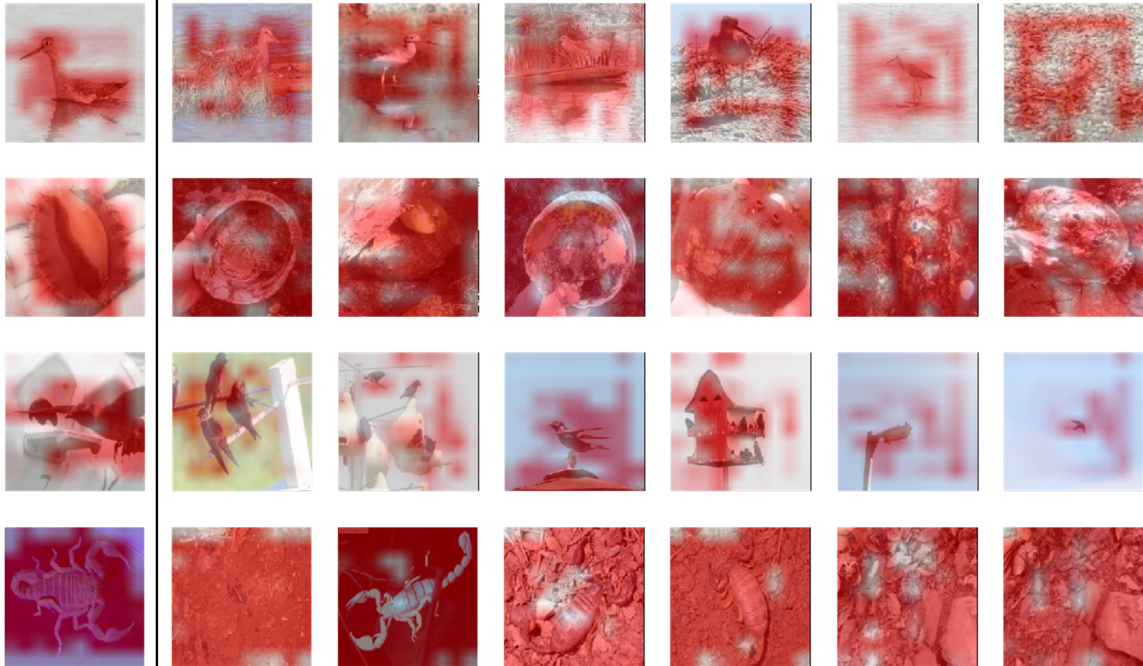
4. Additional Few-Shot Localization Examples

When individual bounding boxes in the annotated reference image are small, localization tends to work well, given the model's lack of power (a four-layer network with 10×10 outputs and no localization supervision). The leftmost image provides the ground truth bounding box(es).

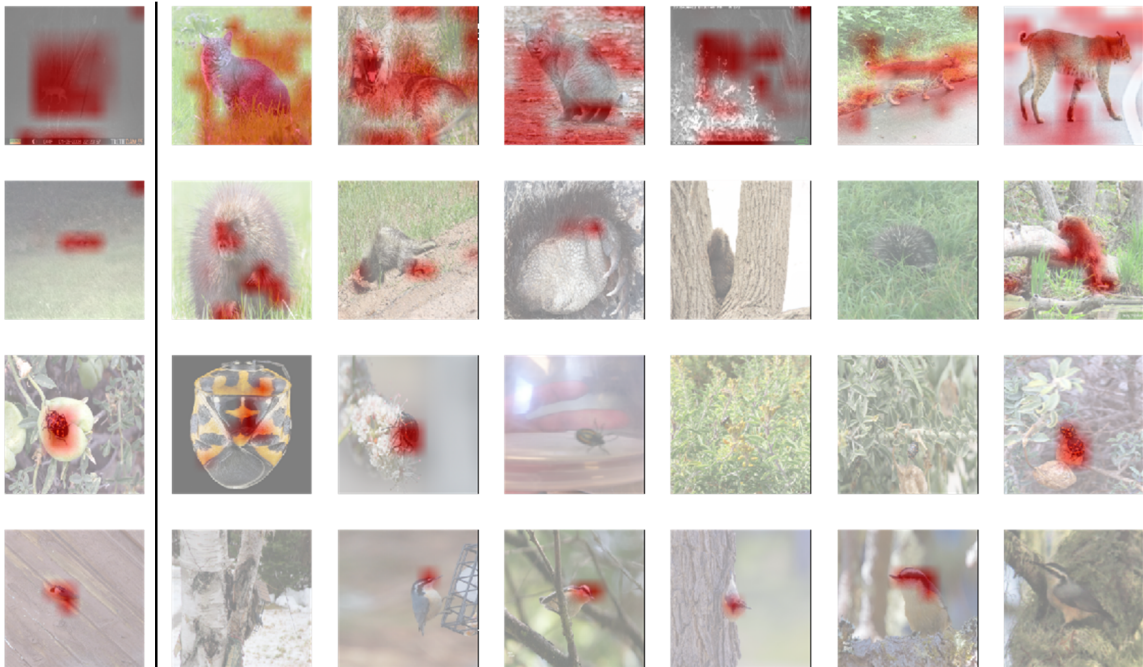


4.1. Failure cases

When bounding boxes in the annotated reference image are too large or too small, localizer performance breaks down. In the former case, too much of the background is included in the bounding box, and the localizer becomes over-inclusive.



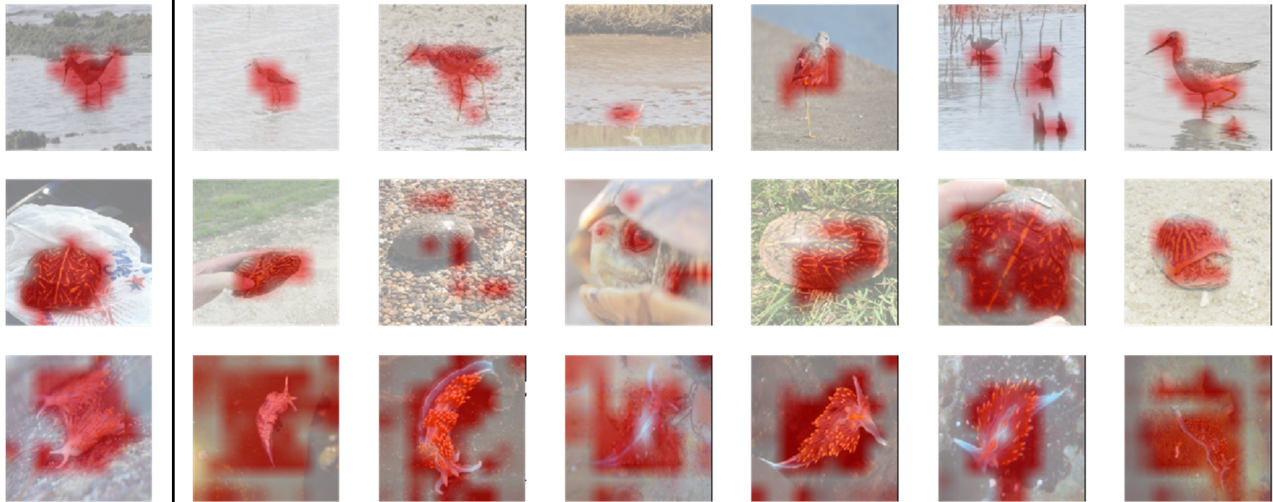
When bounding boxes are too small, the localizer focuses on the wrong things, selects small parts of the object in question, or in some cases fails to detect a region of interest at all.



4.2. Additional annotations

Localizer performance generally improves as more annotations are made available.

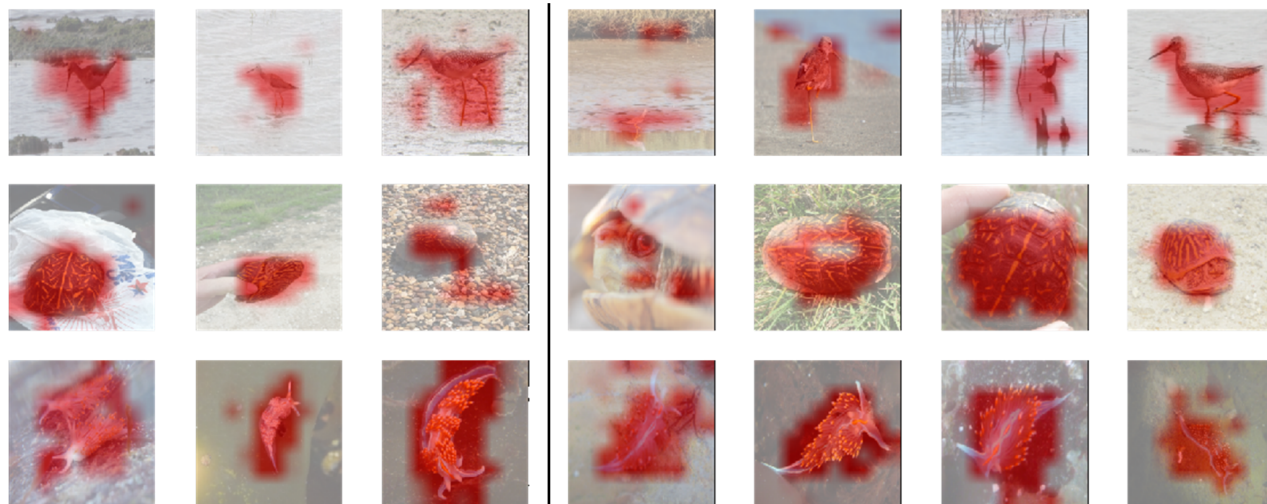
One annotation per row: The localizer often selects only parts of the relevant object, or includes significant portions of the background.



Two annotations per row: The localizer has eliminated much of the irrelevant background areas from its predictions, increasing precision (see bottom row in particular), as well as including more of the relevant object.



Three annotations per row: The localizer includes larger portions for photos where it originally selected only a small subregion, improving recall (see middle row in particular).



5. Meta-iNat Category Splits

The code for meta-iNat is available on GitHub, but we list the category assignments here for the sake of completeness.

Evaluation Categories

Arachnida/Nephila clavipes	Aves/Cygnus columbianus	Aves/Sialia currucoides
Aves/Cyanocitta cristata	Animalia/Patriella regularis	Aves/Sphyrapicus varius
Insecta/Phoebis sennae	Insecta/Hypsopygia olinalis	Aves/Zosterops lateralis
Aves/Selasphorus sasin	Insecta/Ischnura elegans	Insecta/Lasiommata megera
Aves/Anas platyrhynchos domesticus	Aves/Todiramphus sanctus vagans	Insecta/Anthanassa tulcis
Mollusca/Hermisenda opalescens	Aves/Melanerpes carolinus	Insecta/Stagmomantis carolina
Insecta/Murgantia histrionica	Insecta/Atalopedes campestris	Insecta/Tramea onusta
Aves/Clangula hyemalis	Aves/Aphelocoma californica	Insecta/Sceliphron caementarium
Insecta/Speranza pustularia	Aves/Sitta canadensis	Aves/Corvus monedula
Aves/Buteo regalis	Mollusca/Ariolimax columbianus	Insecta/Papilio rutulus
Aves/Gerygone igata	Insecta/Pantala flavescens	Insecta/Argia apicalis
Insecta/Aeshna umbrosa	Insecta/Polistes exclamans	Aves/Polioptila caerulea
Insecta/Nomophila nearctica	Aves/Geranoaetus albicaudatus	Amphibia/Anaxyrus fowleri
Reptilia/Sauromalus ater	Arachnida/Phidippus johnsoni	Aves/Petroica australis longipes
Aves/Athene cucularia	Aves/Numenius phaeopus	Reptilia/Crotalus oreganus oreganus
Aves/Vireo olivaceus	Aves/Rynchops niger	Reptilia/Pituophis catenifer annectens
Aves/Chloroceryle americana	Aves/Tadorna variegata	Mammalia/Sylvilagus audubonii
Insecta/Scopula limboundata	Aves/Tigrisoma mexicanum	Aves/Baeolophus bicolor
Insecta/Cleptis peritana	Aves/Gallus gallus domesticus	Aves/Oreothlypis peregrina
Insecta/Xylocopa virginica	Aves/Phalaropus lobatus	Mammalia/Orcinus orca
Insecta/Leucorrhinia intacta	Insecta/Sympetrum pallipes	Reptilia/Nerodia erythrogaster transversa
Reptilia/Ctenosaura similis	Reptilia/Aspidoscelis gularis	Aves/Chen caerulescens
Insecta/Speyeria cybele	Aves/Botaurus lentiginosus	Mammalia/Tamias striatus
Reptilia/Uta stansburiana elegans	Aves/Thalasseus elegans	Aves/Progne subis
Mammalia/Odocoileus hemionus californicus	Animalia/Strongylocentrotus purpuratus	Aves/Charadrius nivosus
Insecta/Polistes carolina	Aves/Contopus sordidulus	Mammalia/Lynx rufus
Reptilia/Diadophis punctatus	Amphibia/Lithobates berlandieri	Aves/Amazilia violiceps
Insecta/Maniola jurtina	Amphibia/Eurycea bislineata	Aves/Corvus corax
Aves/Melanerpes chrysogenys	Aves/Podiceps auritus	Aves/Pica hudsonia
Aves/Egretta rufescens	Insecta/Tramea lacerata	Aves/Platalea ajaja
Insecta/Callophrys gryneus	Reptilia/Terrapene ornata	Aves/Passerina cyanea
Mollusca/Haliotis rufescens	Aves/Spinus pinus	Insecta/Argia immunda
Reptilia/Coluber constrictor	Aves/Spizelloides arborea	Aves/Histrionicus histrionicus
Insecta/Cycloneda sanguinea	Insecta/Idia americalis	Aves/Melospiza crissalis
Insecta/Anax junius	Insecta/Plutella xylostella	Reptilia/Hierophis viridiflavus
Mollusca/Acanthodoris lutea	Mammalia/Sylvilagus floridanus	Aves/Poecile carolinensis
Aves/Momotus mexicanus	Insecta/Papilio multicaudata	Mollusca/Octopus rubescens
Reptilia/Pituophis catenifer sayi	Insecta/Asterocampa clyton	Aves/Cassidix melanicterus
Amphibia/Plethodon albagula	Reptilia/Phrynosoma hernandesi	Aves/Sterna forsteri
Reptilia/Thamnophis proximus	Insecta/Macromia illinoensis	Aves/Auriparus flaviceps
Mammalia/Erethizon dorsatum	Amphibia/Lithobates palustris	Aves/Phalacrocorax varius varius
Arachnida/Phidippus audax	Insecta/Chauliognathus pennsylvanicus	Insecta/Toxomerus marginatus
Reptilia/Thamnophis proximus orarius	Mollusca/Mopalia muscosa	Insecta/Promachus hinei
Aves/Falco mexicanus	Mollusca/Lottia gigantea	Aves/Toxostoma redivivum
Aves/Pipilo erythrophthalmus	Insecta/Ceratonia undulosa	Reptilia/Heterodon platirhinos
Insecta/Eacles imperialis	Arachnida/Salticus scenicus	Aves/Larus glaucescens
		Insecta/Satyrium calanus

Aves/Alopochen aegyptiaca
Reptilia/Plestiodon fasciatus
Insecta/Papilio eurymedon
Insecta/Lygaeus kalmii
Aves/Calidris melanotos
Aves/Molothrus ater
Aves/Pelecanus occidentalis californicus
Insecta/Dryas iulia
Reptilia/Pantherophis obsoletus lindheimeri
Insecta/Dryocampa rubicunda
Animalia/Armadillidium vulgare
Mammalia/Lontra canadensis
Reptilia/Agkistrodon piscivorus leucostoma
Insecta/Epithea princeps
Aves/Lanius collurio
Aves/Campylorhynchus brunneicapillus
Insecta/Polygona interrogationis
Insecta/Chioidea albofasciatus
Reptilia/Crotalus horridus
Aves/Vireo griseus
Insecta/Danaus gilippus
Insecta/Ladona deplanata
Aves/Junco phaeonotus
Aves/Chroicocephalus ridibundus
Insecta/Archilestes grandis
Arachnida/Uroctonus mordax
Actinopterygii/Lepomis macrochirus
Insecta/Libellula forensis
Aves/Calidris alba
Aves/Ictinia mississippiensis
Mammalia/Ursus americanus
Insecta/Glaucopsyche lygdamus
Aves/Lonchura punctulata
Arachnida/Neoscona oaxacensis
Aves/Loxia curvirostra
Insecta/Polyphylla decemlineata
Aves/Aegithalos caudatus
Reptilia/Crotalus molossus
Amphibia/Anaxyrus woodhousii
Aves/Vireo gilvus
Aves/Sialia sialis
Aves/Amphispiza bilineata
Aves/Egretta novaehollandiae
Insecta/Anicla infecta
Aves/Tringa melanoleuca
Amphibia/Lithobates sylvaticus
Aves/Himantopus mexicanus
Insecta/Chlosyne nycteis
Aves/Anser anser domesticus

Aves/Larus occidentalis
Aves/Prunella modularis
Reptilia/Phrynosoma blainvillii
Aves/Aramus guarauna
Insecta/Hypoprepia fucosa
Insecta/Erynnis tristis
Amphibia/Taricha rivularis
Aves/Aythya fuligula
Animalia/Pollicipes polymerus
Insecta/Cercyonis pegala
Aves/Pica pica
Aves/Larus heermanni
Aves/Phainopepla nitens
Animalia/Pachygrapsus crassipes
Mammalia/Castor canadensis
Amphibia/Salamandra salamandra
Insecta/Anartia jatrophae
Insecta/Aedes albopictus
Mammalia/Bison bison
Reptilia/Lampropeltis californiae
Insecta/Gomphus militaris
Aves/Chlidonias niger
Animalia/Physalia physalis
Aves/Eolophus roseicapilla
Aves/Phalacrocorax penicillatus
Reptilia/Chrysemys picta marginata
Insecta/Epargyreus clarus
Insecta/Bombus impatiens
Aves/Protonotaria citrea
Insecta/Pyrgus communis
Insecta/Bombus ternarius
Insecta/Anax longipes
Aves/Cyanistes caeruleus
Insecta/Polites peckius
Insecta/Orthemis ferruginea
Insecta/Actias luna
Actinopterygii/Salvelinus fontinalis
Reptilia/Thamnophis elegans
Insecta/Colias philodice

Representation Categories

Reptilia/Sceloporus poinsettii
Aves/Chordeiles minor
Aves/Anas cyanoptera
Reptilia/Opheodrys aestivus
Aves/Pelecanus erythrorhynchos
Aves/Tyrannus tyrannus
Reptilia/Ctenosaura pectinata
Insecta/Lophocampa maculata
Mollusca/Aeolidia papillosa
Mammalia/Mus musculus
Arachnida/Centruroides vittatus
Reptilia/Nerodia sipedon
Amphibia/Batrachoseps attenuatus
Insecta/Celithemis eponina
Mammalia/Tursiops truncatus
Insecta/Heraclides crespontes
Aves/Phasianus colchicus
Insecta/Asterocampa celtis
Aves/Setophaga discolor
Aves/Motacilla cinerea
Reptilia/Sceloporus orcutti
Aves/Tachybaptus ruficollis
Aves/Streptopelia decaocto
Insecta/Chinavia hilaris
Aves/Anser cygnoides domesticus
Aves/Cistothorus palustris
Reptilia/Lampropeltis holbrooki
Aves/Garrulus glandarius
Reptilia/Actinemys marmorata
Insecta/Forficula auricularia
Mammalia/Sciurus griseus
Aves/Colaptes auratus
Aves/Melanerpes aurifrons
Aves/Carduelis carduelis
Aves/Gymnogyps californianus
Aves/Bucephala clangula
Aves/Passerina amoena
Insecta/Papilio polyxenes asterius
Aves/Ammodramus savannarum
Aves/Butorides striata
Amphibia/Pseudacris cadaverina
Insecta/Erpetogomphus designatus
Aves/Vanellus vanellus
Insecta/Romalea microptera
Aves/Baeolophus inornatus
Aves/Campephilus guatemalensis
Animalia/Patiria miniata
Reptilia/Crotalus oreganus helleri
Insecta/Ischnura cervula
Insecta/Aglais milberti
Aves/Aix sponsa
Reptilia/Gopherus agassizii
Insecta/Hemaris thysbe
Mammalia/Thomomys bottae
Aves/Zonotrichia atricapilla
Insecta/Spoladea recurvalis
Mammalia/Nasua narica
Amphibia/Hyla cinerea
Aves/Ardea cinerea
Aves/Gallinago delicata
Insecta/Strymon melinus
Aves/Elanus leucurus
Aves/Euphagus carolinus
Insecta/Pyrgus oileus
Mammalia/Antilocapra americana
Aves/Turdus pilaris
Insecta/Cupido comyntas
Insecta/Euphyes vestris
Insecta/Hymenia perspectalis
Animalia/Anthopleura sola
Insecta/Mantis religiosa
Insecta/Automeris io
Insecta/Libellula cyanea
Insecta/Megacyllene robiniae
Mammalia/Cervus elaphus
Reptilia/Coluber constrictor flaviventris
Insecta/Pararge aegeria
Aves/Larus hyperboreus
Insecta/Argia translata
Aves/Archilochus alexandri
Arachnida/Aphonopelma hentzi
Insecta/Spilosoma virginica
Aves/Microcarbo melanoleucos bre-
virostris
Aves/Porzana carolina
Insecta/Necrophila americana
Aves/Sitta carolinensis
Mammalia/Tamiasciurus hudsonicus
Aves/Picoides scalaris
Aves/Icterus gularis
Insecta/Calycopsis isobea
Aves/Setophaga fusca
Mollusca/Limax maximus
Aves/Cardinalis sinuatus
Aves/Galerida cristata
Reptilia/Hemidactylus frenatus
Insecta/Cotinis mutabilis
Aves/Haematopus bachmani
Insecta/Costaconvexa centrostrigaria
Insecta/Polistes apachus
Aves/Piaya cayana
Insecta/Dythemis fugax
Insecta/Zelus longipes
Insecta/Ascalapha odorata
Aves/Icterus cucullatus
Insecta/Heliopetes ericetorum
Aves/Eremophila alpestris
Insecta/Darapsa myron
Insecta/Nymphalis californica
Reptilia/Rhinocheilus lecontei
Aves/Branta hutchinsii
Aves/Columba palumbus
Aves/Coccyzus americanus
Aves/Picoides villosus
Aves/Rallus limicola
Mollusca/Corbicula fluminea
Aves/Stelgidopteryx serripennis
Aves/Geopelia striata
Aves/Thryothorus ludovicianus
Mammalia/Sciurus vulgaris
Aves/Limosa fedoa
Reptilia/Basiliscus vittatus
Aves/Porphyrio melanotus melanotus
Insecta/Sympetrum vicinum
Insecta/Argia moesta
Reptilia/Dipsosaurus dorsalis
Amphibia/Ambystoma opacum
Insecta/Malacosoma disstria
Aves/Acanthis flammea
Insecta/Heraclides rumiko
Aves/Junco hyemalis oreganus
Arachnida/Araneus diadematus
Aves/Catharus guttatus
Aves/Tyrannus melancholicus
Amphibia/Anaxyrus punctatus
Amphibia/Pseudacris hypochondri-
aca
Insecta/Battus philenor
Insecta/Sphecius speciosus
Insecta/Micrathyria hagenii
Insecta/Malacosoma americanum
Insecta/Hetaerina titia
Aves/Passerina versicolor
Aves/Anas acuta
Reptilia/Aspidoscelis tigris stejnegeri
Aves/Ortalis vetula
Reptilia/Iguana iguana
Mammalia/Marmota flaviventris
Aves/Callipepla californica
Aves/Cyanocorax yncas
Mammalia/Oryctolagus cuniculus
Reptilia/Chrysemys picta picta

Aves/Larus michahellis		Aves/Nestor meridionalis septentri-	Amphibia/Gastrophryne carolinensis
Aves/Aythya collaris		onalis	Aves/Parkesia noveboracensis
Reptilia/Agkistrodon contortrix		Reptilia/Storeria dekayi	Insecta/Limenitis arthemis
Aves/Poecile rufescens		Aves/Thraupis abbas	Mammalia/Procyon lotor
Aves/Arenaria interpres		Insecta/Polyommatus icarus	Reptilia/Arizona elegans
Insecta/Lophocampa caryae		Aves/Parabuteo unicinctus	Arachnida/Argiope aurantia
Aves/Thalasseus sandvicensis		Animalia/Limulus polyphemus	Amphibia/Lithobates pipiens
Aves/Geococcyx californianus		Aves/Turdus philomelos	Insecta/Labidomera clivicollis
Insecta/Adelpha californica		Aves/Dryocopus lineatus	Insecta/Oncopeltus fasciatus
Aves/Buteo lagopus		Arachnida/Dysdera crocata	Aves/Thalasseus maximus
Insecta/Papilio polyxenes		Insecta/Xanthocnemis zealandica	Insecta/Diabrotica undecimpunctata
Aves/Pooecetes gramineus		Aves/Anas superciliosa platyrhyn-	Aves/Corvus corone
Aves/Setophaga nigrescens		chos	Amphibia/Taricha granulosa
Aves/Pipilo maculatus		Aves/Dryocopus pileatus	Aves/Melospiza lincolni
Aves/Pluvialis fulva		Insecta/Enallagma basidens	Insecta/Noctua pronuba
Insecta/Libellula croceipennis		Aves/Charadrius semipalmatus	Amphibia/Lithobates sphenoccephalus
Arachnida/Leucauge venusta		Aves/Accipiter striatus	Reptilia/Sonora semiannulata
Insecta/Urola nivalis		Mammalia/Alces americanus	Insecta/Libellula comanche
Amphibia/Rhinella marina		Insecta/Hypercompe scribonia	Insecta/Calycopsis cecrops
Reptilia/Coleonyx brevis		Insecta/Anthanassa texana	Mammalia/Capreolus capreolus
Arachnida/Paraphidippus aurantius		Amphibia/Pseudacris regilla	Insecta/Chrysochus auratus
Aves/Molothrus aeneus		Insecta/Mythimna unipuncta	Insecta/Ctenucha virginica
Aves/Regulus satrapa		Aves/Podilymbus podiceps	Aves/Oenanthe oenanthe
Aves/Egretta tricolor		Reptilia/Gopherus polyphemus	Insecta/Lethe anthedon
Insecta/Udea rubigalis		Insecta/Brachymesia gravaida	Amphibia/Scaphiopus couchii
Insecta/Nymphalis antiopa		Mammalia/Zalophus californianus	Aves/Caracara cheriway
Insecta/Homalodisca vitripennis		Aves/Buteo plagiatus	Aves/Quiscalus quiscula
Aves/Columbina talpacoti		Aves/Pheucticus melanocephalus	Aves/Picoides nuttallii
Aves/Chondestes grammacus		Aves/Actitis macularius	Aves/Setophaga virens
Insecta/Vanessa itea		Aves/Spizella pusilla	Mammalia/Odocoileus hemionus
Insecta/Papilio zelicaon		Insecta/Euphydryas chalcedona	Insecta/Poanes zabulon
Mollusca/Mytilus californianus		Aves/Troglodytes aedon	Insecta/Sphech ichneumoneus
Aves/Vireo huttoni		Mammalia/Didelphis virginiana	Mammalia/Tamiasciurus douglasii
Aves/Hydroprogne caspia		Insecta/Sympetrum semicinctum	Aves/Lanius ludovicianus
Aves/Vireo solitarius		Aves/Nucifraga columbiana	Insecta/Sympetrum obtrusum
Insecta/Ischnura denticollis		Arachnida/Argiope argentata	Aves/Selasphorus platycercus
Aves/Haemorrhous purpureus		Aves/Tringa incana	Aves/Actitis hypoleucos
Insecta/Aglais urticae		Aves/Icterus spurius	Arachnida/Latrodectus hesperus
Amphibia/Notophthalmus viri-	vir-	Aves/Tyrannus verticalis	Animalia/Pisaster ochraceus
descens		Aves/Tringa solitaria	Aves/Gallinula galeata
Aves/Zenaida asiatica		Aves/Aquila chrysaetos	Aves/Cyanocitta stelleri
Reptilia/Pantherophis emoryi		Reptilia/Virginia striatula	Insecta/Lestes australis
Insecta/Nathalis iole		Mollusca/Doriopsilla albopunctata	Mammalia/Lepus europaeus
Aves/Toxostoma curvirostre		Insecta/Dromogomphus spoliatus	Reptilia/Sceloporus variabilis
Animalia/Velella velella		Insecta/Rhionaeschna multicolor	Reptilia/Natrix natrix
Insecta/Melissodes bimaculata		Aves/Volatina jacarina	Insecta/Argia sedula
Mammalia/Phoca vitulina		Amphibia/Incilius nebulifer	Insecta/Coleomegilla maculata
Mollusca/Antaeolidiella oliviae		Aves/Melanerpes uropygialis	Aves/Tringa flavipes
Aves/Contopus virens		Aves/Tyrannus vociferans	Aves/Charadrius melodus
Reptilia/Phrynosoma cornutum		Insecta/Megisto cymela	Insecta/Limenitis archippus
Mammalia/Marmota monax		Aves/Limnodromus griseus	Mollusca/Cryptochiton stelleri
Reptilia/Heloderma suspectum		Insecta/Zelus renardii	Aves/Buteo platypterus
Insecta/Phoebis agarithe		Aves/Fringilla coelebs	Insecta/Dolichovespula maculata

Aves/Plegadis chihi	Insecta/Largus californicus	Aves/Perisoreus canadensis
Aves/Bonasa umbellus	Insecta/Urbanus proteus	Aves/Mniotilta varia
Aves/Tringa semipalmata	Reptilia/Aspidoscelis sexlineata	Aves/Leucophaeus pipixcan
Aves/Spiza americana	Aves/Calidris mauri	Aves/Pyrocephalus rubinus
Aves/Periparus ater	Aves/Aythya americana	Insecta/Cotinis nitida
Aves/Egretta caerulea	Amphibia/Ambystoma maculatum	Aves/Recurvirostra americana
Aves/Oxyura jamaicensis	Aves/Contopus cooperi	Aves/Selasphorus rufus
Insecta/Hippodamia convergens	Aves/Certhia americana	Insecta/Euchaetes egle
Insecta/Atteva aurea	Aves/Mycteria americana	Aves/Ardenna creatopus
Aves/Cygnus olor	Amphibia/Anaxyrus boreas	Aves/Tachycineta bicolor
Insecta/Dromogomphus spinosus	halophilus	Insecta/Eumorphia pandorus
Reptilia/Chrysemys picta	Insecta/Phyciodes mylitta	Arachnida/Peucetia viridans
Aves/Ciconia ciconia	Insecta/Euphydryas phaeton	Aves/Setophaga coronata auduboni
Insecta/Urbanus procne	Insecta/Caenurgina erechtea	Aves/Passerina ciris
Mollusca/Rumina decollata	Insecta/Echinargus isola	Aves/Poecile atricapillus
Reptilia/Sphenodon punctatus	Aves/Hylocichla mustelina	Mammalia/Phocarctos hookeri
Insecta/Lymantria dispar	Arachnida/Latrodectus mactans	Aves/Cygnus atratus
Aves/Columbina inca	Insecta/Epiaeschna heros	Reptilia/Tarentola mauritanica
Aves/Rhipidura leucophrys	Aves/Passerina caerulea	Aves/Catharus ustulatus
Mollusca/Okenia rosacea	Insecta/Argia fumipennis	Animalia/Cancer productus
Animalia/Callinectes sapidus	Animalia/Pugettia producta	Aves/Pitangus sulphuratus
Aves/Gallinula chloropus	Mammalia/Mirounga angustirostris	Insecta/Argia plana
Insecta/Celithemis elisa	Amphibia/Hyla chrysoscelis	Insecta/Ischnura hastata
Reptilia/Scincella lateralis	Insecta/Ochlodes sylvanoides	Insecta/Plebejus acmon
Insecta/Pieris napi	Reptilia/Pituophis catenifer catenifer	Aves/Glaucidium brasilianum
Aves/Bucephala islandica	Insecta/Hypena scabra	Mammalia/Pecari tajacu
Aves/Falco tinnunculus	Amphibia/Bufo bufo	Reptilia/Chelydra serpentina
Amphibia/Anaxyrus boreas	Aves/Pipilo chlorurus	Aves/Sula nebouxii
Insecta/Bagrada hilaris	Insecta/Cicindela repanda	Aves/Pelecanus occidentalis
Amphibia/Plethodon cinereus	Aves/Columba livia domestica	Aves/Turdus grayi
Aves/Prothemadera novaeseelandiae	Insecta/Aglais io	Mollusca/Tegula funebris
Insecta/Sympetrum illotum	Reptilia/Plestiodon skiltonianus	Aves/Cynanthus latirostris
Reptilia/Terrapene carolina triunguis	Insecta/Anaea andria	Insecta/Thymelicus lineola
Aves/Jacana spinosa	Mammalia/Megaptera novaeangliae	Aves/Sporophila torqueola
Insecta/Coenonympha tullia californiana	Reptilia/Anguis fragilis	Aves/Tyrannus forficatus
Mammalia/Neovison vison	Aves/Aythya marila	Insecta/Polygonia comma
Mollusca/Triopha catalinae	Insecta/Vanessa virginienensis	Insecta/Melanoplus bivittatus
Aves/Plegadis falcinellus	Amphibia/Hyla versicolor	Mollusca/Hermisenda crassicornis
Aves/Anas strepera	Mammalia/Oreamnos americanus	Aves/Branta bernicla
Aves/Bubulcus ibis	Reptilia/Crotalus viridis	Aves/Thraupis episcopus
Mammalia/Enhydra lutris nereis	Insecta/Enallagma exsulans	Insecta/Mestra amymone
Insecta/Ascia monuste	Insecta/Sympetrum corruptum	Insecta/Telebasis salva
Aves/Haematopus palliatus	Mollusca/Diaulula sandiegensis	Aves/Calidris minutilla
Aves/Calidris virgata	Insecta/Macroglossum stellatarum	Insecta/Vespa crabro
Insecta/Pelidnota punctata	Aves/Piranga rubra	Amphibia/Dicamptodon ensatus
Aves/Nestor meridionalis	Reptilia/Alligator mississippiensis	Insecta/Ladona julia
Amphibia/Smilisca baudinii	Aves/Dumetella carolinensis	Mollusca/Cepaea nemoralis
Aves/Mergus merganser	Amphibia/Anaxyrus speciosus	Insecta/Atlides halesus
Aves/Bubo scandiacus	Amphibia/Pelophylax	Aves/Setophaga petechia
Reptilia/Tantilla gracilis	Insecta/Coenonympha tullia	Mammalia/Erinaceus europaeus
Aves/Euphagus cyanocephalus	Insecta/Erynnis horatius	Reptilia/Coluber lateralis lateralis
Insecta/Papilio troilus	Aves/Setophaga caerulescens	Animalia/Dermasterias imbricata
	Amphibia/Pseudacris sierra	Insecta/Libytheana carinenta

Insecta/Pantala hymenaea
 Aves/Icterus bullockii
 Aves/Falco columbarius
 Aves/Aythya valisineria
 Aves/Calidris pusilla
 Insecta/Vanessa annabella
 Mollusca/Tonicella lineata
 Aves/Crotophaga sulcirostris
 Reptilia/Sceloporus undulatus
 Aves/Anas crecca
 Aves/Rostrhamus sociabilis
 Aves/Chloris chloris
 Insecta/Abaeis nicippe
 Aves/Anser anser
 Aves/Larus dominicanus dominicanus
 Insecta/Spodoptera ornithogalli
 Reptilia/Podarcis sicula
 Insecta/Haploa clymene
 Insecta/Jadera haematoloma
 Aves/Sturnella magna
 Aves/Milvus migrans
 Aves/Alcedo atthis
 Insecta/Hyles lineata
 Aves/Zonotrichia albicollis
 Reptilia/Crotalus scutulatus
 Aves/Ptiliogonys cinereus
 Mammalia/Felis catus
 Insecta/Ancyloxypha numitor
 Arachnida/Gasteracantha cancriformis
 Insecta/Papilio canadensis
 Insecta/Xylophanes tersa
 Aves/Petrochelidon pyrrhonota
 Insecta/Bombus griseocollis
 Aves/Anser albifrons
 Aves/Gavia immer
 Insecta/Limenitis arthemis astyanax
 Mollusca/Limacia cockerelli
 Mammalia/Arctocephalus forsteri
 Insecta/Panoquina ocola
 Mammalia/Ondatra zibethicus
 Insecta/Brephidium exilis
 Mammalia/Otospermophilus beecheyi
 Insecta/Libellula luctuosa
 Insecta/Enallagma signatum
 Insecta/Popillia japonica
 Insecta/Alaus oculatus
 Insecta/Dione moneta
 Reptilia/Trachemys scripta
 Aves/Geothlypis trichas
 Aves/Aechmophorus occidentalis
 Aves/Acridotheres tristis
 Aves/Porphyrion martinicus
 Animalia/Epiactis prolifera
 Aves/Leucophaeus atricilla
 Aves/Streptopelia chinensis
 Aves/Anas discors
 Mammalia/Ochotona princeps
 Aves/Mergus serrator
 Insecta/Enallagma civile
 Aves/Upupa epops
 Mammalia/Panthera leo
 Aves/Fulmarus glacialis
 Arachnida/Neoscona crucifera
 Insecta/Coccinella septempunctata
 Mammalia/Otospermophilus variegatus
 Reptilia/Coluber flagellum testaceus
 Amphibia/Notophthalmus viridescens viridescens
 Aves/Psilorhinus morio
 Insecta/Libellula vibrans
 Aves/Passer montanus
 Aves/Bubo virginianus
 Aves/Dolichonyx oryzivorus
 Aves/Passerella iliaca
 Aves/Icterus abeillei
 Aves/Strix varia
 Aves/Patagioenas flavirostris
 Aves/Setophaga citrina
 Aves/Emberiza citrinella
 Reptilia/Thamnophis sirtalis sirtalis
 Aves/Sialia mexicana
 Animalia/Procamburus clarkii
 Reptilia/Hemidactylus turcicus
 Aves/Larus californicus
 Aves/Cairina moschata domestica
 Aves/Tityra semifasciata
 Reptilia/Crotaphytus collaris
 Insecta/Argynnis paphia
 Aves/Catharus fuscescens
 Reptilia/Aspidoscelis exsanguis
 Reptilia/Sternotherus odoratus
 Aves/Larus argentatus
 Reptilia/Eretmochelys imbricata
 Aves/Sternula antillarum
 Aves/Salpinctes obsoletus
 Aves/Sturnella neglecta
 Insecta/Phyciodes pulchella
 Insecta/Bombus vosnesenskii
 Insecta/Calopteryx maculata
 Insecta/Pyrrharctia isabella
 Mammalia/Eschrichtius robustus
 Mammalia/Loxodonta africana
 Aves/Arenaria melanocephala
 Amphibia/Ensatina eschscholtzii xanthoptica
 Arachnida/Misumena vatia
 Insecta/Bombus terrestris
 Aves/Piranga olivacea
 Reptilia/Pantherophis alleghaniensis
 Aves/Phalaropus tricolor
 Insecta/Campaea perlata
 Insecta/Prochoerodes lineola
 Aves/Myiarchus cinerascens
 Aves/Baeolophus atricristatus
 Animalia/Anthopleura xanthogrammica
 Aves/Chen rossii
 Aves/Antigone canadensis
 Aves/Parus major
 Amphibia/Rana temporaria
 Mammalia/Equus quagga
 Insecta/Hetaerina americana
 Mollusca/Deroceras reticulatum
 Insecta/Chlosyne lacinia
 Insecta/Phyciodes tharos
 Reptilia/Nerodia rhombifer
 Mammalia/Urocyon cinereoargenteus
 Reptilia/Phrynosoma modestum
 Aves/Buteo swainsoni
 Insecta/Tetraopes tetrophthalmus
 Aves/Phoenicurus ochruros
 Reptilia/Crotalus oreganus
 Insecta/Pontia protodice
 Insecta/Eurytides marcellus
 Insecta/Ischnura posita
 Insecta/Pseudoleon superbus
 Aves/Erithacus rubecula
 Animalia/Emerita analoga
 Insecta/Tenodera sinensis
 Insecta/Bombylius major
 Aves/Cepphus columba
 Insecta/Estigmene acraea
 Reptilia/Pseudemys texana
 Aves/Setophaga dominica
 Insecta/Argia nahuana
 Reptilia/Podarcis muralis
 Aves/Turdus merula
 Aves/Alauda arvensis
 Reptilia/Apalone spinifera
 Reptilia/Sceloporus uniformis
 Aves/Thryomanes bewickii
 Aves/Corvus cornix
 Arachnida/Argiope trifasciata
 Aves/Haemorhous cassinii
 Insecta/Pieris marginalis

Animalia/Harpaghe haydeniana
 Aves/Anthus rubescens
 Insecta/Argia tibialis
 Reptilia/Sceloporus occidentalis bo-
 courtii
 Amphibia/Anaxyrus americanus
 Reptilia/Sceloporus olivaceus
 Insecta/Manduca sexta
 Aves/Psaltriparus minimus
 Aves/Callipepla squamata
 Insecta/Galgula partita
 Aves/Oreothlypis ruficapilla
 Aves/Paroaria coronata
 Aves/Dendrocygna autumnalis
 Aves/Larus canus
 Reptilia/Callisaurus draconoides
 Animalia/Anthopleura elegantissima
 Aves/Colinus virginianus
 Insecta/Limenitis arthemis arthemis
 Mammalia/Callospermophilus later-
 alis
 Insecta/Cicindela sexguttata
 Aves/Pachyrampus aglaiae
 Insecta/Xylocopa micans
 Insecta/Ischnura verticalis
 Reptilia/Crotalus ruber
 Aves/Anas clypeata
 Aves/Nyctanassa violacea
 Aves/Cardellina pusilla
 Insecta/Dythemis nigrescens
 Aves/Hemiphaga novaeseelandiae
 Aves/Passerculus sandwichensis
 Insecta/Battus philenor hirsuta
 Aves/Egretta garzetta
 Aves/Chaetura pelagica
 Insecta/Polygonia satyrus
 Insecta/Dythemis velox
 Aves/Setophaga ruticilla
 Aves/Setophaga magnolia
 Insecta/Poanes melane
 Aves/Buteogallus anthracinus
 Aves/Sterna hirundo
 Animalia/Tetraclita rubescens
 Insecta/Argia lugens
 Reptilia/Elgaria multicarinata webbii
 Reptilia/Sceloporus graciosus
 Aves/Saxicola rubetra
 Insecta/Trimerotropis pallidipennis
 Reptilia/Coluber flagellum
 Aves/Setophaga palmarum
 Amphibia/Taricha torosa
 Insecta/Melanoplus differentialis
 Mollusca/Ambigolimax valentianus
 Aves/Calidris bairdii
 Insecta/Poanes hobomok
 Insecta/Polistes metricus
 Amphibia/Gastrophryne olivacea
 Aves/Setophaga americana
 Aves/Icterus pustulatus
 Aves/Coccothraustes vespertinus
 Insecta/Microcrambus elegans
 Aves/Sphyrapicus ruber
 Aves/Megaceryle alcyon
 Aves/Phalacrocorax pelagicus
 Insecta/Leptoglossus occidentalis
 Aves/Bucephala albeola
 Aves/Dendrocopos major
 Mammalia/Eidolon helvum
 Mammalia/Ovis canadensis
 Insecta/Erythrodiplax umbrata
 Insecta/Bombus pennsylvanicus
 Aves/Pavo cristatus
 Aves/Tachybaptus dominicus
 Insecta/Celastrina echo
 Amphibia/Ensatina eschscholtzii
 Aves/Myiarchus crinitus
 Aves/Gavia pacifica
 Insecta/Argia vivida
 Aves/Ixoreus naevius
 Aves/Pluvialis squatarola
 Amphibia/Rana draytonii
 Actinopterygii/Gambusia affinis
 Aves/Setophaga townsendi
 Mollusca/Doris montereyensis
 Aves/Motacilla alba
 Aves/Quiscalus major
 Aves/Eudocimus albus
 Insecta/Lerodea eufala
 Insecta/Schistocerca nitens
 Aves/Chroicocephalus scopulinus
 Insecta/Hemiargus ceraunus
 Aves/Spizella pallida
 Reptilia/Chelonia mydas
 Insecta/Halyomorpha halys
 Insecta/Perithemis tenera
 Aves/Megaceryle torquata
 Insecta/Polygonia c-album
 Reptilia/Crocodylus acutus
 Aves/Uria aalge
 Aves/Columbina passerina
 Aves/Cygnus buccinator
 Aves/Megascops asio
 Aves/Sula leucogaster
 Aves/Circus cyaneus
 Insecta/Limenitis lorquini
 Aves/Gymnorhina tibicen
 Insecta/Polistes dominula
 Aves/Sayornis phoebe
 Aves/Phalacrocorax carbo
 Actinopterygii/Oncorhynchus mykiss
 Insecta/Ischnura ramburii
 Aves/Callipepla gambelii
 Insecta/Melanchroia chephise
 Insecta/Erynnis baptisiae
 Aves/Psittacula krameri
 Aves/Piranga ludoviciana
 Aves/Lophodytes cucullatus
 Aves/Setophaga pinus
 Reptilia/Hypsiglena jani
 Insecta/Graphocephala coccinea
 Amphibia/Hyla arenicolor
 Insecta/Zerene cesonia
 Insecta/Lerema accius
 Aves/Melanerpes erythrocephalus
 Insecta/Prosapia bicincta
 Insecta/Libellula needhami
 Aves/Anas rubripes
 Insecta/Vanessa gonerilla gonerilla
 Mollusca/Triopha maculata
 Insecta/Libellula semifasciata
 Aves/Zonotrichia querula
 Mollusca/Phidiana hiltoni
 Mammalia/Trichosurus vulpecula
 Reptilia/Thamnophis marcianus
 Insecta/Leptotes marina
 Amphibia/Aneides lugubris
 Aves/Anas penelope
 Amphibia/Lithobates clamitans
 Insecta/Colias eurytheme
 Aves/Haematopus unicolor
 Aves/Zonotrichia capensis
 Aves/Parkesia motacilla
 Reptilia/Nerodia erythrogaster
 Aves/Mimus gilvus
 Mollusca/Calliostoma ligatum
 Aves/Empidonax difficilis
 Aves/Melospiza fusca
 Aves/Aimophila ruficeps
 Reptilia/Nerodia sipedon sipedon
 Mammalia/Lepus californicus
 Insecta/Lycaena phlaeas
 Mammalia/Mephitis mephitis
 Reptilia/Thamnophis sirtalis
 Insecta/Uresiphita reversalis
 Aves/Calidris alpina
 Insecta/Pyrisitia lisa
 Aves/Sitta pygmaea
 Mammalia/Myocastor coypus
 Aves/Gavia stellata

Aves/Aechmophorus clarkii	Aves/Prothemadera novaeseelandiae	Aves/Oreothlypis celata
Actinopterygii/Cyprinus carpio	novaeseelandiae	Mammalia/Cynomys ludovicianus
Reptilia/Sceloporus graciosus vandenburgianus	Reptilia/Pantherophis obsoletus	Insecta/Halysidota tessellaris
Insecta/Anthocharis sara	Insecta/Chlosyne palla	Insecta/Arilus cristatus
Aves/Anhinga anhinga	Aves/Phalacrocorax brasilianus	Insecta/Erynnis funeralis
Insecta/Erythemis collocata	Aves/Himantopus himantopus	Insecta/Coenonympha pamphilus
Amphibia/Pseudacris crucifer	Mammalia/Enhydra lutris	Aves/Eupsittula canicularis
Reptilia/Terrapene carolina	Aves/Numenius americanus	Insecta/Vanessa cardui
Mollusca/Geitodoris heathi	Aves/Melanitta perspicillata	Aves/Myiozetetes similis
Mammalia/Sciurus aureogaster	Mammalia/Sus scrofa	Insecta/Libellula quadrimaculata
Reptilia/Aspidoscelis tigris	Aves/Carduelis cannabina	Insecta/Acanthocephala terminalis
Insecta/Idia aemula	Aves/Podiceps nigricollis	Aves/Anthornis melanura
Aves/Icterus galbula	Aves/Cinclus mexicanus	Insecta/Papilio machaon
Reptilia/Sceloporus occidentalis longipes	Reptilia/Terrapene carolina carolina	Aves/Rupornis magnirostris
Aves/Larus marinus	Insecta/Phyciodes phaon	Mammalia/Dasyus novemcinctus
Insecta/Libellula saturata	Aves/Anas americana	Aves/Buteo buteo
Reptilia/Anolis sagrei	Aves/Tachycineta thalassina	Aves/Troglodytes pacificus
Reptilia/Pituophis catenifer	Insecta/Celastrina neglecta	Reptilia/Sceloporus consobrinus
Aves/Xanthocephalus xanthocephalus	Aves/Archilochus colubris	Reptilia/Nerodia fasciata confluens
Aves/Sitta europaea	Aves/Chamaea fasciata	Insecta/Euptoieta claudia
Insecta/Leptoglossus phyllopus	Insecta/Sympetrum ambiguum	Aves/Chroicocephalus philadelphia
Aves/Regulus calendula	Insecta/Eristalis tenax	Reptilia/Rena dulcis
Reptilia/Micrurus tener	Aves/Tyto alba	Aves/Fregata magnificens
Actinopterygii/Ostracion meleagris	Aves/Somateria mollissima	Aves/Setophaga pensylvanica
Aves/Catherpes mexicanus	Aves/Setophaga coronata coronata	Insecta/Hemaris diffinis
Aves/Plectrophenax nivalis	Aves/Spizella passerina	Reptilia/Elgaria multicarinata
Mollusca/Peltodoris nobilis	Reptilia/Agkistrodon piscivorus	Aves/Patagioenas fasciata
Reptilia/Urosaurus ornatus	Aves/Turdus rufopalliatus	Aves/Pheucticus ludovicianus
Reptilia/Zootoca vivipara	Insecta/Erythrodiplax berenice	Aves/Setophaga striata
Aves/Fulica atra	Reptilia/Crotalus atrox	Aves/Larus fuscus
Amphibia/Osteopilus septentrionalis	Reptilia/Elgaria multicarinata multicarinata	Insecta/Enallagma carunculatum
Insecta/Haematopsis grataria	Aves/Falco peregrinus	Insecta/Alypia octomaculata
Aves/Aphelocoma wollweberi	Aves/Melanerpes formicivorus	Reptilia/Plestiodon laticeps
Mammalia/Vulpes vulpes	Insecta/Libellula incesta	Arachnida/Latrodectus geometricus
Insecta/Olla v-nigrum	Insecta/Marpesia petreus	Actinopterygii/Micropterus salmoides
Aves/Anas platyrhynchos diazi	Aves/Milvus milvus	Aves/Asio otus
Aves/Icteria virens	Mollusca/Otala lactea	
Insecta/Erythemis vesiculosa	Insecta/Heliconius charithonia	
Insecta/Siproeta stelenes	Reptilia/Storeria dekayi texana	
Aves/Sayornis saya	Amphibia/Acris blanchardi	
Aves/Podiceps grisegena	Insecta/Antheraea polyphemus	
Aves/Leptotila verreauxi	Mammalia/Taxidea taxus	
Aves/Toxostoma rufum	Insecta/Cisseps fulvicollis	
Aves/Podiceps cristatus	Aves/Seiurus aurocapilla	
Aves/Aythya affinis	Reptilia/Gopherus berlandieri	
Aves/Melospiza georgiana	Mollusca/Aplysia californica	
Reptilia/Uta stansburiana	Aves/Myiopsitta monachus	
Insecta/Libellula pulchella	Mammalia/Sylvilagus bachmani	
Insecta/Odontotaenius disjunctus	Aves/Poecile gambeli	
Aves/Coragyps atratus	Mammalia/Odocoileus hemionus columbianus	
	Reptilia/Cophosaurus texanus	