PHYLOGENY AND COLOR PATTERN EVOLUTION IN A NEW WORLD BUMBLE BEE (HYMENOPTERA: APIDAE: *BOMBUS*: *PYROBOMBUS*) SPECIES COMPLEX

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Entomology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2010

Urbana, Illinois

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Abstract

Bombus ephippiatus is one of the most common and widespread bumble bee species throughout Mexico and Central America. This robust and charismatic species possesses a highly variable color pattern throughout its wide distribution across montane and lowland regions, which raises the question of whether or not it is in fact one species. I examined the molecular phylogeny of *B. ephippiatus* populations and its sister species, *B. wilmattae* and *B. impatiens*, with the aims of resolving the species relationships, distinguishing species boundaries and examining correlations between color pattern and phylogeny. I applied DNA sequences from three genes to resolve the species-level phylogeny and to gain insight into the population structure of *B. ephippiatus*. The results reveal that *B. impatiens* is the sister group to *B. ephippiatus* + *B. wilmattae*. Results also suggest that *B. ephippiatus* is paraphyletic with respect to *B. wilmattae*, as *B. wilmattae* attaches to the Costa Rican *B. ephippiatus* clade. The *B. ephippiatus* + *B. wilmattae* complex appears to be associated with geography and color pattern, providing new insights into the evolutionary history of this complex.

To my Mother, whom I try to emulate every day,
and to my Father, who has done an excellent job
fulfilling the role of both parents in my Mother's passing

Acknowledgements

This project would not have been possible without the support of many people. First and foremost, I thank my adviser, Dr. Sydney Cameron, for all of her guidance, insight, and comments throughout my research, and for introducing me to the exciting world of bumble bee biology and evolution. Thanks to my committee members, Stewart Berlocher, Kevin Johnson, and Charles Whitfield for their advice on the direction of my project and comments on this manuscript. I am grateful to Josephine Rodriguez for assisting me with analyses in the early stages of my research and providing me with moral support. I thank Alex Wild for helping with primer design. I am grateful to Jeff Lozier for guiding me in the theory of population genetics. I thank Heather Hines for training me in molecular techniques and helping me during my initial data collection. Special thanks to Oliver Schlein at Escuela Agrícola Panamericana Zamorano in Honduras for hosting me during my collection trip, and Julio Torres, who drove me throughout Honduras and helped me collect specimens and learn Spanish. I am obliged to many additional collectors: Heather Hines, Ricardo Ayala, Daniel Sanchez, Paul Hanson, and others. I thank everyone in both the Cameron and Whitfield labs for comments and suggestions on the initial proposal of my Master's research. Last, but not least, I owe a great deal of gratitude to the funding agencies that made this research possible, including the Francis M. and Harlie M. Clark Research Support Grant and the Herbert Holdsworth Ross Memorial Fund, which funded my collection trip to Honduras, as well as additional funding from the Cameron Lab. I owe additional thanks to the School of Integrative Biology Enhancement Fund in cooperation with the Cameron Lab and the Department of Entomology, which funded my attendance at the Workshop on Molecular Evolution in Český Krumlov, Czech Republic.

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Introduction

An important issue in evolutionary biology is the identification of forces that shape genetic structure within species and eventually contribute to their reproductive isolation. Species concepts have been widely debated in the field of systematics for decades (Dobzhansky, 1935; Mayr, 1942; Mayr, 1957; Simpson, 1951; Wiley, 1978; Mishler and Donoghue, 1982; Hull, 1997; Mayden, 1997; de Queiroz, 1999; Rossello-Mora, 2003; Reydon, 2004; Hey, 2001; Hey *et al*., 2005; Hey, 2006a; de Queiroz, 2007; Staley, 2009; Velasco, 2009). Some systematic biologists have argued that species concepts and species delimitation need to be conceptually separate from each other (Mayden, 1999; Hey, 2006b; de Queiroz, 2007). This separation allows species delimitation to step back from the conceptual controversy so that multiple lines of evidence and data can be collected to determine operational criteria (Ross *et al*., 2010). Regardless of debate, species delimitation has loomed in importance in recent years. Species are the functional units for a multitude of analytical methods in evolutionary, biogeographic, and ecological research (Isaac *et al*., 2004; Balakrishnan, 2005; Weins, 2007a; Weins, 2007b; Renema *et al*., 2008; Ross *et al*., 2010). The determination of species has become especially important in the field of conservation biology (Agapow *et al.,* 2004; Ross and Shoemaker, 2005; Ross *et al*., 2010;).

For centuries, bumble bees (*Bombus*: Apidae) have been a subject of fascination for naturalists (Darwin, 1859; Sladen, 1912; Plath, 1934; Heinrich, 1979; Goulson, 2003). They are important native pollinators in all of the areas they inhabit worldwide and are important in pollination services wherever they are reared commercially for greenhouse crops. Recently they have received increased attention because of their substantial global declines (e.g., United

Kingdom: Darvill *et al.* 2010; Redpath *et al*., 2010; North America: Colla and Packer, 2008; Grixti *et al*., 2009; Brazil: Martins and Melo, 2010). A thorough understanding of species boundaries and evolutionary history will be critically important in potential conservation efforts. Historically, species determination has been difficult in bumble bees because of morphological similarity combined with a remarkable degree of color pattern diversity across wide geographic distributions (Williams, 1998; Cameron *et al*., 2007; Williams, 2007). The fact that species also exhibit convergent color patterns in the formation of mimicry complexes (Williams, 2007) adds to the difficulty of species delineation. As a result, bumble bees have been a taxonomic confusion of names, with over 1,100 names having been assigned to the 250 currently recognized species since Linnaeus (Williams, 1998).

The most recognizable feature of bumble bee morphology, and one which has led to much taxonomic disorder, is the pile, the long, brilliantly-colored hairs that cover the abdomen and thorax. The color of their pile is usually a striking contrast of black and yellow stripes, but many species also possess red and white pile. This coloring plays an important role in the formation of Müllerian mimicry complexes, which many species of bumble bees form throughout their worldwide distribution (Williams, 2007). Williams (2007) indentified three main color pattern groups across all bumble bees: entirely black bumble bees, mostly pale (grey, yellow, brown) bumble bees, and bumble bees with contrasting bands of color. All of these color patterns show statistically significant clustering in geographic regions (Williams, 2007). The dark bees all occur in tropical areas and it is hypothesized that their color pattern may be playing a thermoregulatory or cryptic function; the pale bees occur in grasslands, so it is hypothesized that their color pattern is an example of crypsis; the intermediate banded bees occur in regions that might be unsuitable to the other color pattern groups, and it is hypothesized that they play a thermoregulatory and/or aposematic function (Williams, 2007). Although these hypotheses have yet to be tested, these data, in combination with the fact that ancestral color patterns cannot be reliably recovered across most of the *Bombus* phylogeny (Cameron et al., 2007; Cameron *et al*., unpublished data), imply that ecological factors are driving these color pattern complexes in bumble bees.

Prior to DNA sequencing methods, these color pattern complexes added to the difficulty of species identification in this genus. Molecular evidence (Cameron *et al*. 2007) has revealed that some sympatric species pairs and even allopatric species pairs with very different color patterns are genetically identical to each other, while other species groups that were previously thought to be possible conspecifics are in fact genetically distinct. Despite the recent comprehensive molecular phylogeny of *Bombus* (Cameron *et al*., 2007), some species still remain to be delimited.

One *Bombus* complex that remains to be resolved involves the species *B. impatiens*, *B. ephippiatus*, and *B. wilmattae* (Hines *et al*., 2006; Cameron *et al.,* 2007). Phylogenetic analysis of a concatenated five-gene dataset (Cameron *et al*., 2007) suggested (with low support) that the Mesoamerican bumble bee species *B. ephippiatus* was closely related to *B. wilmattae*, a species found only in southern Chiapas, Mexico and northern Guatemala at high elevation in volcanic, semi-tropical areas (Labougle, 1990). Individual gene fragments, however, were incongruent for these three taxa: Arginine kinase (*ArgK)* sequences showed *B. ephippiatus* to be most closely related to *B. impatiens*, a North American species that is becoming increasingly important to the North American agricultural economy as a commercial pollinator (Vergara, 2008); mitochondrial *16S* showed *B. impatiens* and *B. wilmattae* to be most closely related; and the *opsin* sequences showed *B. ephippiatus* and *B. wilmattae* as sister groups (Cameron *et al*., 2007). This lack of concordance among datasets is typical of closely related species and it is clear that the resolution of these relationships requires further analysis.

Bombus impatiens is a North American bumble bee species common throughout the Eastern half of the United States, from Ontario and Maine south to Kansas and Florida (Kearns and Thomson, 2001). It is yellow and black in coloring, with the thorax and first abdominal segment completely covered in yellow pile and the rest of the abdomen covered in black pile. A narrow region in southwestern Texas separates *B. impatiens* from both *B. ephippiatus* and *B. wilmattae* (Vergara, 2008), which occur in Mexico and Central America.

B. ephippiatus is the most common species of bumble bee found in the Southern Neartic; it has a geographic range extending from Northwest Mexico (Chihuahua) to Panama (Labougle, 1990), and possibly as far south as the northwestern region of South America (Ecuador and Colombia, Franklin, 1913) (Fig. 2). *B. ephippiatus* has a highly polymorphic color pattern: the thorax of workers is completely black from a dorsal view, while the abdomen and sides of the thorax are brightly colored, giving the appearance that it is wearing a "saddle" of sorts (Figs. 1a-1d). In fact, the word "*ephippiatus*" is derived from the Greek *ephippion*, which means "saddle" . In Williams' comprehensive online guide to the color patterns of all *Bombus* species (http://www.nhm.ac.uk/research-curation/research/projects/bombus/colour.html), he identified two distinctive color patterns for *B. ephippiatus* queens and three patterns for workers (Figs. 1a-1d). This variation historically has caused a great deal of taxonomic confusion; it has been assigned eleven different names since Thomas Say first classified it in 1837 (Williams, 1998). Some of these names have split the species into two different subspecies based on the differences in color patterns of the workers (Friese, 1903; Friese, 1916; Frison, 1925; Milliron, 1962). The widespread geographic distribution (Franklin, 1913; Labougle, 1990) of *B. ephippiatus* over a topologically complex region (Fig. 2) that may act as a barrier to dispersal, together with the remarkable color pattern variation, suggests the possibility that *B. ephippiatus* may have considerable population genetic structure.

B. wilmattae has a highly restricted range, inhabiting only volcanic, montane regions in Southern Chiapas and Northern Guatemala (Labougle, 1990). The color pattern of *B. wilmattae* is very similar to that of the darker forms of *B. ephippiatus* (Figs. 1e-1f) (Williams, 2007). When Cockerell (1912) classified this species, he considered it a subspecies of *B. ephippiatus* (then classified as *B. lateralis* (Smith, 1879)). Labougle *et al.* (1985) found consistently distinct differences in morphology between *B. ephippiatus* and *B. wilmattae*, but it is still questionable as to whether or not these species are conspecific as a result of gene topology incongruence in phylogeny (Hines *et al*., 2006). In light of the color pattern similarities between *B. ephippiatus* and *B. wilmattae*, integrating color pattern data, geographical range, and genetics can be a powerful approach for understanding species and their boundaries (Ross *et al*. 2010).

Incorporating analyses of phenotypic characteristics with genetic analyses can be a valuable method for understanding the taxonomic status of populations and could aid in elucidating the taxonomic status of these sister species.

The study presented here addresses three main problems: 1) the phylogenetic resolution of *Bombus ephippiatus*, *B. impatiens*, and *B. wilmattae*, 2) the species status of *B. ephippiatus* and 3) the degree of color pattern concordance with the phylogeny of these three taxa. I address these questions using mitochondrial and nuclear DNA sequence data from three gene fragments to infer relationships using a variety of phylogenetic inference methods and by mapping color pattern characters onto phylogeny. The results of this study help to resolve the uncertain classification of these species and elucidate the evolution of color pattern and its function.

Knowledge about the evolutionary processes acting on these important pollinators may provide additional insight into speciation in the Neotropics.

Materials and Methods

Taxa examined

For phylogenetic estimation, I utilized sequences from representatives of three putative *Bombus* species (Table 1). Because *Bombus ephippiatus* was the focal species of this study, I used 43 individuals of this species to generate sequence data. In addition, I sequenced six individuals of *B. wilmattae* and ten individuals of *B. impatiens* for interspecific phylogeny estimation. To test the monophyly of this species complex, I included sequences from species shown to be sister taxa to this complex in previous studies, *B. huntii* and *B. vosnesenskii*.

Taxa were sampled from regions throughout their range (Table 1, Fig. 2). Specimens of *B. ephippiatus* were sampled principally from sites scattered throughout the countries of Mexico, Honduras, and Costa Rica, specimens of *B. wilmattae* were sampled from three sites within Chiapas, Mexico, and specimens of *B. impatiens* were sampled from sites in the states of Maine, Illinois, and Texas within the United States (Table 1, Fig. 2). To maintain an evenly distributed sampling across the range of the complex, approximately two specimens were sequenced from each locality. Males and females were utilized in this study and sex is indicated in Table 1.

All three taxa are represented by each of three gene fragments utilized in this study, but not every individual was sequenced successfully for each gene (see Table 1). Most of the Costa Rican *B. ephippiatus* individuals are represented only by *COI* because these specimens were all at least fifteen years old, making it difficult to amplify DNA obtained from them. Sequences available and general collection localities are presented in Table 1. Specimen vouchers for all DNA sequences are housed at the Illinois Natural History Museum in Urbana, Illinois, and I have submitted all sequences to GenBank.

Gene selection

I obtained fragments of three independently evolving genes: mitochondrial cytochrome oxidase I (*COI*) and nuclear rudimentary (*CAD*) and phosphoenolpyruvate carboxykinase (*PEPCK*). Hines and Cameron (unpublished data) conducted initial sequencing of *COI* to examine this gene's phylogenetic utility in this complex. Exploratory mitochondrial *16S* sequences (Cameron lab, unpublished data) were often too unreadable to accurately align, so this gene was not used. I obtained one *PEPCK* sequence from GenBank for each of these three species, submitted by Hines *et al*. (2006). See Table 1 for complete sequence information.

Mitochondrial genes, such as *COI*, are useful for phylogenetic analyses, especially at the species level, because they usually exhibit extensive intraspecific variation, maternal transmission, and an absence of intermolecular genetic recombination (Avise, 2000). Multiple studies have used this protein-coding gene for determining between-species and within-species relationships (Avise, 2000), including other phylogenetic studies within the family Apidae (Soucy and Danforth, 2002; Bull *et al*., 2003; Kawazoe *et al.*, 2008; Kim *et al.*, 2008) and even within the genus *Bombus* (Koulianos, 1999; Koulianos and Schmid-Hempel, 2000; Kim *et al.*, 2009). I amplified 811 base pairs (bp) from *COI* using the primers RevmtR (5'- AACCAGTAATTATTGGATATCATGA) and FormtR (5'- GGTTGAACTGTATATCCTCCA) by Hines (unpublished data).

While mitochondrial genes are useful for species-level phylogenies, they represent only a single maternally-inherited locus. Nuclear genes are necessary for determining possible interlocus variation in gene tree topologies (Maddison, 1997). Because mitochondrial DNA is passed on maternally, nuclear genes are also useful for examining histories of both sexes. The nuclear gene carbamoyl-phosphate synthetase 2, aspartate transcarbamylase, dihydroorotase or rudimentary (*CAD*) encodes several enzymes involved in the biosynthesis of pyrimidines. A study by Moulton and Wiegmann (2004) showed that *CAD* has considerable phylogenetic utility, especially in insect molecular systematics. It has been demonstrated that *CAD* is useful for resolving Cretaceous-age divergences in the Hymenoptera (Danforth *et al*. 2006), but a study in beetles suggests that it is also useful for more recent divergences (Wild and Maddison, 2008). I designed two forward primers, CDBF1 (5'- TGAATCCTGATTGATTCTACAGAGCAGTC) and CDBF2 (5'- TGGTCTCAGTATCGGTCAAGCG), and used the reverse primer CD688R (Wild and Maddison, 2008) to amplify 840 bases of the *CAD* gene, including two introns totaling 357 bp.

The *PEPCK* gene encodes for the enzyme phosphoenolpyruvate carboxykinase, which is involved in gluconeogenesis and glucose homeostasis (Hanson and Reshef, 1997). This gene has been successful in resolving phylogenetic relationships at multiple levels within the insects (Friedlander *et al.*, 1996; Moulton, 2000; Moulton, 2003; Sota and Vogler, 2003; Leys *et al.* 2002; Wild and Maddison, 2008), including species-level relationships within *Bombus* (Cameron *et al.*, 2007). I used *PEPCK* primers designed by Cameron *et al*. (2007) to amplify 878 bp of the gene, including two introns totaling 515 bp in length.

DNA extraction, amplification, and sequencing

I obtained tissue from specimens (preserved in 95-100% ethanol at 4ºC) by removing one of the forelegs. The foreleg in *Bombus* does not possess any crucial characters for taxonomic identification, thus specimens remained useful as vouchers after I removed tissue. I re-associated the legs with specimens after the completion of DNA extractions. For the few pinned specimens used, I also removed a foreleg for DNA extraction. Tissue was digested for six or more hours in proteinase K at 56ºC on a shaking platform. I then extracted DNA using the DNeasy Blood and Tissue Kit (QIAGEN).

Standard conditions for PCR amplification included: an initial denaturation step of 95ºC for 3 minutes; 35 cycles of denaturation for 60 seconds at 94ºC, annealing for 60 seconds at 45-57ºC, and elongation for 60 seconds at 72ºC; a final extension of 3 minutes at 72ºC. I modified these conditions for some of the reactions. Annealing temperatures for the genes were 44-52ºC for *COI*, 48-57ºC for *CAD*, and 45-52ºC for *PEPCK*. For *CAD*, I carried out a nested PCR reaction, which involves using internal primers to sequence an initial, longer fragment obtained through PCR. This nested PCR of *CAD* involved using the primers CDBF2 and CD688R to amplify a longer region of the gene, then amplifying this PCR product using the primers CDBF1 and CD688R. For most PCRs I used Go*Taq* polymerase (Promega). I purified PCR products primarily using ExoSAP-IT reagent (Affymetrix). Sequencing reaction protocols used the BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems) and PCR primers. I sent sequencing products to the W.M. Keck Center for Comparative and Function Genomics at the University of Illinois, Urbana for purification and direct sequencing on an ABI 3730XL capillary sequencer.

Alignment

Alignment with a computer algorithm was unnecessary due to the high similarity among sequences, therefore I did sequence editing and alignment by hand in BioEdit version 7.0.5 (Hall, 1999). I constructed concatenated datasets using Mesquite version 2.7 (Maddison and Maddison, 2009).

Phylogenetic analyses

I analyzed genes both separately and as one concatenated dataset, using Bayesian methods and maximum parsimony. Because the *PEPCK* dataset contained a homologous five bp indel, I removed this region from the dataset and then coded the indel as either a single binary character (presence-absence) with equal weight to a base substitution in Bayesian analyses (Simmons and Ochoterena, 2000), or as a single "fifth" character in maximum parsimony analyses. The *CAD* sequences were heterozygous (biallelic) for some individuals. One allele possessed a nine bp indel; the other allele did not. This indel caused a frameshift in the chromatogram of heterozygous individuals, rendering the rest of the sequence trace (nearly half) unreadable after the indel. Because so many base pairs of the heterozygous sequences were lost due to unreadable chromatograms, they were excluded from these analyses. Heterozygous individuals are indicated in Table 1. For homozygous *CAD* individuals, this indel is allele-specific and because I used a mix of homozygotes for both alleles I removed it and all sites downstream associated with it. See Appendix A for sequence alignments.

I determined outgroup taxa for rooting the tree using the *Bombus* phylogeny generated by Cameron *et al*. (2007). The closest sister clade to this North American-Mesoamerican complex is a four-taxon North American clade constituting the following species: *B. bifarius* Cresson*, B. ternarius* Say*, B. huntii* Greene*,* and *B. vosnesenskii* Radoszkowski. Within this clade the following sister taxon relationships exist: *B. bifarius* is the closest sister to *B. ternarius*, and *B. huntii* is the closest sister to *B. vosnesenskii*. From this sister clade I chose *B. huntii* and *B. vosnesenskii* as outgroups.

Bayesian inference

I implemented Bayesian phylogenetic analyses in a multiprocessor (MPI) version of MrBayes v3.1.2 (Huelsenbeck and Ronquist, 2001; Altekar *et al.*, 2004) using models based on Akaike information criteria (cAIC) calculated in MrModeltest 2.2 (Nylander, 2004). I partitioned nuclear genes by exon and intron regions. I also partitioned the *PEPCK* indel. The models calculated for each partition are as follows: *COI* (HKY + I), *CAD* intron (HKY), *CAD* exon (HKY + I), *PEPCK* intron (GTR + I), *PEPCK* exon (HKY), *PEPCK* indel character (standard). I conducted six independent runs (2 runs per analysis) using MrBayes to ensure that tree space had been sufficiently sampled. I simulated each run for 8,000,000 generations and 4 chains (1 hot and 3 cold chains) using flat, uninformative priors and mixed models, sampling trees every 100 generations. I compared the log likelihood plots of the two runs from a single MrBayes analysis using Tracer v1.5 (Rambaut and Drummond, 2007) to ensure proper mixing of the runs and to determine at what generation stationarity occurred so that all trees prior could be discarded (burnin). I then concatenated all genes and partitions using Mesquite version 2.7 (Maddison and Maddison, 2009). I ran this concatenated dataset as a single analysis in a multiprocessor version of MrBayes for 12,000,000 generations, 4 chains, saving trees every 100 generations using flat priors and mixed models. The analysis was repeated for a total of three analyses and 6 independent runs. Clade support was determined for each analysis by calculating posterior probabilities on all trees retained after burnin using MrBayes.

Parsimony methods

Strict consensus trees for each individual gene and the concatenated dataset were constructed using parsimony algorithms implemented in PAUP* version 4.0 (Swofford, 2003).

For each dataset, a heuristic search was performed with 1000 random additions using tree bisection and reconnection (TBR) branch swapping, retaining a maximum of 500 trees per replicate. Clade support was estimated using non-parametric bootstrapping implemented in PAUP* v4.0 (500 pseudoreplicates, 10 random additions per pseudoreplicate, retaining 200 trees per replicate).

Color pattern

To test the concordance between phylogeny and color pattern, I developed a morphological coding scheme for the metasomal color patterns of *Bombus ephippiatus* and *B. wilmattae*. I observed individuals specimens and drew the color patterns by hand onto a metasomal template (Fig. 1). After I had sketched several individuals of both *B. ephippiatus* and *B. wilmattae*, I used the drawings of the individual specimens to delineate variable regions of color on the metasoma. Based on my drawings, I delimited twenty-nine variable regions or characters on the dorsum of the metasoma (Fig. 3a), and coded each character for one of ten character states, each of which represents a possible color pattern (Fig. 3b). I scored only the females for this analysis. All intact female specimens used for sequencing were coded for color pattern. I then subjected the color pattern matrix to maximum parsimony (MP) analysis implemented in PAUP* 4.0 (Swofford, 2003). All characters were unordered and equally weighted and 1000 heuristic searches were initiated using random stepwise addition and TBR branch swapping, saving a maximum of 500 trees per replicate. Clade support was estimated using non-parametric bootstrapping with 500 pseudoreplicates, 10 random stepwise additions per replicate and TBR branch swapping. I also used neighbor-joining analysis implemented in PAUP* to determine color pattern groupings based on distance.

The topologies of the strict consensus trees derived from parsimony analysis as well as neighbor-joining of these morphological data defined a selected number of color pattern groups to which all of the individuals belonged. Using these newly defined color pattern classifications determined by both distance and parsimony analyses, I mapped color pattern by hand onto the concatenated Bayesian phylogeny in correspondence with the major groupings identified by parsimony and neighbor-joining analyses.

Results

Tree resolution

Under parsimony and Bayesian criteria, neither nuclear gene provides much resolution at this low taxonomic level, but they do share some topological congruence (Figs. 4-7). The only ingroup resolution that *CAD* elucidates is the placement of all *B. impatiens* individuals into a monophyletic clade in Bayesian inference (Figs. 4-5). Branch lengths (Fig. 4-5) indicate that *B. impatiens* is more divergent (contains more nucleotide substitutions) than the rest of the ingroup taxa. Parsimony analysis of *CAD* (Fig. 5) provides no resolution in the ingroup. *PEPCK* shows a similar pattern (Figs. 6-7), but places *B. impatiens* basal to *B. ephippiatus* and *B. wilmattae* in both Bayesian and parsimony methods. Bootstrap support for this phylogenetic separation is low (bootstrap (bp) = 78) while posterior probability support is moderate (posterior probability (pp) = 0.92) (cut-off for strong support: pp ≥ 0.95; bp ≥ 90). These nuclear genes provide moderate support and minimal resolution for the relationships in this species complex.

COI is more informative for the complex than either nuclear gene (Figs. 8-9). Bayesian and parsimony analyses are congruent in topology, with the exception of a few nodes. Parsimony analysis (Fig. 9) places *B. impatiens* basal to *B. ephippiatus* and *B. wilmattae* with high support (bp = 100), but Bayesian methods (Fig. 8) place *B. impatiens* only as a more divergent lineage within a polytomy, giving high support (pp = 1.00) for the monophyly of this species. *COI* also provides resolution at the tips within species groups, which is lacking for either nuclear gene.

None of the genes utilized are informative enough to completely resolve these relationships, but combined (Fig. 10-11) they provide a more lucid picture of the evolutionary history of this species complex, with Bayesian inference presenting a slightly more defined topology of the history of this group than maximum parsimony. From the bootstrap values present, it appears that maximum parsimony was able to reconstruct the root relationships, as well as some of the more recently diverged relationships, but was unable to recover some of the more recent tip relationships determined by Bayesian inference, specifically the grouping of the Mexican *B. ephippiatus* and a subset of the Honduran *B. ephippiatus* into a single clade (Fig. 10). In general, Bayesian analysis performed slightly better than parsimony analysis in terms of resolving relationships, but as a whole they presented very similar topologies across all genes.

Interspecific relationships

There is robust support for the placement of *B. impatiens* as a monophyletic clade basal to *B. ephippiatus* and *B. wilmattae*. While *PEPCK* and *COI* are able to successfully place *B. impatiens* as basal, *CAD* and Bayesian analysis of *COI* place the *B. impatiens* clade on a longer, more divergent branch from the rest of the taxa within a polytomy. This higher amount of nucleotide sequence divergence in *B. impatiens* across all of the genes results in its basal placement in the combined gene dataset phylogeny with high support across both Bayesian and parsimony inference methods (pp = 1.00; bp = 99).

There is also evidence that *B. ephippiatus* is paraphyletic with respect to *B. wilmattae*, or at the very least that they are each other's closest sister. Both *PEPCK* and *CAD* are unable provide any resolution in the relationship between these species. While *COI* resolves some of the tip relationships within *B. ephippiatus*, the amount of variation within this gene does not distinguish *B. ephippiatus* and *B. wilmattae* as separate, reciprocally monophyletic lineages. When these genes are combined, *B. wilmattae* is placed as the closest sister to the Costa Rican *B.*

ephippiatus. This relationship appears only in Bayesian analyses and consistently has low posterior probability support (0.78).

Intraspecific relationships

As discussed above, *B. wilmattae* is consistently placed within or near *B. ephippiatus* across all genes and phylogenetic inference methods, but only *COI* is able to provide intraspecific resolution within *B. ephippiatus* (Fig. 8). At the root of the *B. ephippiatus* + *B. wilmattae* clade, there is an unresolved polytomy, but near the tips there is some resolution of the relationships within *B. ephippiatus*. All individuals of *B. ephippiatus* from Mexico group into a single clade, which is placed as closest sister to a subset of the individuals from Honduras. While the support for the branch connecting all of the Mexican individuals (concatenated pp = 0.86, *COI* pp = 0.76) is not substantial, there is strong support (concatenated pp = 0.98, *COI* pp = 0.95) for the placement of this subset of Honduran individuals as sister to the Mexican clade.

There is strong evidence that the Costa Rican *B. ephippiatus* (concatenated pp = 1.00, concatenated bp = 97) and *B. wilmattae* (concatenated pp = 1.00, concatenated bp = 93) are separate monophyletic clades, but, as discussed above, there is low support for their placement as sister clades. There is also robust support for the monophyly of a subset of the Honduran *B. ephippiatus* (concatenated pp = 1.00, concatenated bp = 99), but Bayesian and parsimony methods provide no resolution as to where this clade fits within the *B. ephippiatus* + *B. wilmattae* complex.

Color pattern

Neighbor-joining and maximum parsimony analysis of the color pattern matrix revealed two major color pattern groupings in *B. ephippiatus* and *B. wilmattae* (Figs. 13-14). For nominal purposes, these groups will be called the "red phenotype," which possesses yellow, red, and black hair on its abdomen, and the "black phenotype," which possesses only yellow and black hair on its abdomen. When these phenotypes are mapped by hand onto the molecular phylogeny (Fig. 15), one can see that the red phenotype predominates in the Mexican *B. ephippiatus* clades, and the black phenotype predominates in the Costa Rican *B. ephippiatus*, Honduran *B. ephippiatus*, and *B. wilmattae* clades, but there is also some mixing. All of the individuals within the Mexican *B. ephippiatus* clade possessing the black phenotype are from localities in close proximity (see overlapping coordinate points on Fig. 16) within the Mexican state of Querétaro, a more southern state within the country. These are the only female samples from Querétaro, therefore all samples from this state possess the black phenotype. The Honduran *B. ephippiatus* possessing the red phenotype, VEP51, is from the department of Francisco Morazán, but individual VEP50 was collected from the same locality in Honduras and it possesses a black phenotype.

Discussion

Interspecific relationships

The molecular data provide robust support for the placement of *Bombus impatiens* basal to *B. ephippiatus* and *B. wilmattae*. *PEPCK* and parsimony analysis of *COI* show strong support for this basal placement. While *CAD* and Bayesian analysis of *COI* are unable to resolve *B. impatiens* as basal, the relatively higher amount of divergence in *B. impatiens* present in both of these gene topologies lends to the high support for its basal placement in the concatenated phylogeny. These data provide a different picture of these relationships than the *Bombus* phylogeny of Cameron *et al.* (2007). This previous study presents incongruent gene topologies regarding this species complex. The concatenated phylogeny of Cameron *et al*. (2007) places *B. impatiens* and *B. wilmattae* as sister taxa, yet this relationship is supported only by *16S* gene fragment data; the phylogeny for the *opsin* gene shows *B. ephippiatus* and *B. wilmattae* as sister groups, and the phylogeny for arginine kinase (*ArgK)* shows *B. impatiens* and *B. ephippiatus* as sister taxa. The placement of *B. ephippiatus* and *B. wilmattae* as sisters in the present analysis is logical due to the high morphological similarity between these two species. Because their color patterns are so similar, they have been considered variants of the same species in the past (Cockerell, 1912). The very slight differences in genitalia features (Williams, 1998) have also served as evidence towards the argument that they are conspecific. This relationship is logical also in terms of the species' geographic distribution. *B. wilmattae* exists in a highly restricted distribution within the range of *B. ephippiatus* and neither of these species comes into contact with the range of *B. impatiens* (Labougle, 1990; Vergara, 2008). The hypothesis that *B. ephippiatus* and *B. wilmattae* share a more recent common ancestor with each other than *B.*

impatiens seems much more probable than either of these species being sister taxa to *B. impatiens* in light of geographic distribution.

These results also raise questions regarding the ancestral distribution of this species complex. Hines (2008) estimated the ancestral distribution of this clade to have been in the Southern Nearctic, but in light of this new phylogeny, biogeographic analyses might reveal an Eastern Nearctic origin. In the phylogeny used by Hines to reconstruct ancestral distributions (2008), *B. impatiens* and *B. wilmattae* were sister taxa and *B. ephippiatus* was basal. Therefore the predicted distribution was Southern Neartic, with the clade originating in Central America. Given this biogeographic hypothesis, the speciation of *B. impatiens* was the result of a dispersal event into North America. In light of the data presented here, as well as the fact that all of the closest sister species to this complex have North American distributions (Cameron *et al*., 2007), it is now plausible that the *B. impatiens-B. ephippiatus-B. wilmattae* clade originated in North America and then dispersed into Central America. It is presumed many other species of *Bombus* have dispersed from North America into Central and South America (Hines, 2008), but biogeographic analyses are needed to test this hypothesis.

These data also provide evidence for the paraphyly of *B. ephippiatus* with respect to *B. wilmattae*, or that they are at least each other's closest relatives. As discussed above, *B. ephippiatus* and *B. wilmattae* possess very similar color patterns, both having yellow or white pile on the first and middle of the second abdominal tergites and black pile throughout the rest of the abdomen (Fig. 1) This has led to some debate over the taxonomic status of these species (Labougle *et al*., 1985; Labougle, 1990). There are consistent morphological differences between *B. ephippiatus* and *B. wilmattae* (Labougle *et al*., 1985), but these genetic data seem to suggest that gene flow between these two putative species is not restricted, or at the very least that these two species diverged recently and complete lineage sorting of alleles has not yet occurred. Without explicitly testing divergence hypotheses under an evolutionary model, inferences about gene flow and incomplete lineage sorting remain conjecture.

Intraspecific relationships

There is considerable geographic structure within *B. ephippiatus* + *B. wilmattae* (Fig. 12). All *B. ephippiatus* individuals from Costa Rica form a well-supported, reciprocally monophyletic clade, as do *B. wilmattae* from Mexico. In addition there is evidence for geographic structure within *B. ephippiatus* in Mexico. All of the individuals from Guerrero (VEP05, VEP29, VEP43) form a well-supported clade with the individuals from an adjacent state, Oaxaca (VEP07, VEP25). Individuals from Chiapas (VEP17, VEP19, SC198) also form their own well-supported clade. Even though the Honduran individuals do not group into single clade, their separation is still geographically structured. Although not resolved in the Bayesian phylogeny, maximum likelihood analyses consistently group the second Honduran *B. ephippiatus* clade with the Costa Rican *B. ephippiatus* + *B. wilmattae* clade (data not shown). This makes a northern clade including the *B. ephippiatus* from Mexico and Honduras and a southern clade including *B. wilmattae* from Chiapas, Mexico and *B. ephippiatus* from Honduras and Costa Rica (Fig. 12).

The separation of the *B. ephippiatus* from Honduras between the two principle clades appears to coincide with geography from a country-level view, but when localities of each individual are examined some discrepancies are apparent. For example, individuals VEP44 and VEP45 were collected from the same small flower garden in Reserva Biológica El Uyuca in Francisco Morazán, Honduras, yet they are more genetically distinct than most of the individuals collected from across the entirety of Mexico. The same is true for individuals VEP50 + VEP51 from Parque Nacional La Tigra in Francisco Morazán and VEP52 + VEP53 from Montaña de Comayagua in Comayagua (Fig. 10). There is also geographic incongruence concerning individuals sampled from Chiapas, Mexico. The *B. ephippiatus* and *B. wilmattae* individuals from Chiapas were collected from the same localities, yet they are clearly genetically distinct.

These examples of incongruence between geography and phylogeny generate several possible hypotheses for the evolution of this *Bombus* species complex. One possible explanation for the observed patterns of gene diversity and paraphyly is ancestral polymorphism. When isolating mechanisms take effect in a population, sorting of genetic variation between lineages will occur via genetic drift, which facilitates speciation, but in recently diverged lineages it is often the case that some populations still retain the amount of genetic variation present in the ancestral population (Avise, 2000). The high genetic diversity within the individuals from Honduras could be a case of ancestral polymorphism. Honduras might represent the ancestral distribution of the *B. ephippiatus* + *B. wilmattae* clade.

Another possible explanation of these patterns is that the region between Chiapas, Mexico and Honduras is a contact zone between northern (Mexican and Honduran *B. ephippiatus*) and southern populations (Chiapan *B. wilmattae* and Honduran and Costa Rican *B. ephippiatus*) of the *B. ephippiatus-B. wilmattae clade*. Other studies of Mesoamerican species have found differentiation between northern taxa and southern taxa (Cavers *et al.* 2003; Novick *et al.* 2003; Devitt, 2006). For example, a study of a Mesoamerican wren species (*Campylorhynchus rufinucha*) with a distribution similar to that of *B. ephippiatus* (Vázquez-Miranda *et al.,* 2009) found patterns similar to those found here in *Bombus*, with a contact zone in Chiapas, Mexico, and determined that either of these hypotheses was plausible, but that population expansion and hybridization was more likely. Additional population genetic tests, including model-based coalescent methods (e.g., Knowles and Maddison, 2002; Hey and Nielsen, 2004; Hickerson *et al.*, 2006), as well as larger taxa sampling and additional genetic data will be needed to distinguish between hypotheses for the evolution of the *B. ephippiatus*-*B. wilmattae* species complex.

Color pattern

Mapping color pattern onto the *B. ephippiatus*-*B. wilmattae* clade suggests that color pattern variation has phylogenetic signal. The same color pattern groupings were determined from neighbor-joining methods (Fig. 13) and maximum parsimony analysis (Fig. 14). One clade represents the “red phenotype,” with individuals possessing red pile on the second and third abdominal tergites; the other clade represents the “black phenotype” with individuals possessing black pile instead of red pile. When these color pattern groupings are mapped onto the phylogeny (Fig. 15), only two cases of incongruence are apparent. First, one Honduran individual possesses the red phenotype predominant in the Mexican clade, a result that can likely be explained by limited sampling. While only twelve individuals from Honduras were sequenced for this phylogeny to keep sampling across localities consistent, 160 individual specimens from six localities were collected in total from this region, and each was scored for color pattern (data not shown). While the red phenotype does not appear common in Honduras based on sequenced individuals, these specimens are a subset of the total sample. The red phenotype is much more common in the total sample than shown from this small subset represented in the phylogeny (data not shown). There is a more evenly mixed phenotypic distribution within Honduras (Fig. 16), which is congruent with the “mixed” phylogenetic separation of the Honduran individuals (Fig. 12). This high amount of variation in color pattern in Honduras along with the high amount of genetic diversity provides more evidence that Honduras is either a contact zone between expanding populations or represents the ancestral distribution.

The other individuals that show incongruence between color pattern and phylogeny are in the Mexican clade of *B. ephippiatus*. The individuals within the Mexican clade that possess a black phenotype all originate from localities within the state of Querétaro (Fig. 16). A pattern similar to this morphological differentiation is also present in the rufous-naped wren that shares a similar distribution (Vázquez-Miranda *et al.,* 2009); one of the subspecies along the Eastern coast of Mexico possesses a different color pattern than those along the Western coast. It is possible that increased sampling of *B. ephippiatus* closer to the Eastern coast of Mexico might reveal a black phenotype throughout the East, and a red phenotype throughout the West.

This amount of congruence between color pattern and phylogeny is atypical in *Bombus*. Recent efforts to reconstruct ancestral color patterns using the *Bombus* phylogeny (Cameron *et al.* 2007) have been unsuccessful due to strong convergence in color patterns associated with the abundance of Müllerian mimicry complexes within the genus (Cameron *et al*., unpubl.). The recent divergence of the *B ephippiatus*-*wilmattae*-*impatiens* clade in concert with a lack of mimicking species might explain this unusual amount of morphological and phylogenetic concordance.

With the exception of the individuals from Querétaro, these color pattern groupings are also concordant with geography (Fig. 16). The distribution of morphology across geography is similar to the distribution of phylogenetic clades (Fig. 12), and both exhibit intermediate geographic regions where color pattern groupings or phylogenetic clades overlap. The distribution of the red, bright forms in the North and the black, darker forms in the South follows patterns typical of bumble bee species in general. Williams (2007) found that the all-black and mostly black species of bumble bees are most frequent near the equator and the palest forms are most frequent at mid latitudes (e.g. Neotropics). The biological phenomena behind this pattern have yet to be determined, but *B. ephippiatus* might prove to be an exemplar system in which to study the effect of bioclimatic variables on color pattern.

Implications for commercial rearing

Bees have been imported and introduced for the commercial pollination of crops around the world, and the importation of bumble bees for greenhouse pollination has increased in recent years. The two main species used for greenhouse pollination are the European *Bombus terrestris* and *B. impatiens*. *B. terrestris* has been introduced to Australia, Asia, and South America and has established in many areas of its introduction (Macfarlane and Gurr, 1995; Goulson, 2003; Thorp, 2003; Frietas *et al*, 2003). Where the importation of this species is causing the most problems are Japan, where interspecific mating of *B. terrestris* with *B. hypocrita* is causing significant reproductive disturbance (Kondo *et al*., 2009), and Korea, where it is actively hybridizing with the native species, *B. ignitus* (Yoon *et al*. 2009).

Currently, *B. impatiens* is being imported throughout the United States, Canada, and Mexico for greenhouse pollination (Velthuis and van Doorn, 2006). The Dutch agricultural company Koppert Biological Systems has had a *B. impatiens* rearing facility in Querétaro, Mexico since 2001 and imports bees for greenhouse pollination to Sinaloa, Sonora, Baja California, Jalisco Michoacán, and Querétaro (Vergara, 2008). The data presented here show that *B. impatiens* is closely related to *B. ephippiatus* and *B. wilmattae*, as closely related as *B. terrestris* is to *B. ignitus* (Cameron *et al*. 2007). This suggests that *B. impatiens* might be fully capable of hybridizing with *B. ephippiatus* and *B. wilmattae* if it were to escape from its greenhouse enclosures and naturalize in the wild. The sighting of a *B. impatiens* queen in Ciudad Guzmán, Jalisco implies that naturalization might already be occurring and the possibility of hybridization has been confirmed by experimental breeding in the Bee Lab at the University of Guadalajara in Autlán (Vergara, 2008). If *B. impatiens* were to establish in the wild in Mexico, not only does it pose a hybridization threat, but it could also transmit diseases to native species as well as cause competition for floral resources and habitat (Thorp, 2003). *B. ephippiatus* is a widespread, common species throughout Mesoamerica, and the fact that it is already being reared in laboratories (Vergara, 2008) shows that it could serve as an excellent commercial pollinator for Mexico and Central America.

Future directions

While these genetic results are insightful at the species-level, they are only able to provide a general picture in regard to the relationships within *B. ephippiatus*-*B. wilmattae*. Even though mitochondrial genes represent a single maternally inherited locus, adding another mitochondrial gene might be able to provide more resolution at the species-level and aid in constructing mitochondrial haplotype networks to reveal population structure. Microsatellites would be better suited to elucidating population structure even further, so that more detailed biogeographic hypotheses can be formulated and tested. In order to accurately determine the population structure of *B. ephippiatus-B. wilmattae*, additional sampling is needed. This study represents only scattered populations of *B. ephippiatus* and *B. wilmattae* throughout their ranges. *B. wilmattae* specimens from Guatemala and other sites in Chiapas, Mexico are needed. Sampling of populations of *B. ephippiatus* in Guatemala, Nicaragua, and Panama, as well as further sampling in Mexico are also needed. Extensively sampling the species throughout its entire range will make population genetic analyses more complete and will also make it easier to identify possible geographic barriers to gene flow.

The morphological results do provide some insight into the evolution of color pattern within this species complex, but mapping traits onto phylogeny is by no means a definitive way to reconstruct evolutionary patterns. Because this group does not seem to have convergence in color pattern like most *Bombus* species (Williams, 2007), it may be possible to reconstruct ancestral color patterns using Bayesian inference methods, which can be implemented in programs like BayesTraits (Pagel *et al.*, 2004), but only once all polytomies within the phylogeny have been resolved. It is also possible that environmental factors are influencing color pattern as well. Conducting independent contrasts between color pattern data and bioclimatic variables, as well as altitude, latitude, and longitude can identify if there are any correlations between habitat and morphology.

Conducting colony-level experiments could also help to elucidate how much of an influence both variables, genetics and environment, are having on color pattern development. Hybrid experiments have been used in bumble bees in the past to conduct Mendelian genetic experiments (Owen and Plowright, 1980) involving color pattern; this study found that a single pair of alleles at one locus was controlling the expression of a red color pattern or a black color pattern in another *Pyrobombus* species, *B. melanopygus*. Crosses between black Costa Rican colonies and red Mexican colonies could provide insight into the genetic mechanisms controlling color pattern in this species. If bioclimatic variables relating to temperature are correlated with color pattern, raising *B. ephippiatus* and *B. wilmattae* colonies at different temperatures could aid in determining the role environment plays in color pattern development.

Conclusions

This study provides strong support that *B. impatiens* is the more distant sister within this New World species complex, diverging earlier than *B. ephippiatus* and *B. wilmattae*. This research also supports the paraphyly of *B. ephippiatus* with respect to *B. wilmattae*, bringing in to question the taxonomic status of these two species. The *B. ephippiatus*-*B. wilmattae* clade appears to possess geographic structure, but further population genetic analyses are needed to confirm this conclusion. The morphology of this recently diverged clade appears to be concordant with phylogeny as well as geography, but continued investigation is needed to provide insight into the mechanisms behind color pattern evolution.

In a world suffering extreme losses in biodiversity, the identification of species and the forces shaping their evolutionary history is of undeniable importance in the fields of biology and conservation. This study provides insight into the evolutionary relationships among important native pollinators in the New World, while generating biogeographic hypotheses about speciation processes in the Neotropics.

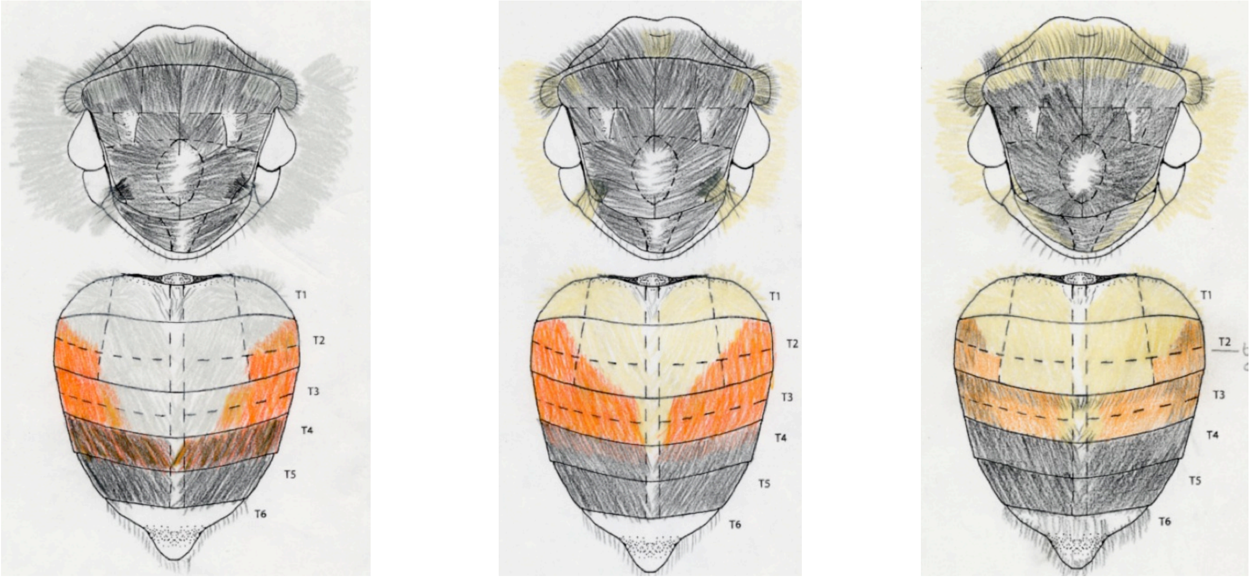
Table 1. Collection localities and sequence sources of taxa examined. Unless otherwise indicated with a ♂, all specimens are female. A + indicates that sequence was obtained by the author. A (+) indicates that sequence was obtained by Hines and Cameron (unpublished data). A [+] indicates that sequence was obtained by Cameron *et al*. (2007). A "Ht" indicates that individual was heterozygous for *CAD* and therefore was not used in analyses. All spaces left blank under the gene categories indicates that sequencing of that gene was unsuccessful for that individual. Accession numbers are given for those PEPCK sequences that were obtained from GenBank.

Species	Collection locality	Collector	V.#	COI	CAD	PEPCK	Acc. #
ephippiatus	Michoacan, Mexico	H. Hines, R. Ayala	VEP01	(+)	Ht	+	
ephippiatus	San Jose, Costa Rica	L. Masner	VEP02	(+)			
ephippiatus	Chihuahua, Mexico	K. Shaw	VEP03	(+)	+	+	
ephippiatus	Guerrero, Mexico	H. Hines, R. Ayala	VEP05	(+)	+	+	
ephippiatus	Oaxaca, Mexico	H. Hines, R. Ayala	VEP07	(+)	+	+	
ephippiatus	Puntarenas, Costa Rica	K. Martines	VEP09	(+)	Ht	+	
ephippiatus	Jalisco, Mexico	R. Ayala	VEP12	(+)	+	+	
ephippiatus	Queretaro, Mexico	R. Ayala	VEP13	(+)	+		
ephippiatus	Chihuahua, Mexico	K. Shaw	VEP14	+			
ephippiatus	Chiapas, Mexico	D. Sanchez	VEP17	+	+	+	
ephippiatus	San Jose, Costa Rica	P. Hanson	VEP18	+			
ephippiatus	Chiapas, Mexico	D. Sanchez	VEP19	+	Ht	+	
ephippiatus	Cartago, Costa Rica	P. Hanson	VEP20	+	+		
ephippiatus	Queretaro, Mexico	R. Ayala	VEP21	+	+	+	
ephippiatus	Jalisco, Mexico	R. Ayala	VEP22	+	+		
ephippiatus	Villa Mills, Costa Rica	A. Picado, B. Gamboa	VEP23	+	Ht	+	
ephippiatus	Cartago, Costa Rica	P. Hanson	VEP24	+			
ephippiatus	Oaxaca, Mexico	H. Hines, R. Ayala	VEP25	+	+	+	
ephippiatus	Chihuahua, Mexico	K. Shaw	VEP26	+	+		
ephippiatus	Cartago, Costa Rica	P. Hanson	VEP27	+			
ephippiatus	Puntarenas, Costa Rica	K. Martines	VEP28	+			
ephippiatus	Guerrero, Mexico	H. Hines, R. Ayala	VEP29	+	+		
ephippiatus	San Jose, Costa Rica	P. Hanson	VEP30	+			
ephippiatus	Jalisco, Mexico	R. Ayala	VEP33	+			
ephippiatus	Queretaro, Mexico	R. Ayala	VEP34	+	+	+	
ephippiatus	Queretaro, Mexico ♂	R. Ayala	VEP35	+	+	+	
ephippiatus	Jalisco, Mexico	R. Ayala	VEP36	+	+		
ephippiatus	Jalisco, Mexico ♂	R. Ayala	VEP37	+	+	+	
ephippiatus	Jalisco, Mexico	R. Ayala	VEP38	+	+		
ephippiatus	Guerrero, Mexico	H. Hines, R. Ayala	VEP43	+	+		
ephippiatus	Francisco Morazan, Honduras	M. Duennes, J. Torres	VEP44	+	Ht	+	
ephippiatus	Francisco Morazan, Honduras	M. Duennes, J. Torres	VEP45	+	+	+	
ephippiatus	Francisco Morazan, Honduras	M. Duennes, J. Torres	VEP46	+	+	+	
ephippiatus	Francisco Morazan, Honduras	M. Duennes, J. Torres	VEP47	+	+	+	
ephippiatus	El Paraiso, Honduras ♂	M. Duennes, J. Torres	VEP48	+		+	
ephippiatus	El Paraiso, Honduras ♂	M. Duennes, J. Torres	VEP49	+	+	+	
ephippiatus	Francisco Morazan, Honduras	M. Duennes, J. Torres	VEP50	+			
ephippiatus	Francisco Morazan, Honduras	M. Duennes, J. Torres	VEP51	+			

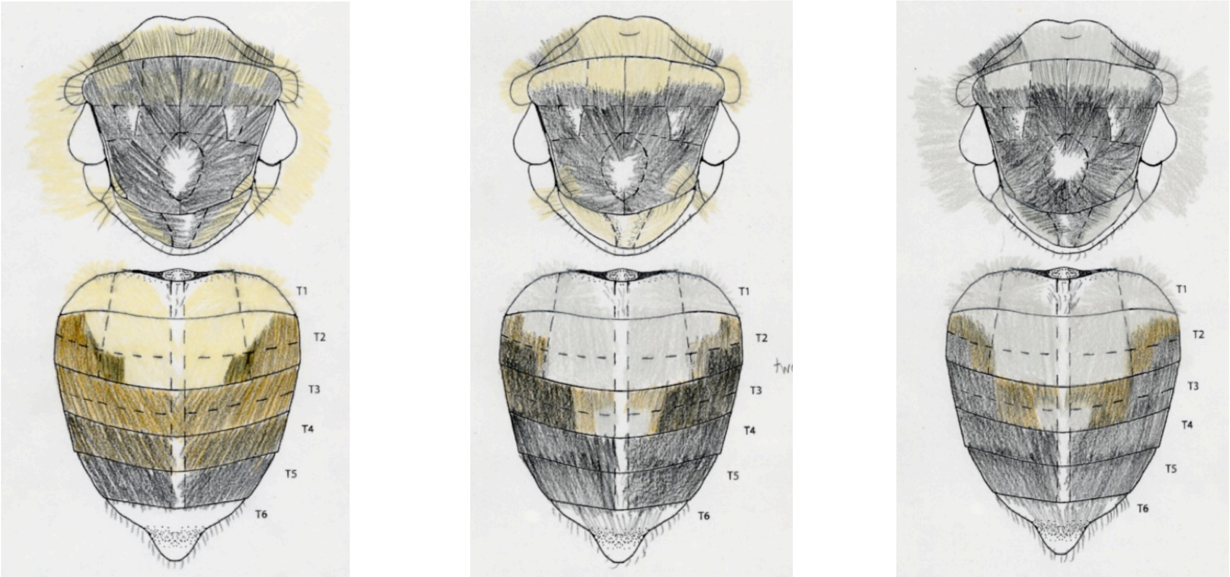
Table 1. (cont.)

ephippiatus	Comayagua, Honduras	M. Duennes, J. Torres	VEP52	+		+	
ephippiatus	Comayagua, Honduras	M. Duennes, J. Torres	VEP53	+		+	
ephippiatus	Santa Barbara, Honduras	M. Duennes, J. Torres	VEP54	+		+	
ephippiatus	Santa Barbara, Honduras	M. Duennes, J. Torres	VEP55	+			
ephippiatus	Chiapas, Mexico	M. Guzman	SC198	(+)		[+]	EF050844
wilmattae	Chiapas, Mexico ♂	S. Cameron	Vwilm03	(+)	+		
wilmattae	Chiapas, Mexico	D. Sanchez	Vwilm04	+	+		
wilmattae	Chiapas, Mexico	J. Nieh, R. Vandame	Vwilm06	+	Ht	+	
wilmattae	Chiapas, Mexico	J. Nieh, R. Vandame	Vwilm07	+	Ht		
wilmattae	Chiapas, Mexico	J. Nieh, R. Vandame	Vwilm10	+			
wilmattae	Chiapas, Mexico	R. Vandame	SC199	(+)		[+]	EF050843
impatiens	Maine, USA	S. Cameron, J. Whitfield	Vimpa02	+	+		
impatiens	Illinois, USA	H. Hines	Vimpa03	+	Ht	+	
impatiens	Illinois, USA ♂	H. Hines	Vimpa04	+	+		
impatiens	Maine, USA	S. Cameron, J. Whitfield	Vimpa06	+	+		
impatiens	Texas, USA	I. Stewart	IM412	+			
impatiens	Texas, USA	I. Stewart	IM420	+			
impatiens	Texas, USA	I. Stewart	IM423	+			
impatiens	Texas, USA	I. Stewart	IM424	+			
impatiens	Texas, USA	I. Stewart	IM426	+			
impatiens	Illinois, USA	H. Hines	SC060			[+]	EF050842

Figure 1. Worker color patterns of *B. ephippiatus* and *B. wilmattae*. All cartoon drawings were illustrated by the author.



1a. *B. ephippiatus* **1b**. *B.ephippiatus* **1c**. *B.ephippiatus*



1d. *B. ephippiatus* **1e**. *B. wilmattae* **1f**. *B. wilmattae*

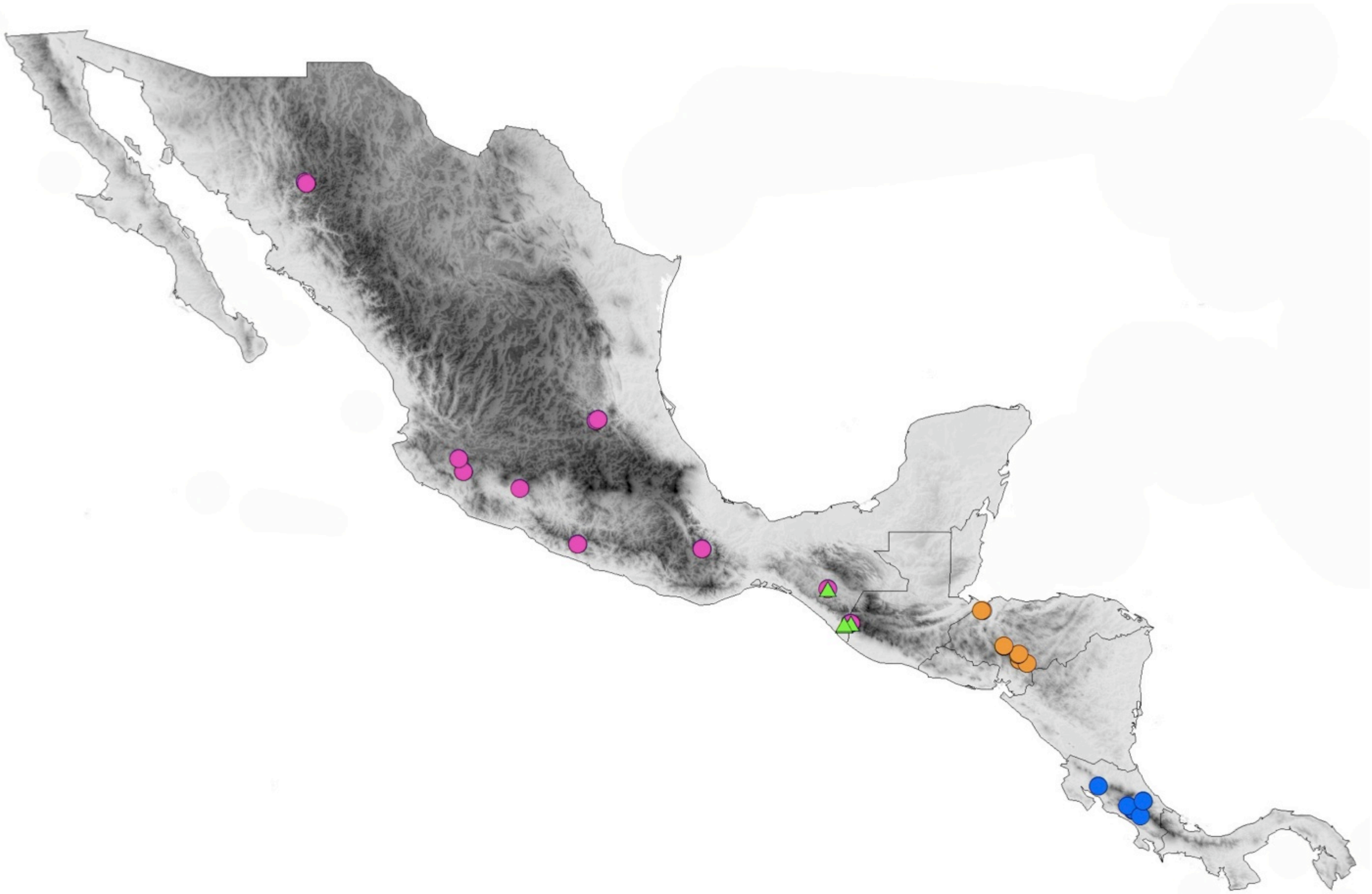


Figure 2. Map of collection localities of all specimens examined, excluding *B. impatiens*. Circles are *B. ephippiatus* specimens and triangles are *B. wilmattae* specimens. The colors of the points represent the country of origin. Pink = *B. ephippiatus* from Mexico; green = *B. wilmattae* from Chiapas, Mexico; orange = *B. ephippiatus* from Honduras; blue = *B. ephippiatus* from Costa Rica. Individual points on the map represent multiple samples of specimens.

Figure 3. Regions (characters) of the metasoma used for morphological coding and the different colors (character states) that each region can possess.

Figure 3a.

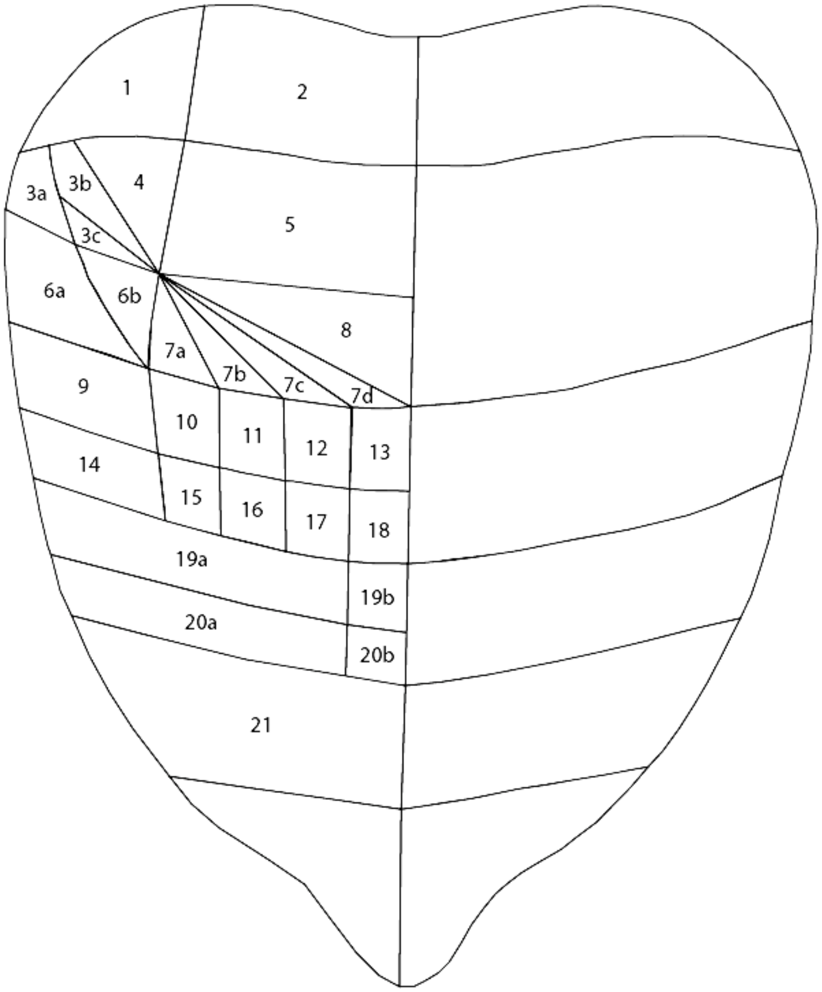


Figure 3b.

	Character states
1	white
2	ivory
3	yellow
4	orange
5	black/orange mix
6	two-toned
7	black
8	black/ivory or two-tone/ivory mix
9	black/yellow mix
10	orange/yellow mix

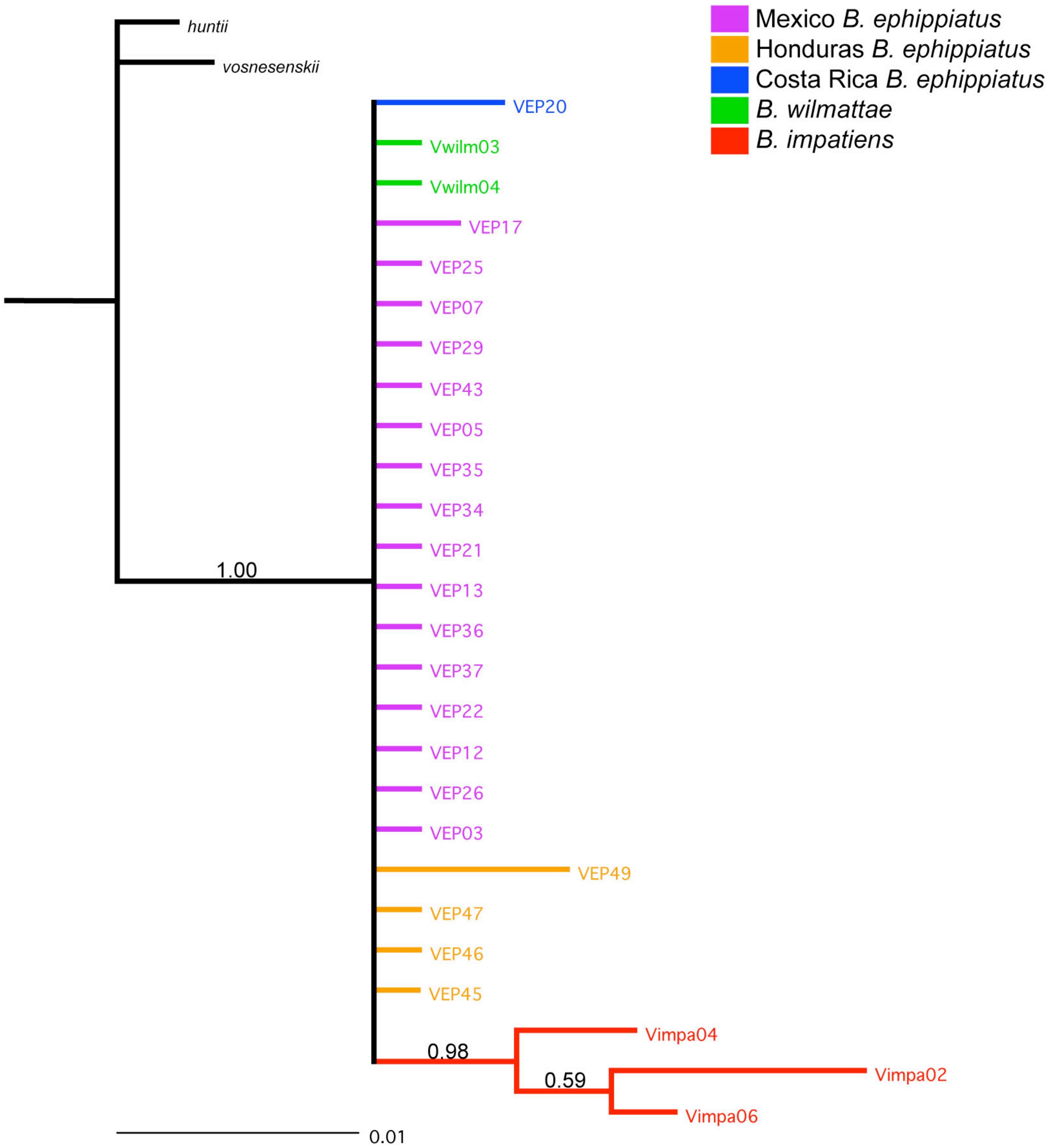


Figure 4. Bayesian phylogeny based on the *CAD* dataset. Phylogeny estimated from 159,600 trees (2 runs: 8,000,000 generations, 4 chains, sampling every 100 trees, burnin=200 trees per run) using flat priors and a HKY model for the intron region (nst=2) and a HKY + I model for the exon region (nst=2). Colors on the branches correspond to geographic location and species, as color-coded on the legend in the right hand corner. Scale bar indicates % substitution that the branch lengths represent.

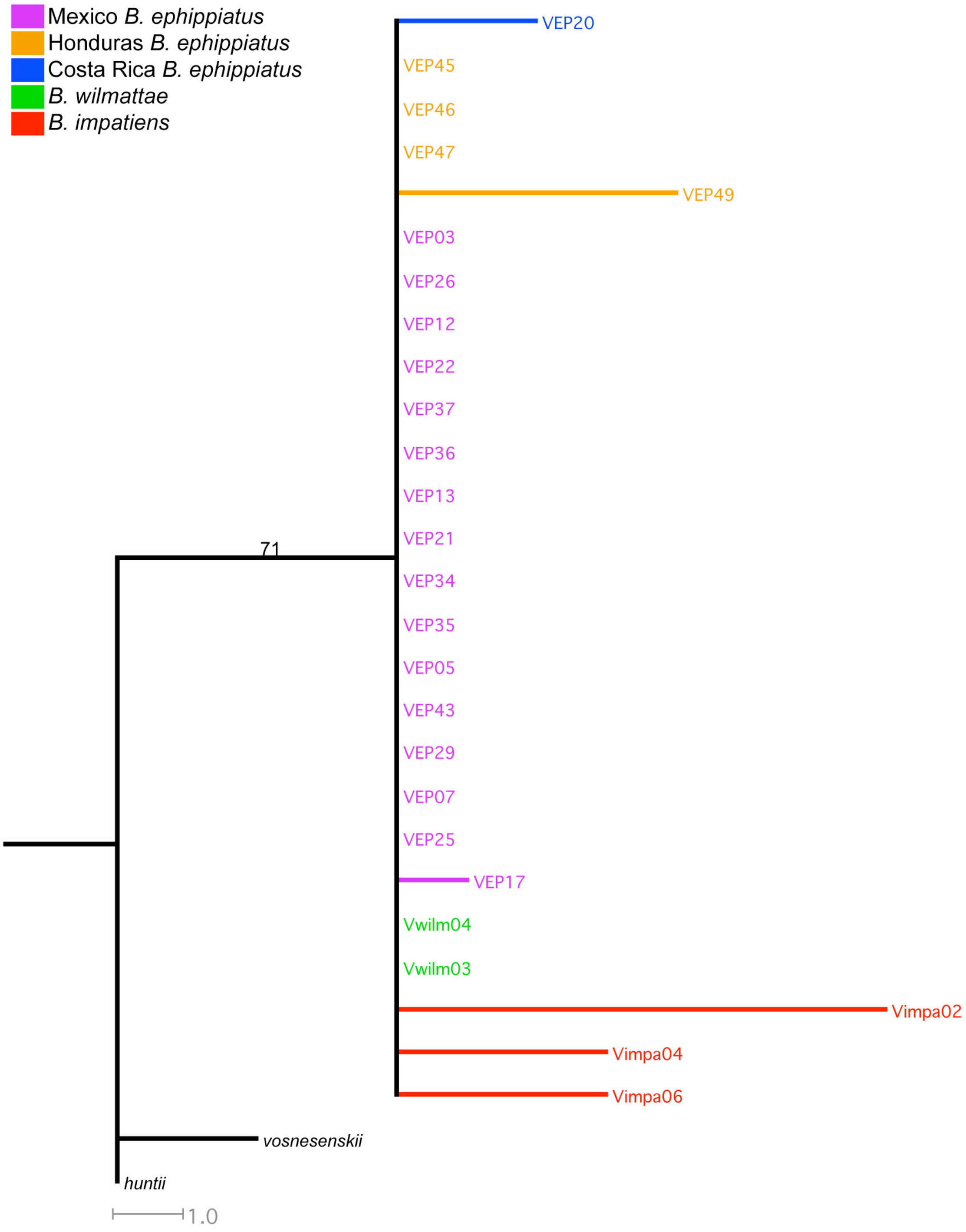


Figure 5. Parsimony-based phylogeny of the *CAD* dataset. Strict consensus of 9 most parsimonious trees obtained using a heuristic search (1000 random additions, TBR branch swapping, a maximum of 500 trees saved per random addition). Numbers above branches indicate all bootstrap support values ≥ 50. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates the number of substitutions that the branch lengths represent.

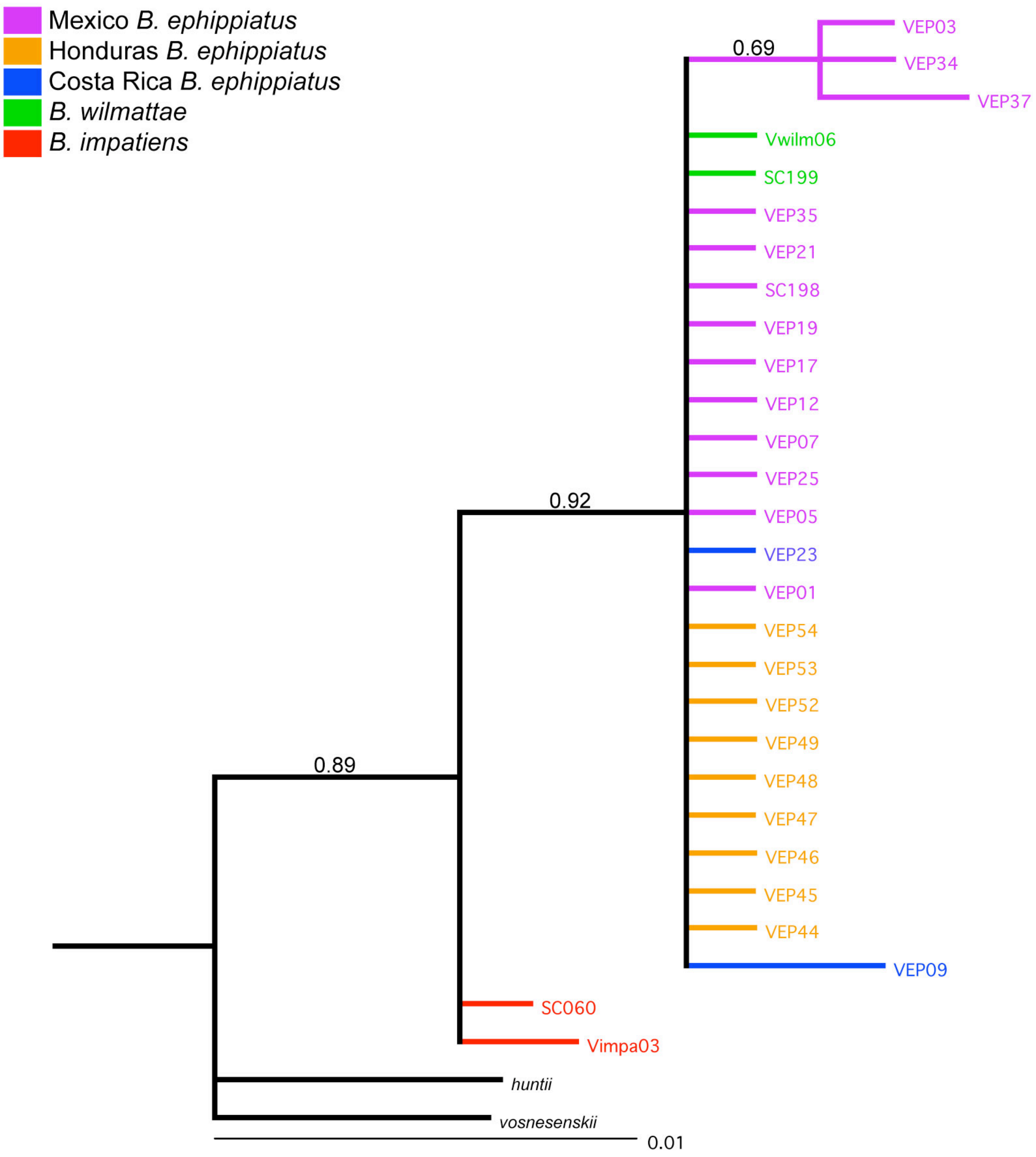


Figure 6. Bayesian phylogeny based on the *PEPCK* dataset. Phylogeny estimated from 159,600 trees (2 runs: 8,000,000 generations, 4 chains, sampling every 100 trees, burnin=200 trees per run) using flat priors and a GTR + I model for the intron region (nst=6), a HKY model for the exon region (nst=2) and a standard model for gap characters. Clade support values are Bayesian posterior probabilities. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates % substitution that the branch lengths represent.

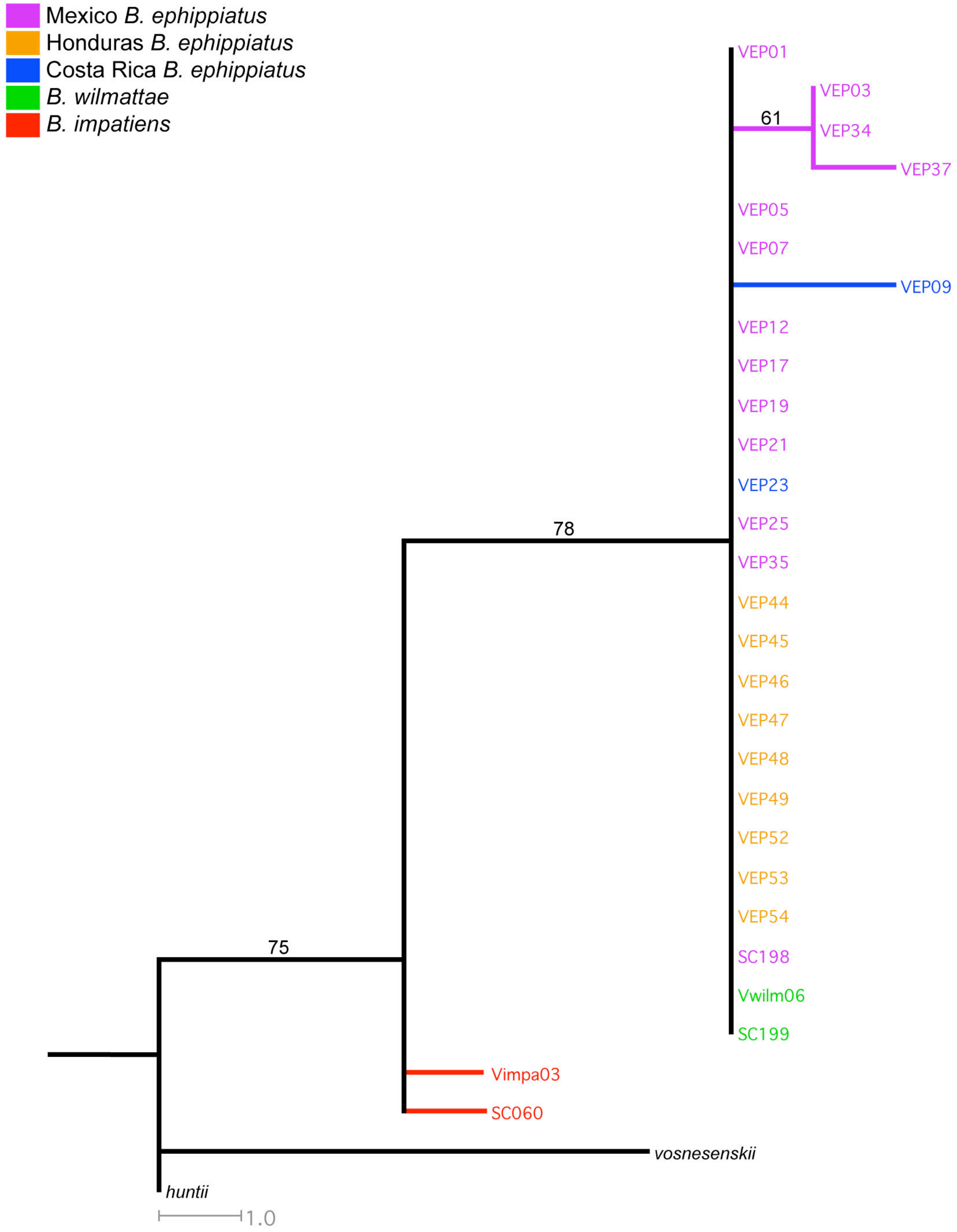


Figure 7. Parsimony-based phylogeny of the *PEPCK* dataset. Strict consensus of 3 most parsimonious trees obtained using a heuristic search (1000 random additions, TBR branch swapping, a maximum of 500 trees saved per random addition). Gaps were treated as a unique character state. Numbers above branches indicate all bootstrap support values ≥ 50. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates the number of substitutions that the branch lengths represent.

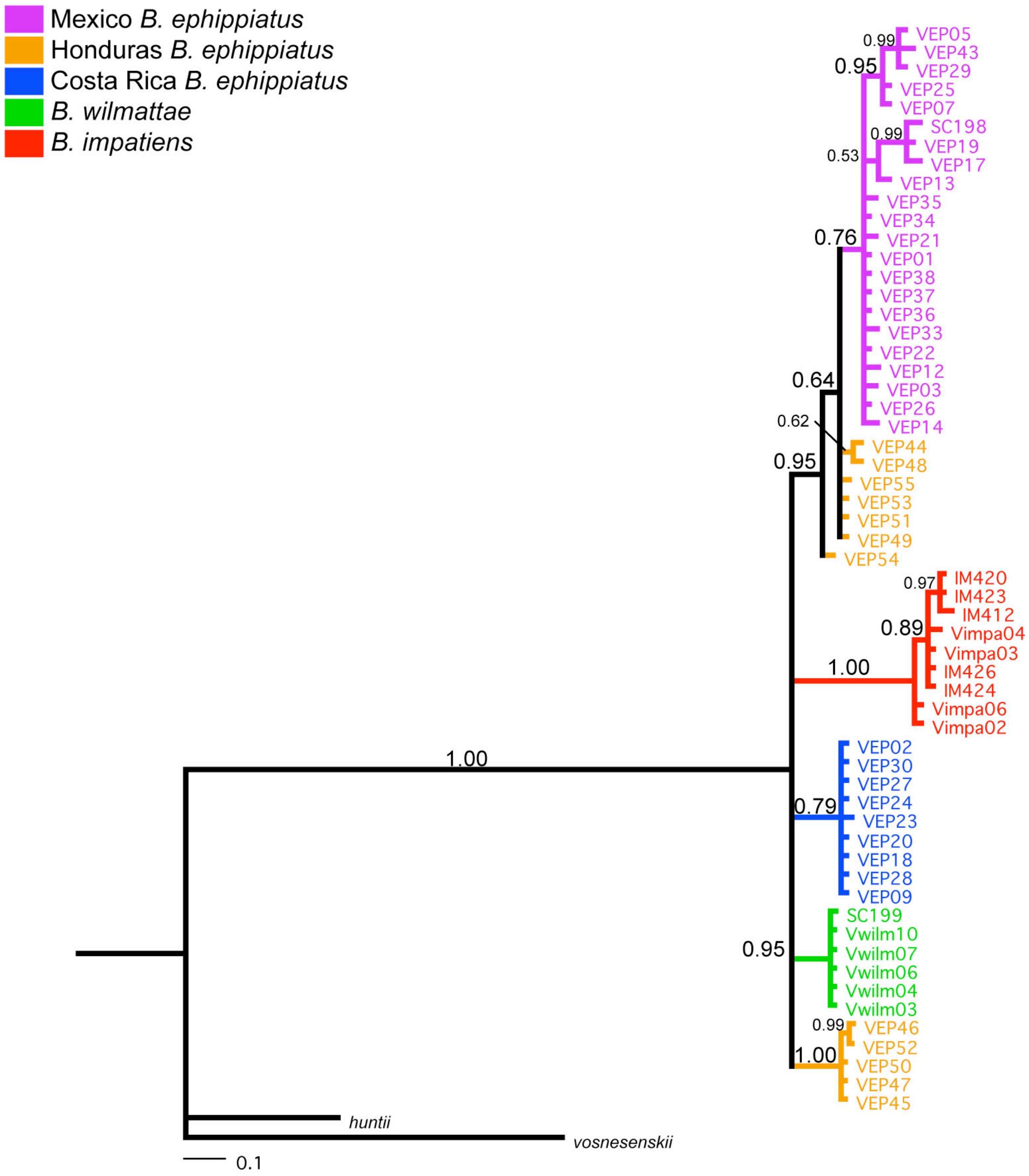


Figure 8. Bayesian phylogeny based on the *COI* dataset. Phylogeny estimated from 159,000 trees (2 runs: 8,000,000 generations, 4 chains, sampling every 100 trees, burnin=500 trees per run) using flat priors and a GTR + I model (nst=6). Clade support values are Bayesian posterior probabilities. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates % substitution that the branch lengths represent.

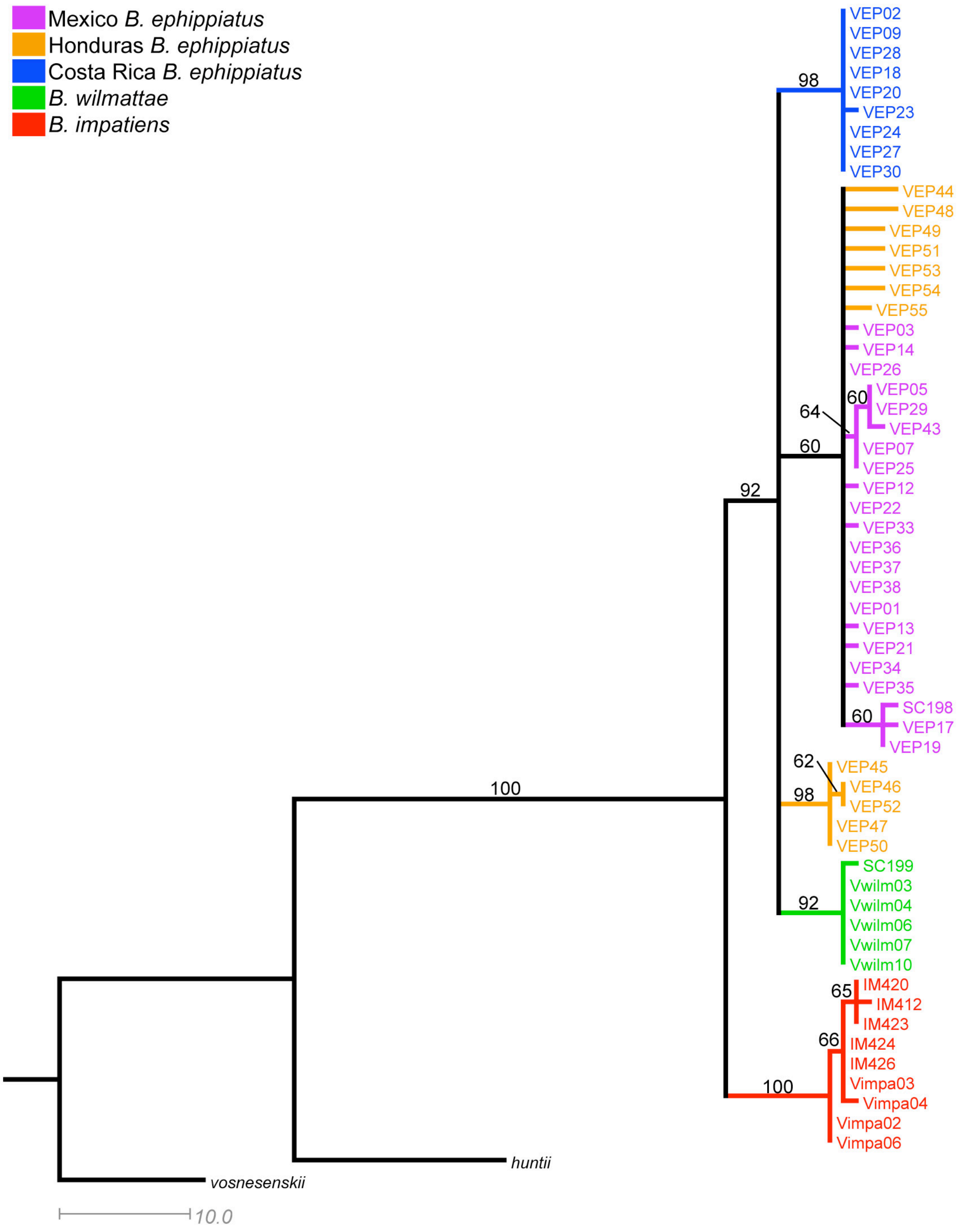


Figure 9. Parsimony-based phylogeny of the *COI* dataset. Strict consensus of 11,482 most parsimonious trees obtained using a heuristic search (1000 random additions, TBR branch swapping, a maximum of 500 trees saved per random addition). Numbers above branches indicate all bootstrap support values ≥ 50. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates the number of substitutions that the branch lengths represent.

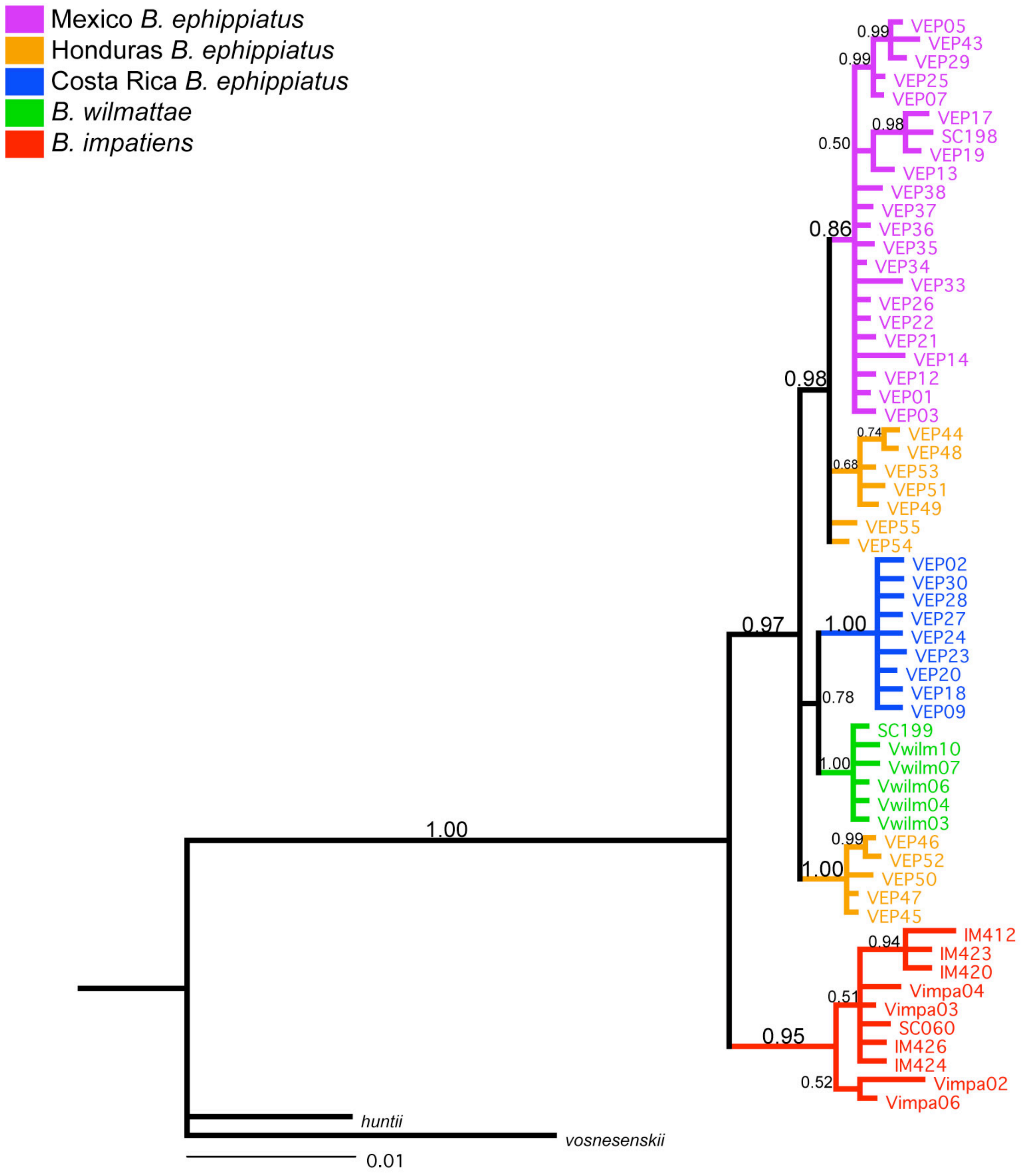


Figure 10. Bayesian phylogeny based on the combined gene dataset (*CAD* + *PEPCK* + *COI*). Phylogeny estimated from 237,000 trees (2 runs: 12,000,000 generations, 4 chains, sampling every 100 trees, burnin=1,500 trees per run) using flat priors, mixed models, and partitioning by gene, exon/intron, and gap characters when suitable. Clade support values are Bayesian posterior probabilities. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates % substitution that the branch lengths represent.

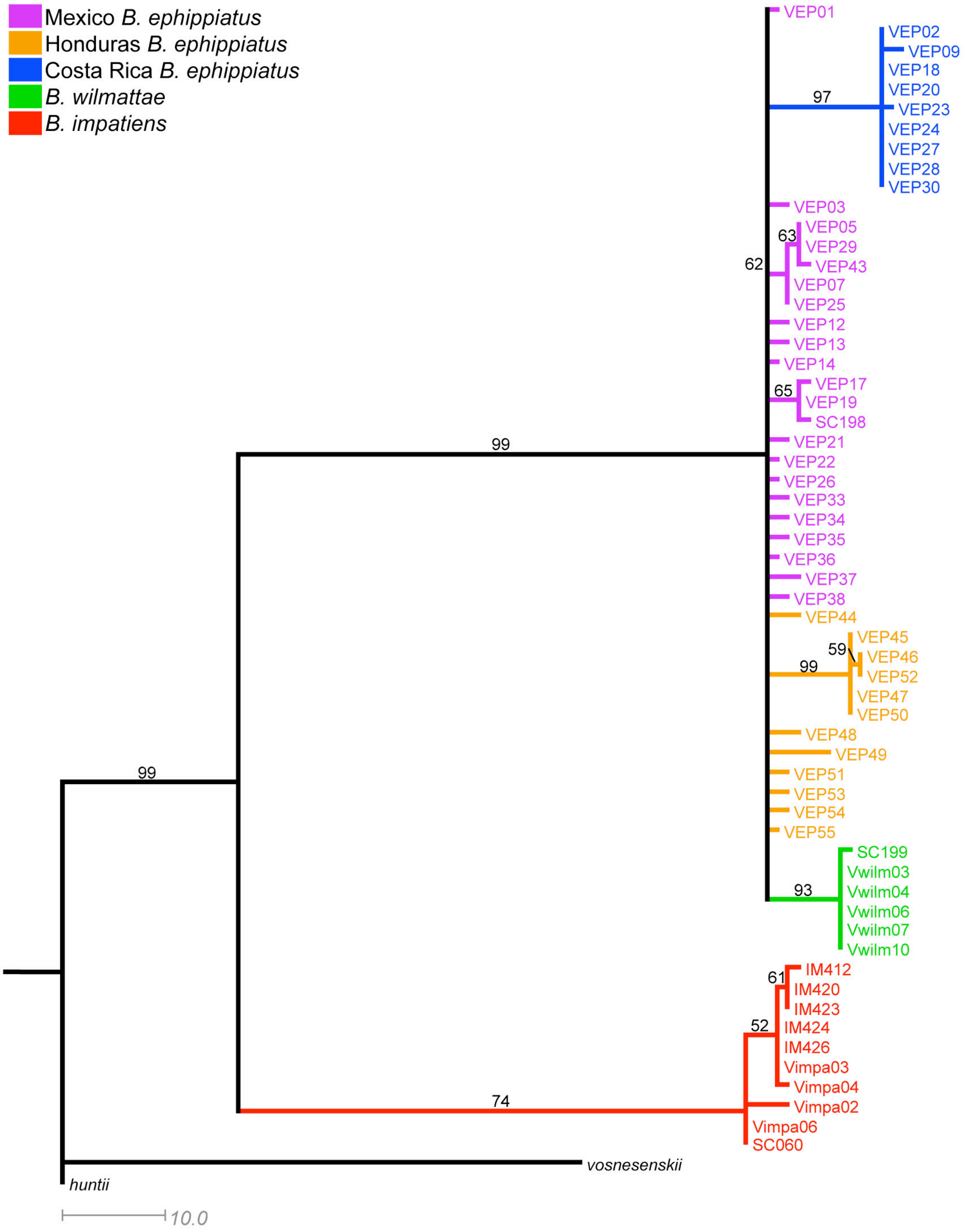


Figure 11. Parsimony-based phylogeny of the combined gene dataset (*CAD* + *PEPCK* + *COI*). Strict consensus of 500,000 most parsimonious trees obtained using a heuristic search (1000 random additions, TBR branch swapping, a maximum of 500 trees saved per random addition). Numbers above branches indicate all bootstrap support values ≥ 50. Colors on the branches correspond to geographic location and species, as color-coded on the legend in the left hand corner. Scale bar indicates the number of substitutions that the branch lengths represent.

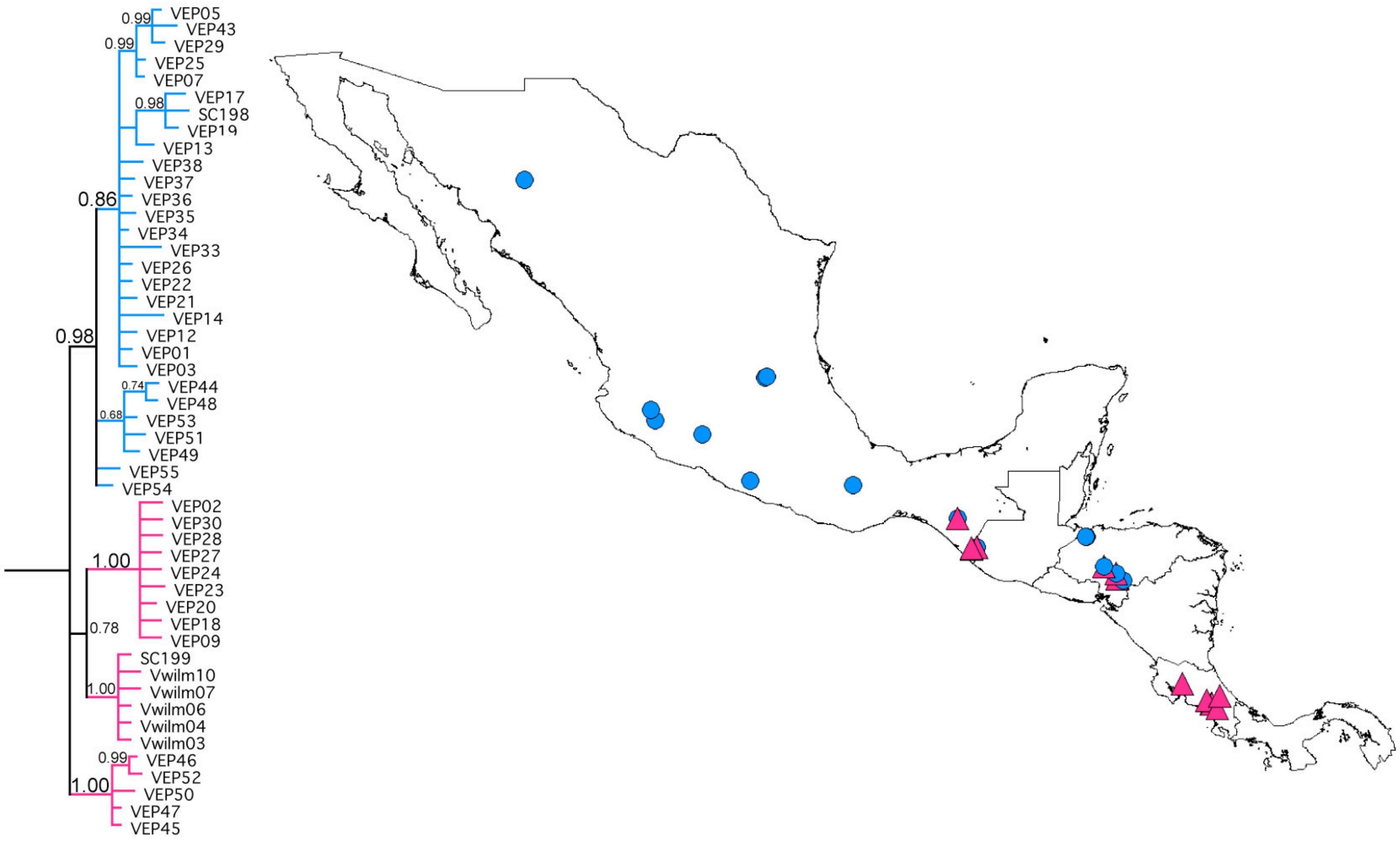


Figure 12. Map of collection localities of all specimens examined, excluding *B. impatiens*. This map is coded by phylogenetic clade placement. Blue circles represent specimens placed in the Mexico-Honduras clade. Pink triangles represent specimens placed in the Chiapas-Honduras-Costa Rica clade.

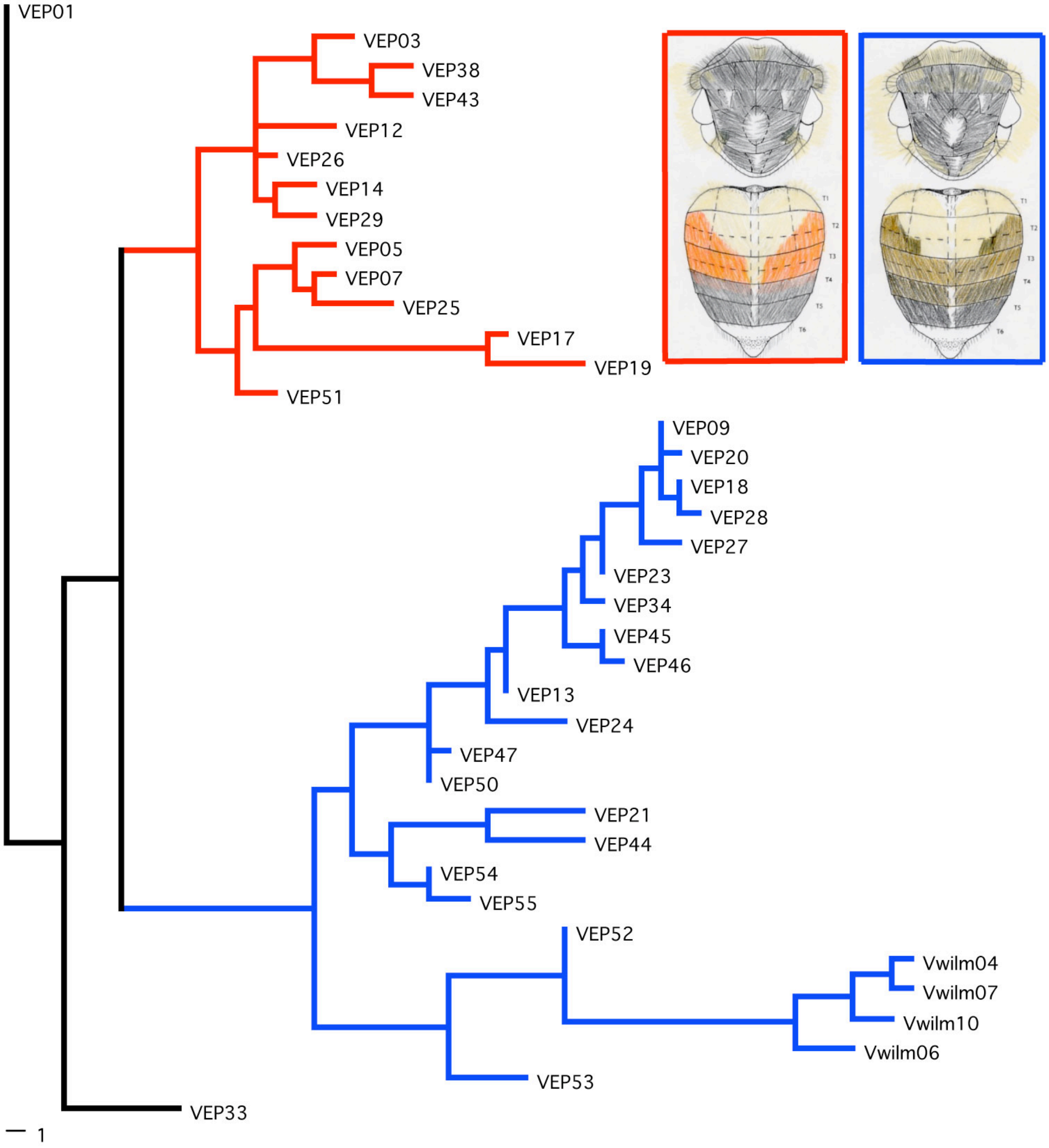


Figure 13. Neighbor-joining analysis of color pattern data for voucher specimens used in DNA phylogenies. The colors of the branches in the distance-based phylogeny correspond with color pattern phenotype, which is represented by the drawings of color pattern done by the author in the right hand corner.

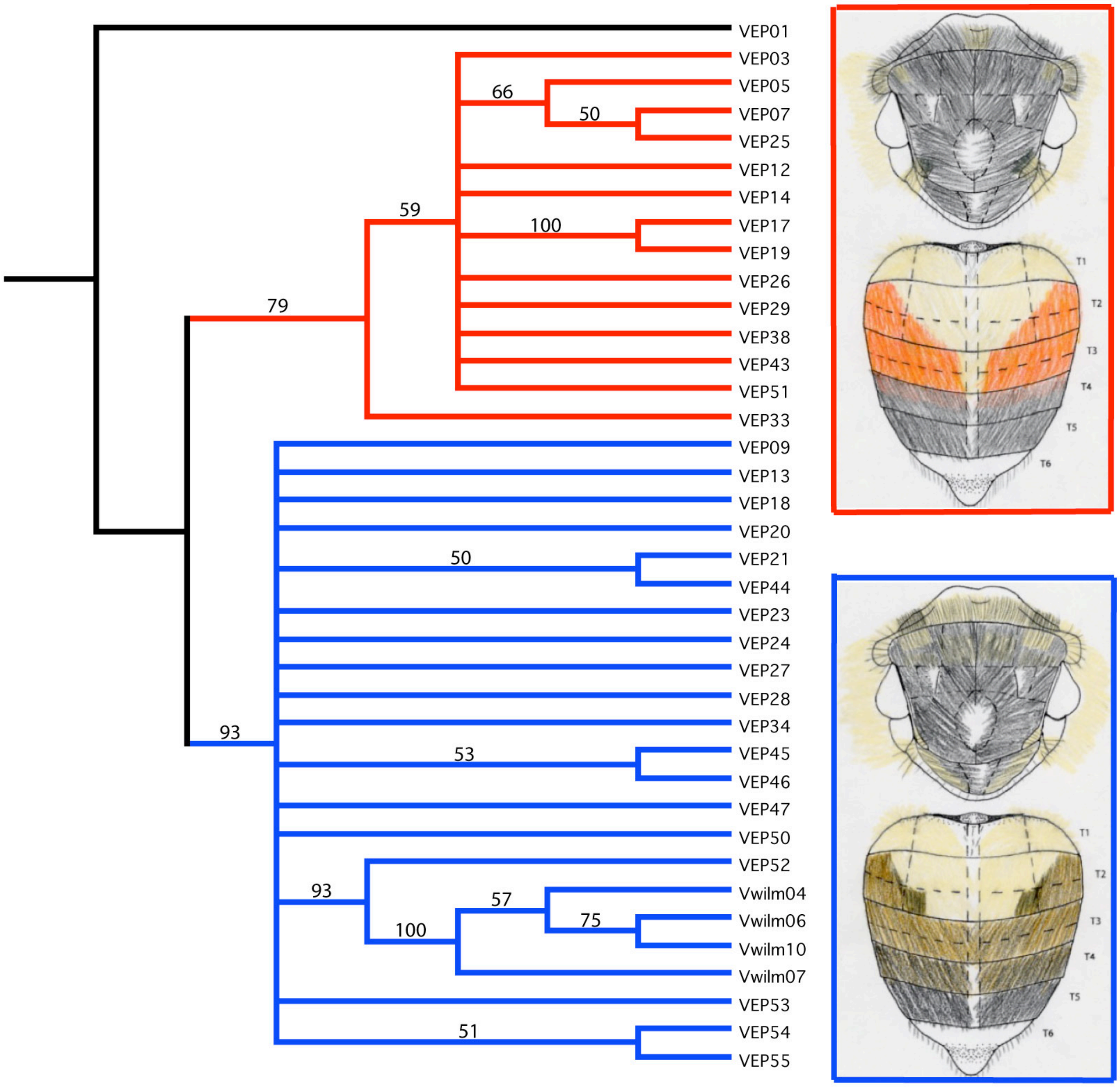


Figure 14. Parsimony-based phylogeny of the color pattern morphological data. Strict consensus of 45,873 most parsimonious trees obtained using a heuristic search (1000 random additions, TBR branch swapping, a maximum of 500 trees saved per random addition). Numbers above branches indicate all bootstrap support values ≥ 50. Colors on the branches correspond to color pattern phenotype, as color-coded around the drawings on the right.

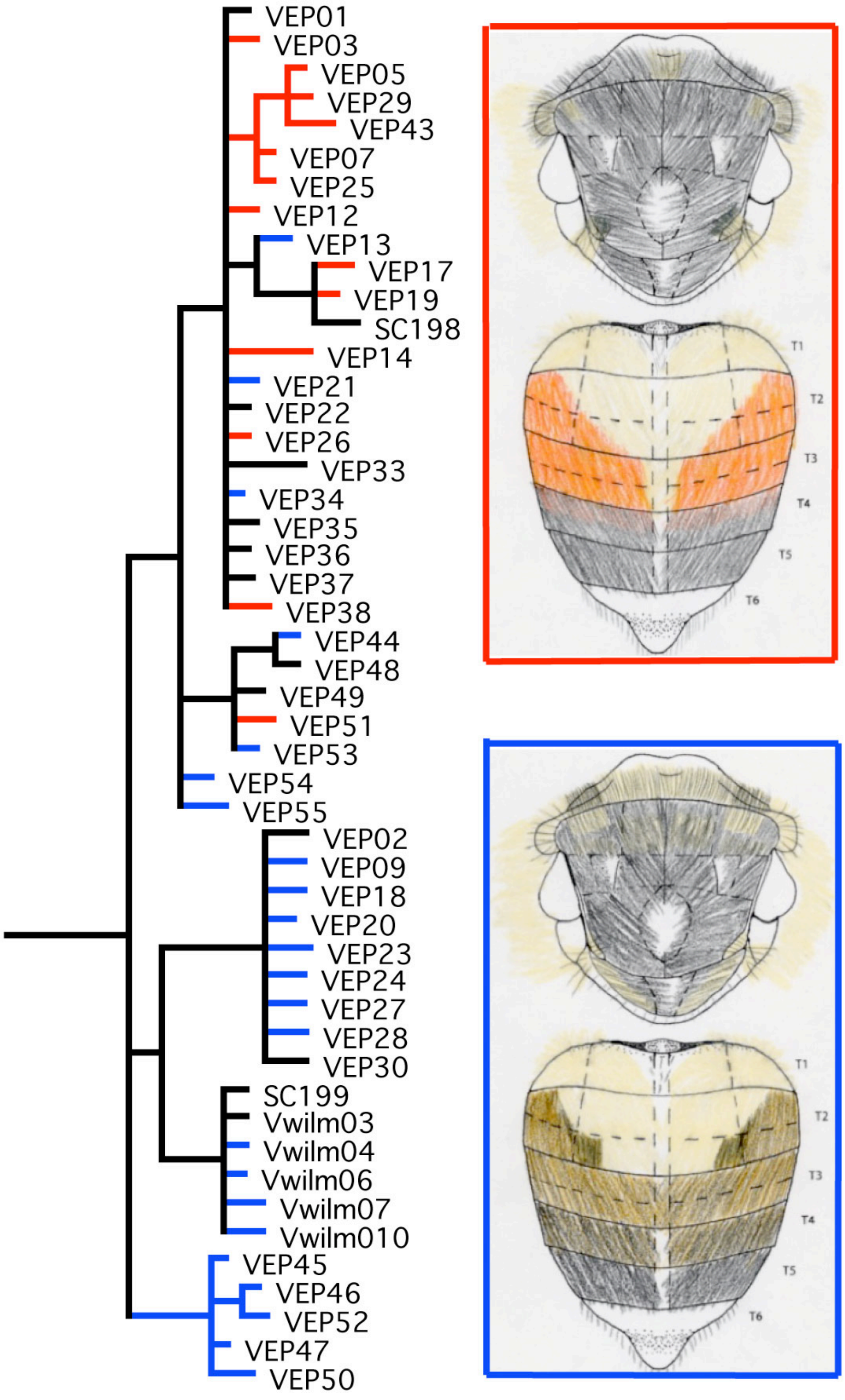


Figure 15. Color pattern groupings based on neighbor-joining and parsimony analyses mapped onto the molecular Bayesian phylogeny of the combined gene dataset. Colors on the branches represent the two main color pattern groupings, which are depicted to the right. The black terminal branches are associated with individuals that were not coded for color pattern, either because they were male or were too damaged.

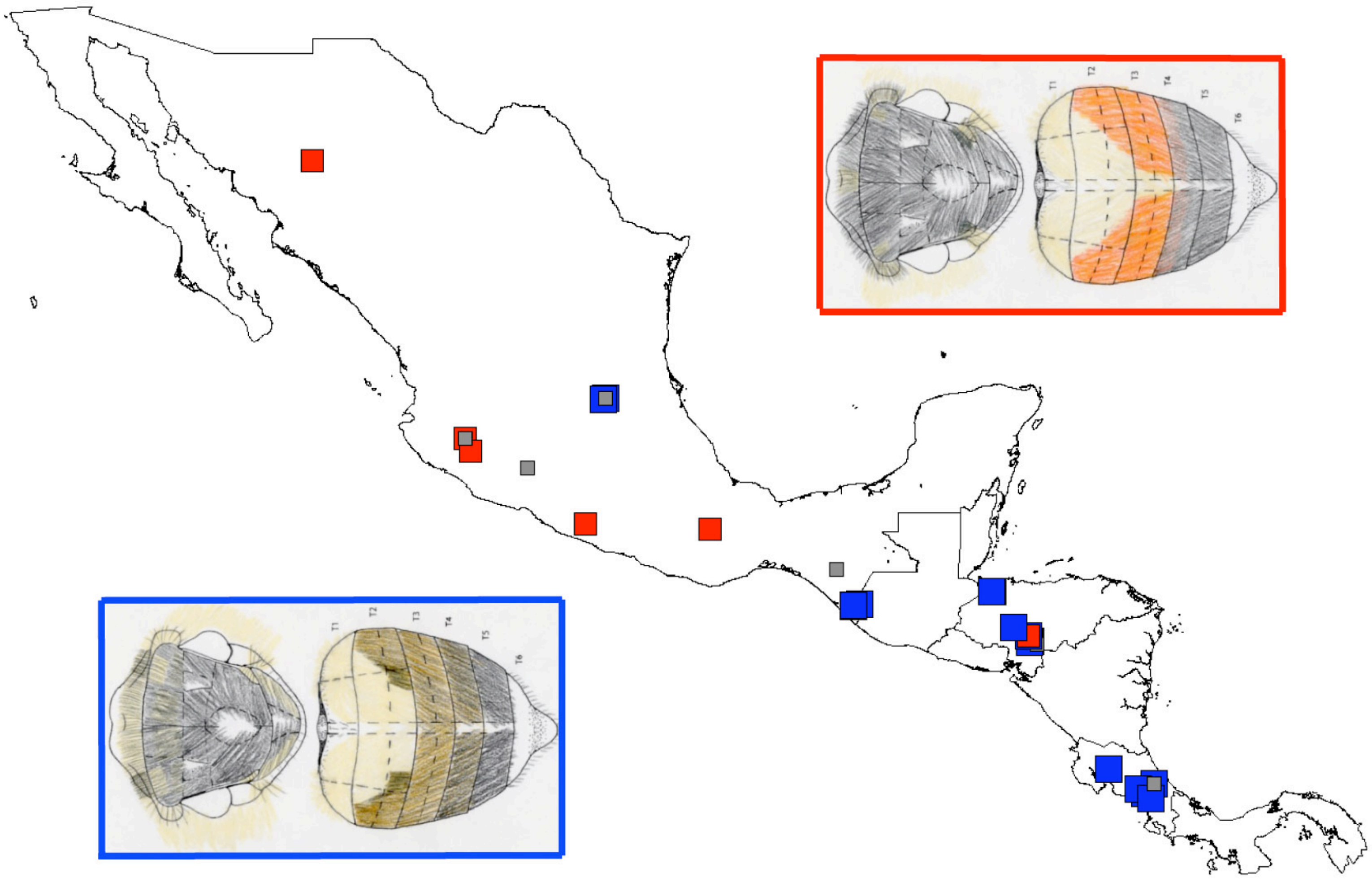


Figure 16. Map of collection localities of all specimens examined, excluding *B. impatiens*. This map represents the distribution of the two main color patterns across geographic range. Red squares represent specimens that possess the red phenotype. Blue squares represent specimens that possess the black phenotype. Smaller grey squares represent other voucher specimens that were included in the molecular analyses, but were not coded for color pattern, either because they were male or were too damaged.

References

Agapow, P., Bininda-Emonds, O., Crandall, K., Gittleman, J., Mace, G., & Marshall, J. (2004). The impact of species concept on biodiversity studies. *The Quarterly Review of Biology, 79*(2), 161-179.

Altekar, G., Dwarkadas, S., Huelsenbeck, J., & Ronquist, F. (2004). Parallel Metropolis coupled Markov chain Monte Carlo for Bayesian phylogenetic inference. *Bioinformatics, 20*(3), 407.

Avise, J. C. (2000). The history and purview of phylogeography. In *Phylogeography: The history and formation of species* (pp. 3-36). Cambridge, MA: Harvard University Press.

Balakrishnan, R. (2005). Species concepts, species boundaries and species identification: A view from the tropics. *Systematic Biology, 54*(4), 689-693.

Bull, N. J., Schwarz, M. P., & Cooper, S. J. B. (2003). Phylogenetic divergence of the Australian allodapine bees (Hymenoptera : Apidae). *Molecular Phylogenetics and Evolution, 27*(2), 212-222.

Cameron, S. A., Hines, H. M., & Williams, P. H. (2007). A comprehensive phylogeny of the bumble bees (*Bombus*). *Biological Journal of the Linnean Society, 91*(1), 161-188.

Cavers, S., Navarro, C., & Lowe, A. (2003). Chloroplast DNA phylogeography reveals colonization history of a Neotropical tree, *Cedrela odorata* L., in Mesoamerica. *Molecular Ecology, 12*(6), 1451-1460.

Cockerell, T. D. A. (1912). Descriptions and records of bees – XLV. *Annals and Magazine of Natural History, 10*(8), 21-31.

Colla, S. R. & Packer, L. (2008). Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. *Biodiversity and Conservation, 17*(6), 1379-1391.

Danforth, B., Fang, J., & Sipes, S. (2006). Analysis of family-level relationships in bees (Hymenoptera : Apiformes) using 28S and two previously unexplored nuclear genes: CAD and RNA polymerase II. *Molecular Phylogenetics and Evolution, 39*(2), 358.

Darvill, B., O'Connor, S., Lye, G. C., Waters, J., Lepais, O., & Goulson, D. (2010). Cryptic differences in dispersal lead to differential sensitivity to habitat fragmentation in two bumblebee species. *Molecular Ecology, 19*(1), 53-63.

Darwin, C. (1859). The origin of species by means of natural selection, or, the preservation of favoured races in the struggle for life. London, UK: Murray.

de Queiroz, K. (1999). The general lineage concept of species and the defining properties of the species category. In R. A. Wilson (Ed.), *Species* (pp. 49-89). Boston, MA: MIT Press.

de Queiroz, K. (2007). Species concepts and species delimitation. *Systematic Biology, 56*(6), 879-886.

Devitt, T. (2006). Phylogeography of the western lyresnake (*Trimorphodon biscutatus*): Testing aridland biogeographical hypotheses across the Nearctic-Neotropical transition. *Molecular Ecology, 15*(14), 4387-4407.

Dobzhansky, T. (1935). A critique of the species concept in biology. *Philosophy of Science, 2*, 344-355.

Evans, D. L., & Waldbauer, G. P. (1982). Behavior of adult and naïve birds when presented with a bumblebee and its mimic. *Zeitschrift fur Tierpsychologie, 53*(3), 247-259.

Fisher, R., & Pomeroy, N. (1989). Pollination of greenhouse muskmelons by bumble bees (Hymenoptera: Apidae). *Journal of Economic Entomology, 82*(4), 1061-1066.

Franklin, H. J. (1913). The Bombidae of the New World - Part 2. Species South of the United States. *Transactions of the American Entomological Society, Philadelphia, 39*, 73-200.

Freitas, B., Imperatriz-Fonseca, V., Medina, L., Kleinert, A., Galetto, L., & Nates-Parra, G. (2009). Diversity, threats and conservation of native bees in the neotropics. *Apidologie, 40*(3), 332-346.

Friedlander, T., Regier, J., Mitter, C., & Wagner, D. (1996). A nuclear gene for higher level phylogenetics: Phosphoenolpyruvate carboxykinase tracks Mesozoic-age divergences within Lepidoptera (Insecta). *Molecular Biology and Evolution, 13*(4), 594.

Friese, H. (1903). Neue *Bombus*-Arten aus der neotropischen region (Hym.). *Allgemeine Zeitschrift fur Entomologie, 3*, 253-255.

Friese, H. (1916). Zur bienenfauna von Costa Rica. (Hym.). *Stettiner Entomologische Zeitung, 77*, 287-350.

Frison, T. (1925). Contribution to the classification of the Bremidae (bumble-bees) of Central and South America. *Transactions of the American Entomological Society, Philadelphia, 51*, 137-165.

Goulson, D. (2003). *Bumblebees: Behaviour and ecology.* London: Oxford University Press.

Grixti, J. C., Wong, L. T., Cameron, S. A., & Favret, C. (2009). Decline of bumble bees (*Bombus*) in the North American Midwest. *Biological Conservation, 142*(1), 75-84.

Hall, T. A. (1999). BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series, 41*, 95-98.

Hanson, R., & Reshef, L. (1997). Regulation of phosphoenolpyruvate carboxykinase (GTP) gene. *Annual Review of Biochemistry, 66*, 581.

Heinrich, B. (1979). *Bumblebee economics.* Cambridge, MA: Harvard University Press.

Hey, J. (2001). The mind of the species problem. *Trends in Ecology Evolution, 16*(7), 326-329.

Hey, J., Fitch, W., & Ayala, F. (2005). Systematics and the origin of species: An introduction. *Proceedings of the National Academy of Sciences of the United States of America, 102*, 6515-6519.

Hey, J. (2006a). On the failure of modern species concepts. *Trends in Ecology Evolution, 21*(8), 447-450.

Hey, J. (2006b). Recent advances in assessing gene flow between diverging populations and species. *Current Opinion in Genetics Development, 16*(6), 592-596.

Hey, J., & Nielsen, R. (2004). Multilocus methods for estimating population sizes, migration rates and divergence time, with applications to the divergence of *Drosophila pseudoobscura* and *D. persimilis*. *Genetics, 167*(2), 747-760.

Hickerson, M., Stahl, E., & Lessios, H. (2006). Test for simultaneous divergence using approximate Bayesian computation. *Evolution, 60*(12), 2435-2453.

Hines, H. M. (2008). Historical biogeography, divergence times, and diversification patterns of bumble bees (Hymenoptera: Apidae: *Bombus*). *Systematic Biology, 57*(1), 58-75.

Hines, H. M., Cameron, S. A., & Williams, P. H. (2006). Molecular phylogeny of the bumble bee subgenus *Pyrobombus* (Hymenoptera : Apidae : *Bombus*) with insights into gene utility for lower-level analysis. *Invertebrate Systematics, 20*(3), 289-303.

Huelsenbeck, J. P., & Ronquist, F. (2001). MRBAYES: Bayesian inference of phylogenetic trees. *Bioinformatics, 17*(8), 754-755.

Hull, D. L. (1997). The ideal species concept – and why we cannot get it. In M. F. Claridge *et al.*(Ed.), *Species: The Units of Biodiversity* (pp. 357–380). London, UK: Chapman & Hall.

Isaac, N., Mallet, J., & Mace, G. (2004). Taxonomic inflation: Its influence on macroecology and conservation. *Trends in Ecology Evolution, 19*(9), 464-469.

Jandt, J., Huang, E., & Dornhaus, A. (2009). Weak specialization of workers inside a bumble bee (*Bombus impatiens*) nest. *Behavioral Ecology and Sociobiology, 63*(12), 1829-1836.

Kawazoe, K., Kawakita, A., Sugiura, S., & Kato, M. (2008). Phylogenetic position of the endemic large carpenter bee of the Ogasawara Islands, *Xylocopa ogasawarensis*

(Matsumura, 1912) (Hymenoptera: Apidae), inferred from four genes. *Zoological Science, 25*(8), 838.

Kearns, C. A., & Thomson, J. D. (2001). *The natural history of bumblebees: A sourcebook for investigations.* Boulder, CO: University Press of Colorado.

Kevan, P., Clark, E., & Thomas, V. (1990). Insect pollinators and sustainable agriculture. *American Journal of Alternative Agriculture, 5*(1), 13-22.

Kim, H., Lee, K., Lee, S., Kim, S., Hong, M., & Kim, D. (2008). Mitochondrial DNA sequence variation of the mason bee, *Osmia cornifrons* (Hymenoptera: Apidae). *International Journal of Industrial Entomology, 16*(2), 75.

Kim, M., Yoon, H., Im, H., Jeong, H., Kim, M. I., & Kim, S. (2009). Mitochondrial DNA sequence variation of the bumblebee, *Bombus ardens* (Hymenoptera: Apidae). *Journal of Asia-Pacific Entomology, 12*(3), 133.

Knowles, L., & Maddison, W. (2002). Statistical phylogeography. *Molecular Ecology, 11*(12), 2623-2635.

Kondo, N., Yamanaka, D., Kanbe, Y., Kunitake, Y., Yoneda, M., & Tsuchida, K. (2009). Reproductive disturbance of Japanese bumblebees by the introduced European bumblebee *Bombus terrestris*. *Die Naturwissenschaften, 96*(4), 467-475.

Koulianos, S. (1999). Phylogenetic relationships of the bumblebee subgenus *Pyrobombus* (Hymenoptera : Apidae) inferred from mitochondrial cytochrome B and cytochrome oxidase I sequences. *Annals of the Entomological Society of America, 92*(3), 355-358.

Koulianos, S., & Schmid-Hempel, P. (2000). Phylogenetic relationships among bumble bees (*Bombus*, Latreille) inferred from mitochondrial cytochrome b and cytochrome oxidase I sequences. *Molecular Phylogenetics and Evolution, 14*(3), 335-341.

Labougle, J. M. (1990). *Bombus* of Mexico and Central America (Hymenoptera: Apidae). *University of Kansas Science Bulletin, 54*(3), 35-73.

Labougle, J. M., Ito, M., & Okazawa, T. (1985). The species of the genus *Bombus* (Hymenoptera: Apidae) of Chiapas, Mexico and Guatemala with a morphometric and altitudinal analysis. *Folia Entomologica Mexicana,* (64), 55-72.

Leys, R., Cooper, S., & Schwarz, M. (2002). Molecular phylogeny and historical biogeography of the large carpenter bees, genus *Xylocopa* (Hymenoptera : Apidae). *Biological Journal of the Linnean Society, 77*(2), 249.

Lutz, F. (1916). The geographic distribution of *Bombidae* (Hymenoptera) with notes on certain species of boreal America. *Bulletin of the American Museum, New York, 35*, 501-521.

Macfarlane, R., & Gurr, L. (1995). Distribution of bumble bees in New Zealand. *The New Zealand Entomologist, 18*, 29-36.

Maddison, W. P., D.R. Maddison. (2009). *Mesquite: A modular system for evolutionary analysis.* Version 2.72. http://mesquiteproject.org.

Maddison, W. P. (1997). Gene trees in species trees. *Systematic Biology, 46*(3), 523-536.

Martins, A., & Melo, G. (2010). Has the bumblebee *Bombus bellicosus* gone extinct in the northern portion of its distribution range in Brazil? *Journal of Insect Conservation, 14*(2), 207-210.

Mayden, R. L. (1997). A hierarchy of species concepts: The denouement in the saga of the species problem. In M. F. Claridge *et al.* (Ed.), *Species: The Units of Biodiversity* (381-424). London, UK: Chapman & Hall.

Mayden, R. (1999). Consilience and a hierarchy of species concepts: Advances toward closure on the species puzzle. *Journal of Nematology, 31*(2), 95-116.

Mayr, E. (1942). *Systematics and the origin of species*. New York: Columbia University Press.

Mayr, E. (1957). Species concepts and definitions. In E. Mayr (Ed.), *The species problem* (pp. 1-22). Washington D.C.: American Association for the Advancement of Science.

Medler, J. (1962). Morphometric studies on bumble bees. *Annals of the Entomological Society of America, 55*(2), 212-218.

Meisels, S., & Chiasson, H. (1997). Effectiveness of *Bombus impatiens* Cr. as pollinators of greenhouse sweet peppers (*Capsicum annuum* L.). *Acta Horticulturae, 437*, 425-429.

Milliron, H. (1962). Taxonomic notes on some American bumblebees (Hymenoptera: Apidae: Bombinae). *Canadian Entomology, 94*(*7*), 728-735.

Mishler, B., & Donoghue, M. (1982). Species concepts – a case for pluralism. *Systematic Zoology, 31*(4), 491-503.

Moulton, J. (2000). Molecular sequence data resolves basal divergences within Simuliidae (Diptera). *Systematic Entomology, 25*(1), 99-113.

Moulton, J. (2003). Can the current molecular arsenal adequately track rapid divergence events within Simuliidae (Diptera)? *Molecular Phylogenetics and Evolution, 27*(1), 45-57.

Moulton, J. K., & Wiegmann, B. M. (2004). Evolution and phylogenetic utility of CAD (rudimentary) among Mesozoic-aged Eremoneuran Diptera (Insecta). *Molecular Phylogenetics and Evolution, 31*(1), 363-378.

Novick, R., Dick, C., Lemes, M., Navarro, C., Caccone, A., & Bermingham, E. (2003). Genetic structure of Mesoamerican populations of big-leaf mahogany (*Swietenia macrophylla*) inferred from microsatellite analysis. *Molecular Ecology, 12*(11), 2885.

Nylander, J. A. A. (2004). *MrModeltest2: C program for selecting DNA substitution models using PAUP**. Version 2.3. Evolutionary Biology Centre, Uppsala University. http://www.abc.se/~nylander/mrmodeltest2/mrmodeltest2.html.

Owen, R., & Plowright, R. (1980). Abdominal pile color dimorphism the bumble bee, *Bombus melanopygus*. *The Journal of Heredity, 71*(4), 241-247.

Pagel, M., Meade, A., & Barker, D. (2004). Bayesian estimation of ancestral character states on phylogenies. *Systematic Biology, 53*(5), 673-684.

Plath, O. E. (1934). *Bumblebees and their ways*. New York: The Macmillian Company.

Rambaut, A., & Drummond A. J. (2007). *Tracer*. Version 1.4. http://beast.bio.ed.ac.uk/Tracer.

Redpath, N., Osgathorpe, L., Park, K., & Goulson, D. (2010). Crofting and bumblebee conservation: The impact of land management practices on bumblebee populations in Northwest Scotland. *Biological Conservation, 143*(2), 492-500.

Renema, W., Bellwood, D., Braga, J., Bromfield, K., Hall, R., & Johnson, K. (2008). Hopping hotspots: Global shifts in marine biodiversity. *Science, 321*(5889), 654-657.

Reydon, T. (2004). Why does the species problem still persist? *BioEssays, 26*(3), 300-305.

Richards, O. (1968). The subgeneric division of the genus *Bombus* Latreille (Hymenoptera: Apidae). *Bulletin of the British Museum of Natural History, Entomology, 22*, 209-276.

Ross, K., Gotzek, D., Ascunce, M., & Shoemaker, D. (2010). Species delimitation: A case study in a problematic ant taxon. *Systematic Biology, 59*(2), 162-184.

Ross, K., & Shoemaker, D. (2005). Species delimitation in native South American fire ants. *Molecular Ecology, 14*(11), 3419-3438.

Rossello-Mora, R. (2003). Opinion: The species problem, can we achieve a universal concept? *Systematic and Applied Microbiology, 26*(3), 323-326.

Sakagami, S. (1976). Specific differences in the bionomic characters of bumble bees: A comparative review. *Journal of the Faculty of Science, Hokkaido University.Series VI, Zoology, 20*(3), 390-447.

Simmons, M. P., & Ochoterena, H. (2000). Gaps as characters in sequence-based phylogenetic analyses. *Systematic Biology, 49*(2), 369-381.

Simpson, G. (1951). The species concept. *Evolution, 5*, 285-298.

Sladen, F. W. L. (1912). *The humble-bee, its life history and how to domesticate it, with descriptions of all the British species of* Bombus *and* Psithyrus. London: The Macmillan Company.

Smith, F. (1879). *Description of new species of Hymenoptera in the collection of the British museum*. London: British Museum.

Sota, T., & Vogler, A. (2003). Reconstructing species phylogeny of the carabid beetles *Ohomopterus* using multiple nuclear DNA sequences: Heterogeneous information content and the performance of simultaneous analyses. *Molecular Phylogenetics and Evolution, 26*(1), 139.

Soucy, S. L., & Danforth, B. N. (2002). Phylogeography of the socially polymorphic sweat bee *Halictus rubicundus* (Hymenoptera : Halictidae). *Evolution, 56*(2), 330-341.

Staley, J. (2009). Universal species concept: Pipe dream or a step toward unifying biology? *Journal of Industrial Microbiology Biotechnology, 36*(11), 1331-1336.

Swofford, D. L. (2003). *PAUP*. Phylogenetic Analysis Using Parsimony (*and other methods).* Sunderland, MA: Sinauer Associates.

Thorp, R. (2003). Bumble bees (Hymenoptera: Apidae): Commercial use and environmental concerns. In K. Strickler, & J. H. Cane (Eds.), *For non-native crops, whence pollinators of the future?* (pp. 21-40). Lanhan, MD: Thomas Say Publications in Entomology: Proceedings, Entomological Society of America.

Vazquez-Miranda, H., Navarro-Siguenza, A., & Omland, K. (2009). Phylogeography of the rufous-naped wren (*Campylorhynchus rufinucha*): speciation and hybridization in Mesoamerica. *The Auk, 126*(4), 765-778.

Velasco, J. (2009). When monophyly is not enough: Exclusivity as the key to defining a phylogenetic species concept. *Biology and Philosophy, 24*(4), 473-486.

Velthuis, H., & van Doorn, A. (2006). A century of advances in bumblebee domestication and the economic and environmental aspects of its commercialization for pollination. *Apidologie, 37*(4), 421-451.

Vergara, C. H. (2008). Environmental impact of exotic bees introduced for crop pollination. In James, R.R. and Pitts-Singer, T.L. (Ed.), *Bee pollination in agricultural ecosystems* (pp. 145-165). New York, NY: Oxford University Press.

Waldbauer, G., & Laberge, W. (1985). Phenological relationships of wasps, bumblebees, their mimics and insectivorous birds in northern Michigan. *Ecological Entomology, 10*(1), 99-110.

Wiens, J. (2007a). Global patterns of diversification and species richness in amphibians. *The American Naturalist, 170*, 86-S106.

Wiens, J. (2007b). Species delimitation: New approaches for discovering diversity, symposium articles. *Systematic Biology, 56*(6), 857-955.

Wild, A. L., & Maddison, D. R. (2008). Evaluating nuclear protein-coding genes for phylogenetic utility in beetles. *Molecular Phylogenetics and Evolution, 48*(3), 877-891.

Wiley, E. (1978). Evolutionary species concepts reconsidered. *Systematic Zoology, 27*(1), 17-26.

Williams, P. (1998). An annotated checklist of bumble bees with an analysis of patterns of description (Hymenoptera: Apidae, Bombini). *Bulletin of the Natural History Museum, Entomology Series, 67*(1), 79-152.

Williams, P. (2007). The distribution of bumblebee colour patterns worldwide: Possible significance for thermoregulation, crypsis, and warning mimicry. *Biological Journal of the Linnean Society, 92*(1), 97-118.

Williams, P. H., Cameron, S. A., Hines, H. M., Cederberg, B., & Rasmont, P. (2008). A simplified subgeneric classification of the bumblebees (genus *Bombus*). *Apidologie, 39*(1), 46-74.

Yoon, H., Kim, S., Lee, K., Lee, S., Park, I., & Kim, I. (2009). Interspecific hybridization of the bumblebees *Bombus ignitus* and *B. terrestris*. *International Journal of Industrial Entomology, 18*(1), 45-52.

Appendix A. Alignments. Alignments used for phylogenetic inference. Regions excluded from analyses are indicated with X's above the alignment and with red letters. For nuclear genes, brackets enclose introns and numbers above the alignment indicate codon position. Dashes enclosed in vertical lines above the alignment are gap regions and numbers associated with them indicate the number of the gap character starting with the first '0' or '1' at the end of the matrix for that gene.

CAD Alignment

```
             [
             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 5   10   15   20   25   30   35   40   45   50   55   60   65   70
VEP03        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP05        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP07        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP12        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP13        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP17        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGWACTCCGAGTGGACGTAGRATTTTATGTCTT
VEP20        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP21        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP22        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP25        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP26        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP29        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP34        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP35        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP36        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP37        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP43        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP45        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP46        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP47        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
VEP49        GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
Vwilm03      GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
Vwilm04      GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
Vimpa02      GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
Vimpa04      GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGAACTCCGAGTGGACGTAGGATTTTATGTCTT
Vimpa06      GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTACTCCGAGTGGACGTAGGATTTTATGTCTT
huntii       GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTAYTCCGAGTGGACGTAGGATTTTATGTCYT
vosnesenskii GATTCTACAGAGCAGTCGCTTTTCTTTTCTGGCAAATTTTGATGTATTCCGAGTGGACGTAGGATTTTATGTCTT

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                80   85   90   95  100  105  110  115  120  125  130  135  140  145
VEP03        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP05        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP07        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP12        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP13        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP17        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP20        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP21        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP22        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP25        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP26        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP29        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP34        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP35        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP36        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP37        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP43        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP45        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP46        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP47        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
VEP49        TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
Vwilm03      TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
Vwilm04      TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
Vimpa02      TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
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Appendix A. (cont.)

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Vimpa04      TGAATATTTCAGGTAATACAATCGGARCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
Vimpa06      TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
huntii       TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT
vosnesenskii TGAATATTTCAGGTAATACAATCGGAGCGGCCCGATGGTGTCCTCTTGACATTTGGCGGACAGACTGCTCTCAAT

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                     155  160  165  170  175  180  185  190  195  200  205  210  215  220
VEP03        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP05        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP07        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP12        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP13        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP17        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP20        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAGAATTTTAGGAACGCCTATACAGTCG
VEP21        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP22        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP25        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP26        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP29        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP34        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP35        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP36        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP37        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP43        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP45        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP46        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP47        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
VEP49        TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
Vwilm03      TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
Vwilm04      TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAAAATTTTAGGAACGCCTATACAGTCG
Vimpa02      TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAGAATTTTAGGAACGCCTATACAGTCG
Vimpa04      TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAGAATTTTAGGAACGCCTATACAGTCG
Vimpa06      TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAGAATTTTAGGAACGCCTATACAGTCG
huntii       TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAGAATTTTAGGAACGCCTATACAGTCG
vosnesenskii TGTGGCGTTGAACTCGAGAAGAATGGAGTATTTCAGAAATATAATATCAGAATTTTAGGAACGCCTATACAGTCG

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                     230  235  240  245  250  255  260  265  270  275  280  285  290  295
VEP03        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP05        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP07        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP12        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP13        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP17        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP20        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP21        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP22        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP25        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP26        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP29        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP34        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP35        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP36        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP37        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP43        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP45        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP46        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP47        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
VEP49        ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
Vwilm03      ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
Vwilm04      ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
Vimpa02      ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
Vimpa04      ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
Vimpa06      ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
huntii       ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
vosnesenskii ATCATAGAGACGGAAGATAGAAAGATCTTCGCAGAACGTATCGCGGAGATCAATGAAAACGTGGCGCCAAGTGCG
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Appendix A. (cont.)

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                305  310  315  320  325  330  335  340  345  350  355  360  365  370
VEP03        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP05        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP07        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP12        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP13        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP17        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGTTGTGGCGGATCTGAA
VEP20        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP21        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP22        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP25        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP26        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP29        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP34        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP35        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP36        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP37        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP43        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
VEP45        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGTTGTGGCGGATCTGAA
VEP46        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGTTGTGGCGGATCTGAA
VEP47        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGTTGTGGCGGATCTGAA
VEP49        GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGTTGTGGCGGATCTGAA
Vwilm03      GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGTTGTGGCGGATCTGAA
Vwilm04      GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
Vimpa02      GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
Vimpa04      GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGC---------GATTAATTCGGATGTGATGTGGCGGATCTGAA
Vimpa06      GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGWTGTGGCGGATCTGAA
huntii       GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGAYGTGGCGGATCTGAA
vosnesenskii GCGGTCTATTCTATCGAAGAGGTAAGAGAATCGCAAGTCTCGCGATTAATTCGGATGTGATGTGGCGGATCTGAA

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                380  385  390  395  400  405  410  415  420  425  430  435  440  445
VEP03        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP05        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP07        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP12        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP13        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP17        TTGCGAGAGCTCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP20        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP21        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP22        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP25        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP26        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP29        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP34        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP35        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP36        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP37        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP43        TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP45        TTGCGAGAGCTCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP46        TTGCGAGAGCTCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP47        TTGCGAGAGCTCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
VEP49        TTGCGAGAGCTCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
Vwilm03      TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
Vwilm04      TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
Vimpa02      TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATAGAAAGTACGATC
Vimpa04      TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATAGAAAGTACGATC
Vimpa06      TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATAGAAAGTACGATC
huntii       TTGCGAGAGCCCATMTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC
vosnesenskii TTGCGAGAGCCCATCTTCGGCGATCTATACTTTCGGAAAATACAGATTCTTACACAGGCTATCGAAAGTACGATC

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                455  460  465  470  475  480  485  490  495  500  505  510  515  520
VEP03        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP05        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP07        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP12        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
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Appendix A. (cont.)

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VEP13        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP17        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP20        TATTCACTGAGTTTTGAAGTTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP21        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP22        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP25        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP26        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP29        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP34        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP35        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP36        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP37        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP43        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP45        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP46        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP47        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
VEP49        TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
Vwilm03      TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
Vwilm04      TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
Vimpa02      TATTCACTGAGTTTTGACATTTCACAGTTTATTCATTACCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
Vimpa04      TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
Vimpa06      TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATCGATTATTCACTGAGAGGAGGATAT
huntii       TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATTGATTATTCACTGAGAGGAGGATAT
vosnesenskii TATTCACTGAGTTTTGAAATTTCACAGTTTATTCATTATCGATATTCAATTGATTATTCACTGAGAGGAGGATAT

                                                                           X
             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 530  535  540  545  550  555  560  565  570  575  580  585  590  595
VEP03        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP05        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP07        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP12        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP13        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP17        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
VEP20        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP21        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP22        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP25        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP26        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP29        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP34        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP35        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP36        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP37        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP43        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
VEP45        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
VEP46        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
VEP47        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
VEP49        TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
Vwilm03      TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
Vwilm04      TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
Vimpa02      TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
Vimpa04      TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
Vimpa06      TTATTRATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTATTATTATTTCAA
huntii       TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA
vosnesenskii TTATTGATTTTTCTGGAAATTGAAAAGTAATTATAACCATTATTATTTACAATACTATTACTGTTATTATTTCAA

                ]1
             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 605  610  615  620  625  630  635  640  645  650  655  660  665  670
VEP03        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP05        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP07        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP12        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP13        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP17        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP20        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP21        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP22        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP25        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP26        TCAGGCATTAGATGCAGCAGAAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
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Appendix A. (cont.)

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VEP29        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP34        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP35        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP36        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP37        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP43        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP45        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP46        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP47        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
VEP49        TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
Vwilm03      TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
Vwilm04      TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
Vimpa02      TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
Vimpa04      TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
Vimpa06      TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
huntii       TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG
vosnesenskii TCAGGCATTAGATGCAGCAGAAAAATTGGGCTACCCAGTAATGGCTAGAGCAGCGTTTTCTCTTGGAGGATTGGG

             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                     680  685  690  695  700  705  710  715  720  725  730  735  740  745
VEP03        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP05        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP07        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP12        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP13        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP17        RTCCGGCTTCGCRAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAAGCGTTCGCTCATTCGACTCAATTGAT
VEP20        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP21        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP22        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP25        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP26        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP29        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP34        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP35        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP36        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP37        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP43        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP45        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP46        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP47        ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
VEP49        GTCCGGCTTCGCAAACTCTAAGAAAGAACTACGAAACCTCGCTCAACAAGCGTTCGCTCATTCGACTCAATTGAT
Vwilm03      ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
Vwilm04      ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
Vimpa02      GTCCGGYTTCGCRAACTCTAAGAAAGAACTACGAAACCTCGCTCAACAAGCGTTCGCTCATTCGACTCAATTGAT
Vimpa04      ATCCGGCTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
Vimpa06      GTCCGGCTTCGCRAACTCCAAGAAAGAACTACGAAACCTCGCTCAACARGCGTTCGCTCATTCGACTCAATTGAT
huntii       GTCCGGTTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAGGCGTTCGCTCATTCGACTCAATTGAT
vosnesenskii GTCCGGTTTCGCGAACTCCAAGAAAGAACTACGAAACCTCGCTCAACAAGCGTTCGCTCATTCGACTCAATTGAT

             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                     755  760  765  770  775  780  785  790  795  800  805  810  815  820
VEP03        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP05        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP07        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP12        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP13        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP17        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP20        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP21        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP22        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP25        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP26        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP29        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP34        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP35        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP36        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP37        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP43        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP45        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP46        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
VEP47        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
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Appendix A. (cont.)

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VEP49        CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
Vwilm03      CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
Vwilm04      CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
Vimpa02      CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
Vimpa04      CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
Vimpa06      CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
huntii       CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC
vosnesenskii CATCGATAAATCATTGAAAGGCTGGAAAGAGGTGGAATACGAGGTCGTTCGGGATGCGTACGACAATTGTATCAC

             ....|....|....|
                 830  835
VEP03        AGTTTGCAACATGGA
VEP05        AGTTTGCAACATGGA
VEP07        AGTTTGCAACATGGA
VEP12        AGTTTGCAACATGGA
VEP13        AGTTTGCAACATGGA
VEP17        AGTTTGCAACATGGA
VEP20        AGTTTGCAACATGGA
VEP21        AGTTTGCAACATGGA
VEP22        AGTTTGCAACATGGA
VEP25        AGTTTGCAACATGGA
VEP26        AGTTTGCAACATGGA
VEP29        AGTTTGCAACATGGA
VEP34        AGTTTGCAACATGGA
VEP35        AGTTTGCAACATGGA
VEP36        AGTTTGCAACATGGA
VEP37        AGTTTGCAACATGGA
VEP43        AGTTTGCAACATGGA
VEP45        AGTTTGCAACATGGA
VEP46        AGTTTGCAACATGGA
VEP47        AGTTTGCAACATGGA
VEP49        AGTTTGCAACATGGA
Vwilm03      AGTTTGCAACATGGA
Vwilm04      AGTTTGCAACATGGA
Vimpa02      AGTTTGCAACATGGA
Vimpa04      AGTTTGCAACATGGA
Vimpa06      AGTTTGCAACATGGA
huntii       AGTTTGCAACATGGA
vosnesenskii AGTTTGCAACATGGA
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Appendix A. (cont.)

PEPCK Alignment

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                 5    10   15   20   25   30   35   40   45   50   55   60   65   70
VEP01        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP03        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP05        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP07        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP09        ATGTTGAAACCTTTAAAGGCAATTGTATCAGAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP12        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP17        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP19        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP21        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP23        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP25        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP34        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP35        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP37        ATGTTGAAACCTTTAAAGACAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP44        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP45        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP46        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP47        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP48        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP49        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP52        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP53        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
VEP54        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
SC198        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
Vwilm06      ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
SC199        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
Vimpa03      ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
SC060        ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
huntii       ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT
vosnesenskii ATGTTGAAACCTTTAAAGGCAATTGTATCAAAGTTTAATTTTACAGAGATTACTATCATATAGATTAAGAACAAT

              ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 80   85   90   95  100  105  110  115  120  125  130  135  140  145
VEP01        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP03        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP05        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP07        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP09        TATCTCAGATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP12        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP17        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP19        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP21        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP23        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP25        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP34        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP35        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP37        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP44        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP45        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP46        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP47        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP48        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP49        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP52        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP53        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
VEP54        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
SC198        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
Vwilm06      TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
SC199        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
Vimpa03      TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
SC060        TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
huntii       TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAA
vosnesenskii TATCTCAAATACTAAGCTTCGTTTCTAATATAAATTAAAAGCAATTGTTTTAAACTCTAAATTGATATAATATAG
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                155  160  165  170  175  180  185  190  195  200  205  210  215  220
VEP01        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP03        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP05        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP07        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP09        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP12        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP17        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP19        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP21        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP23        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP25        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP34        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP35        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP37        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP44        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP45        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP46        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP47        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP48        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP49        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP52        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP53        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
VEP54        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
SC198        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
Vwilm06      ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
SC199        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAATATCA
Vimpa03      ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAAYATCA
SC060        ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAAYATCA
huntii       ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAACATCA
vosnesenskii ATTAAAGTCAATTTTGTGTATGTCTTGAACATCAAGACTCACAATATAGATTAAAGACAATTGTCATAAACATCA

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                230  235  240  245  250  255  260  265  270  275  280  285  290  295
VEP01        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP03        AAACCTACACTTTAAATAAAAATAACAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP05        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP07        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP09        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP12        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP17        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP19        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP21        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP23        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP25        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP34        AAACCTACACTTTAAATAAAAATAACAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP35        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP37        AAACCTACACTTTAAATAAAAATAACAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP44        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP45        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP46        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP47        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP48        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP49        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP52        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP53        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
VEP54        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
SC198        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
Vwilm06      AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
SC199        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACTTCACTAT
Vimpa03      AAACCTACAYTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACT-----AT
SC060        AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACT-----AT
huntii       GAACCTACAYTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACT-----AT
vosnesenskii AAACCTACACTTTAAATAAAAATAAAAATTTTTAGTTTTTAAGATATCAAAGCAGTGACAACTTCACT-----AT
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                305  310  315  320  325  330  335  340  345  350  355  360  365  370
VEP01        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP03        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP05        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP07        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP09        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP12        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP17        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP19        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP21        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP23        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP25        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP34        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP35        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP37        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP44        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP45        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP46        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP47        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP48        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP49        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP52        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP53        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
VEP54        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
SC198        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
Vwilm06      TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
SC199        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
Vimpa03      TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
SC060        TACTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
huntii       TGCTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC
vosnesenskii TGCTCTTATAATCAATTTCAATCGTTACTTGGCACTTGCAAGTACATTAGTCGCTTAAGATTCTGTATCAGTTAC

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                380  385  390  395  400  405  410  415  420  425  430  435  440  445
VEP01        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP03        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP05        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP07        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP09        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP12        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP17        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP19        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP21        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP23        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP25        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP34        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP35        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP37        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP44        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP45        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP46        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP47        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP48        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP49        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP52        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP53        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
VEP54        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
SC198        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
Vwilm06      CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
SC199        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
Vimpa03      CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
SC060        CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
huntii       CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
vosnesenskii CTTTTGTAGATACTGGCTATCACAAATCCAAAAGGTAGAAAGCGTTACATTACTGCAGCGTTCCCCAGTGCTTGC
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                     455  460  465  470  475  480  485  490  495  500  505  510  515  520
VEP01        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP03        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP05        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP07        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP09        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP12        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP17        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP19        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP21        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP23        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP25        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP34        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP35        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP37        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP44        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP45        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP46        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP47        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP48        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP49        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP52        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP53        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
VEP54        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
SC198        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
Vwilm06      GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
SC199        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
Vimpa03      GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
SC060        GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
huntii       GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTGGGAGATGATATCACC
vosnesenskii GGCAAGACCAACCTAGCCATGATGCAGCCGACGTTACCAGGGTACAAAGTCGAGTGCGTAGGAGATGATATCACC

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                     530  535  540  545  550  555  560  565  570  575  580  585  590  595
VEP01        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP03        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP05        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP07        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP09        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP12        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP17        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP19        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP21        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP23        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP25        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP34        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP35        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP37        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP44        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP45        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP46        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP47        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP48        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP49        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP52        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP53        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
VEP54        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
SC198        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
Vwilm06      TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
SC199        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
Vimpa03      TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
SC060        TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
huntii       TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
vosnesenskii TGGATGAAATTCGACCGGGAAGGCAGACTCCGTGCTATAAATCCAGAAAATGGATTCTTCGGCGTGGCACCCGGA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                605  610  615  620  625  630  635  640  645  650  655  660  665  670
VEP01        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP03        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP05        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP07        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP09        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP12        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP17        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP19        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP21        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP23        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP25        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP34        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP35        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP37        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP44        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP45        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP46        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP47        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP48        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP49        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP52        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP53        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
VEP54        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
SC198        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
Vwilm06      ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
SC199        ACCAATAGCGCTACCAATCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
Vimpa03      ACCAATAGCGCTACCAAYCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
SC060        ACCAATAGCGCTACCAAYCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
huntii       ACCAATAGCGCTACCAACCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC
vosnesenskii ACCAATAGCGCTACCAACCCTAATGCTATGAGAACTATCTTCAAGAACACTATCTTCACCAATGTGGCCGCAACC

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                680  685  690  695  700  705  710  715  720  725  730  735  740  745
VEP01        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP03        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP05        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP07        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP09        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP12        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP17        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP19        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP21        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP23        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP25        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP34        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP35        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP37        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP44        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP45        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP46        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP47        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP48        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP49        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP52        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP53        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
VEP54        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
SC198        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
Vwilm06      AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
SC199        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
Vimpa03      AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
SC060        AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
huntii       AGCGACGGAGGAGTCTTCTGGGAGGGATTGGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
vosnesenskii AGCGACGGAGGAGTCTTCTGGGAGGGATTAGAAAAAGAAATCAGCGATGACGTTGAAGTAGGAATTCATTATTAC
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 755  760  765  770  775  780  785  790  795  800  805  810  815  820
VEP01        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP03        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP05        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP07        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP09        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP12        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP17        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP19        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP21        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP23        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP25        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP34        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP35        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP37        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP44        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP45        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP46        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP47        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP48        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP49        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP52        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP53        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
VEP54        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
SC198        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
Vwilm06      GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
SC199        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
Vimpa03      GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
SC060        GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
huntii       GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA
vosnesenskii GCATGAAAGTATTTAAAAAATCCTTATCATTAAACTGCGGATGTTTTTCTATTTATAAGAAATTTAAAAACTCAA

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             ....|....|....|....|....|....|....|....|....|....|....|...
                 830  835  840  845  850  855  860  865  870  875
VEP01        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP03        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP05        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP07        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP09        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP12        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP17        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP19        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP21        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP23        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP25        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP34        CATTTCCTAAAACTTYCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP35        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP37        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP44        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP45        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP46        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP47        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP48        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP49        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP52        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP53        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
VEP54        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
SC198        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
Vwilm06      CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
SC199        CATTTCCTAAAACTTTCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG1
Vimpa03      CATCTCCTAAAACTTYCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG0
SC060        CATYTCCTAAAACTTYCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG0
huntii       AATTTCCTAAAACTTCCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG0
vosnesenskii CATTTCCTAAAACTTGCCTAAGTAAACATATTTGTATAGATCACCGATTGGCG0
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Appendix A. (cont.)

COI Alignment

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 5   10   15   20   25   30   35   40   45   50   55   60   65   70
VEP01        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP02        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP03        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP05        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCTATTTTTTCTTTACATATA
VEP07        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP09        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP12        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCATTACATATA
VEP14        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATG
VEP13        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP17        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP18        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP19        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP20        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP21        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP22        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP23        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP24        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP25        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP26        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP27        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP28        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP29        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCTATTTTTTCTTTACATATA
VEP30        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP33        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP34        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP35        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP36        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP37        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP38        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP43        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCTATTTTTTCTTTACATATA
VEP44        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP45        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP46        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP47        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP48        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP49        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP50        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP51        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP52        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP53        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP54        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
VEP55        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
SC198        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
Viwlm03      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vwilm04      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vwilm06      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vwilm07      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vwilm10      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
SC199        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCTTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vimpa02      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vimpa03      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vimpa04      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
Vimpa06      GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
IM420        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
IM412        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATGGCAATTTTTTCTTTACATATA
IM423        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
IM424        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
IM426        GTATATCCTCCATTATCATCTTATTTATTTCATTCATCACCCTCAGTAGATATTGCAATTTTTTCTTTACATATA
huntii       GTATATCCACCTTTATCTTCTTATATATTTCATTCATCACCTTCTGTAGATATTGCAATTTTTTCATTACATATA
vosnesenskii GTATATCCACCCCTATCATCTTATATATTTCACTCATCACCATCTGTAGATATTGCAATTTTTTCACTTCATATA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 80   85   90   95  100  105  110  115  120  125  130  135  140  145
VEP01        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP02        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP03        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP05        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP07        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP09        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP12        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP14        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP13        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP17        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP18        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP19        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP20        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP21        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP22        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP23        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP24        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP25        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP26        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP27        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP28        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP29        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP30        ACAGGAATTTCTTCCATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP33        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP34        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP35        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP36        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP37        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP38        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP43        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP44        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP45        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP46        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP47        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP48        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP49        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP50        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP51        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP52        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP53        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP54        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
VEP55        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
SC198        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
Viwlm03      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAC
Vwilm04      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAC
Vwilm06      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAC
Vwilm07      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAC
Vwilm10      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAC
SC199        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAC
Vimpa02      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
Vimpa03      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
Vimpa04      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
Vimpa06      ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
IM420        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
IM412        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
IM423        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
IM424        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
IM426        ACAGGAATTTCTTCTATTATTGGTTCATTAAATTTTATTGTTACAATTATATTAATAAAAAATTTTTCATTAAAT
huntii       ACAGGAATTTCTTCAATTATTGGCTCATTAAATTTTATTGTAACTATTATATTAATAAAAAATTTTTCATTAAAT
vosnesenskii ACAGGAATCTCTTCAATTATTGGTTCATTAAATTTTATCGTTACTATTTATTAATAAAAAATTTTTCATTAAAT
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
               155  160  165  170  175  180  185  190  195  200  205  210  215  220
VEP01        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP02        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP03        TATGATCAAATTACTTTATTTTCTTGATCTGTRTGTATTACAGTATTATTATTAATTTTATCATTACCAGTTYTA
VEP05        TATGATCAAATTAATTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP07        TATGATCAAATTAATTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP09        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP12        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP14        TATGATCAAATTACTTTATTTTCTTGATCTGTRTGTATTACAGTATTATTATTAATTTTATCATTACCAGTTYTA
VEP13        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP17        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP18        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP19        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP20        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP21        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP22        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP23        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP24        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP25        TATGATCAAATTAATTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP26        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP27        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP28        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP29        TATGATCAAATTAATTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP30        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP33        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP34        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP35        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP36        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP37        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP38        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP43        TATGATCAAATTAATTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTCTA
VEP44        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP45        TATGATCAAATTACTTTATTTTCTTGATCCGTATGTATTACAGTATTATTATTAATTTTATCATTACCGGTTTTA
VEP46        TATGATCAAATTACTTTATTTTCTTGATCCGTATGTATTACAGTATTATTATTAATTTTATCATTACCGGTTTTA
VEP47        TATGATCAAATTACTTTATTTTCTTGATCCGTATGTATTACAGTATTATTATTAATTTTATCATTACCGGTTTTA
VEP48        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP49        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP50        TATGATCAAATTACTTTATTTTCTTGATCCGTATGTATTACAGTATTATTATTAATTTTATCATTACCGGTTTTA
VEP51        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP52        TATGATCAAATTACTTTATTTTCTTGATCCGTATGTATTACAGTATTATTATTAATTTTATCATTACCGGTTTTA
VEP53        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP54        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
VEP55        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
SC198        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTACCAGTTTTA
Viwlm03      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTGCCAGTTTTA
Vwilm04      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTGCCAGTTTTA
Vwilm06      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTGCCAGTTTTA
Vwilm07      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTGCCAGTTTTA
Vwilm10      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTGCCAGTTTTA
SC199        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTATTATTATTAATTTTATCATTGCCAGTTTTA
Vimpa02      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
Vimpa03      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
Vimpa04      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
Vimpa06      TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
IM420        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
IM412        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
IM423        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
IM424        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
IM426        TATGATCAAATTACTTTATTTTCTTGATCTGTATGTATTACAGTTTTATTATTAATTTTATCATTACCAGTTTTA
huntii       TATGATCAAATTAATTTATTTTCATGATCAGTATGTATTACTGTTATACTATTAATTTTATCTCTTCCAGTTTTA
vosnesenskii TATGATCAAATTAACTTATTTTCATGATCAGTATGTATTACTGTTATATTATTAATTTTATCTCTTCCAGTTCTA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                230  235  240  245  250  255  260  265  270  275  280  285  290  295
VEP01        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP02        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP03        GCTGGARCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP05        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP07        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP09        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP12        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP14        GCTGGARCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP13        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGACCCAATAGGTGGTGGAGAT
VEP17        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGACCCAATAGGTGGTGGAGAT
VEP18        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP19        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGACCCAATAGGTGGTGGAGAT
VEP20        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP21        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP22        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP23        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP24        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP25        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP26        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP27        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP28        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP29        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP30        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGAGGAGAT
VEP33        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP34        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP35        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGGGAT
VEP36        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP37        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP38        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP43        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP44        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP45        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGGGGTGGAGAT
VEP46        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGGGGTGGAGAT
VEP47        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGGGGTGGAGAT
VEP48        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP49        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP50        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGGGGTGGAGAT
VEP51        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP52        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGGGGTGGAGAT
VEP53        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP54        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
VEP55        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
SC198        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGACCCAATAGGTGGTGGAGAT
Viwlm03      GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
Vwilm04      GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
Vwilm06      GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
Vwilm07      GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
Vwilm10      GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
SC199        GCTGGGGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGAGAT
Vimpa02      GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
Vimpa03      GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
Vimpa04      GCTGGAGCAATTACCATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
Vimpa06      GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
IM420        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGWGAT
IM412        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
IM423        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
IM424        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGTGAT
IM426        GCTGGAGCAATTACTATACTTCTTTTTGATCGAAATTTTAATACATCATTTTTTGATCCAATAGGTGGTGGWGAT
huntii       GCAGGGGCAATTACTATACTTTTATTTGATCGAAATTTTAATACATCATTTTTTGATCCTATAGGAGGAGGAGAT
vosnesenskii GCAGGAGCAATTACCATACTTTTATTCGATCGAAATTTTAATACATCATTTTTCGATCCTATAGGAGGTGGAGAT
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                305  310  315  320  325  330  335  340  345  350  355  360  365  370
VEP01        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP02        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP03        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP05        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP07        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP09        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP12        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP14        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP13        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP17        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP18        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP19        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP20        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP21        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP22        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP23        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP24        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP25        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP26        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP27        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP28        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP29        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP30        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP33        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP34        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP35        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP36        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP37        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP38        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP43        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCCGGATTTGGA
VEP44        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP45        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP46        CCAATTTTATATCAACATTTATTTTGATTTTTTGGGCATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP47        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP48        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP49        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP50        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP51        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP52        CCAATTTTATATCAACATTTATTTTGATTTTTTGGGCATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP53        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP54        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
VEP55        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
SC198        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGG
Viwlm03      CCAATTTTATACCAACATTTATTTTGATTTTTTGGACAYCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vwilm04      CCAATTTTATACCAACATTTATTTTGATTTTTTGGACACCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vwilm06      CCAATTTTATACCAACATTTATTTTGATTTTTTGGRCAYCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vwilm07      CCAATTTTATACCAACATTTATTTTGATTTTTTGGACACCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vwilm10      CCAATTTTATACCAACATTTATTTTGATTTTTTGGACACCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
SC199        CCAATTTTATACCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vimpa02      CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vimpa03      CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vimpa04      CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
Vimpa06      CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
IM420        CCAATTTTATAYCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
IM412        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
IM423        CCAATTTTATATCAACATTTATTTTGATTTTTTGGRCATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
IM424        CCAATTTTATATCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
IM426        CCAATTTTATAYCAACATTTATTTTGATTTTTTGGACATCCTGAAGTTTATATTTTAATTCTTCCTGGATTTGGA
huntii       CCAATTTTATATCAACATTTATTTTGATTTTTCGGTCACCCAGAAGTTTATATTTTAATTCTTCCAGGATTTGGA
vosnesenskii CCAATTTTATATCAACACTTATTTTGATTTTTTGGTCACCCAGAAGTTTATATTTTAATTCTTCCAGGATTTGGA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 380  385  390  395  400  405  410  415  420  425  430  435  440  445
VEP01        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP02        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP03        CTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP05        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP07        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP09        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP12        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP14        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP13        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP17        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP18        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP19        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP20        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP21        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP22        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP23        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP24        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP25        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP26        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP27        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP28        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP29        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP30        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP33        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP34        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP35        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP36        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP37        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP38        YTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP43        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP44        CTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP45        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP46        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP47        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP48        CTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP49        CTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP50        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP51        CTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP52        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP53        CTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP54        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
VEP55        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
SC198        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Viwlm03      TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vwilm04      TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vwilm06      TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vwilm07      TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vwilm10      TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
SC199        TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vimpa02      TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vimpa03      TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vimpa04      TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
Vimpa06      TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
IM420        TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
IM412        TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
IM423        TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
IM424        TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
IM426        TTAATTTCACAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
huntii       TTAATTTCTCAAATTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCTATA
vosnesenskii TTAATTTCTCAAGTTATTATAAATGAAAGAGGAAAAAAAGAAACTTTTGGAAATTTAAGAATAATTTATGCAATA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
               455  460  465  470  475  480  485  490  495  500  505  510  515  520
VEP01        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP02        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP03        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCWCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP05        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP07        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP09        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP12        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP14        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCWCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP13        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP17        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP18        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP19        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP20        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP21        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP22        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP23        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP24        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP25        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP26        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP27        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP28        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP29        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP30        ATAGGAATTGGCTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP33        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP34        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP35        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP36        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP37        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP38        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP43        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP44        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP45        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP46        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP47        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP48        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP49        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP50        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP51        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP52        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP53        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP54        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
VEP55        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
SC198        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Viwlm03      ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vwilm04      ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vwilm06      ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vwilm07      ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vwilm10      ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
SC199        ATAGGAATTGGTTTTTTAGGTTTTATTGTTTGAGCACATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vimpa02      ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vimpa03      ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vimpa04      ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
Vimpa06      ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
IM420        ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGGTTAGATGTTGATACTCGA
IM412        ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGGTTAGATGTTGATACTCGA
IM423        ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGGTTAGATGTTGATACTCGA
IM424        ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
IM426        ATAGGAATTGGATTTTTAGGATTTATTGTTTGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
huntii       TTAGGAATTGGATTCTTAGGATTTATTGTATGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
vosnesenskii CTAGGAATTGGATTTTTAGGCTTTATTGTATGAGCTCATCATATATTTACTGTTGGATTAGATGTTGATACTCGA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
               530  535  540  545  550  555  560  565  570  575  580  585  590  595
VEP01        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP02        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP03        GCTTAYTTTACYTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP05        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP07        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP09        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP12        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP14        GCTTAYTTTACYTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP13        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP17        GCTTATTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP18        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP19        GCTTATTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP20        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP21        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP22        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP23        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP24        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP25        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP26        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP27        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP28        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP29        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP30        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP33        GCTTACTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP34        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP35        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP36        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP37        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP38        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP43        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP44        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP45        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP46        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP47        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP48        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP49        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP50        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP51        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP52        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP53        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP54        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
VEP55        GCTTACTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
SC198        GCTTATTTTACCTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
Viwlm03      GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
Vwilm04      GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
Vwilm06      GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
Vwilm07      GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
Vwilm10      GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
SC199        GCTTATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAT
Vimpa02      GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
Vimpa03      GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
Vimpa04      GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
Vimpa06      GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
IM420        GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAY
IM412        GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
IM423        GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
IM424        GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
IM426        GCATATTTTACTTCAGCTACAATAATTATTGCAGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACATAC
huntii       GCTTATTTTACATCAGCAACAATAATTATTGCTGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACTTAT
vosnesenskii GCTTATTTCACATCAGCAACTATAATTATTGCTGTTCCTACAGGAATTAAAGTATTTAGATGATTAGCAACTTAT
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                     605  610  615  620  625  630  635  640  645  650  655  660  665  670
VEP01        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP02        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP03        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATSAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP05        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP07        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP09        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP12        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP14        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATSAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP13        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP17        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP18        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP19        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP20        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP21        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP22        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP23        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP24        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP25        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP26        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP27        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP28        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP29        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP30        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP33        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP34        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP35        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP36        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP37        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP38        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP43        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP44        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP45        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP46        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP47        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP48        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP49        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP50        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP51        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP52        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP53        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP54        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
VEP55        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
SC198        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
Viwlm03      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
Vwilm04      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
Vwilm06      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
Vwilm07      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
Vwilm10      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
SC199        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
Vimpa02      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
Vimpa03      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
Vimpa04      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
Vimpa06      CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
IM420        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
IM412        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
IM423        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
IM424        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
IM426        CATGGTTCAAAAATAAATTTAAATATTACAATTATTTGATCAATTGGTTTTATCTTAATATTTACAATTGGAGGA
huntii       CACGGTTCAAAAATAAATTTTAATATTACAATCATTTGATCAATTGGTTTTATTTTAATATTTACAATTGGAGGA
vosnesenskii CATGGTTCAAAAATAAATTTTAATATTACAACTATTTGATCTATTGGTTTTATTTTAATATTCACAATTGGTGGA
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
                 680  685  690  695  700  705  710  715  720  725  730  735  740  745
VEP01        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP02        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP03        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP05        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP07        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP09        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP12        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP14        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP13        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP17        TTAACAGGGGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP18        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP19        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP20        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP21        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP22        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP23        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP24        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP25        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP26        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP27        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP28        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP29        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP30        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTACTATGTAGTAGGTCATTTT
VEP33        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP34        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP35        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP36        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP37        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP38        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP43        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
VEP44        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP45        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP46        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP47        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP48        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP49        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP50        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP51        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP52        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP53        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP54        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
VEP55        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
SC198        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCACTTT
Viwlm03      TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vwilm04      TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vwilm06      TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vwilm07      TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vwilm10      TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
SC199        TTAACAGGAGTAATATTATCAAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vimpa02      TTAACAGGAGTAATATTATCAAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vimpa03      TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vimpa04      TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
Vimpa06      TTAACAGGAGTAATATTATCAAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
IM420        TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
IM412        TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
IM423        TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
IM424        TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
IM426        TTAACAGGAGTAATATTATCGAACTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTAGGTCATTTT
huntii       TTAACAGGTGTAATATTATCTAATTCATCAATTGATATTATTTTACATGATACTTATTATGTAGTTGGACATTTT
vosnesenskii TTAACGGGAGTAATATTATCTAATTCATCAATTGATATTATTTTACATGATACCTATTATGTAGTTGGACATTTC
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Appendix A. (cont.)

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             ....|....|....|....|....|....|....|....|....|....|....|....|.
                755  760  765  770  775  780  785  790  795  800  805
VEP01        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP02        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP03        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP05        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP07        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP09        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP12        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP14        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP13        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP17        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP18        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP19        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP20        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP21        CATTATGTATTATCAATAGGGGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP22        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP23        CATTATGTATTATCAATAGGGGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP24        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP25        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP26        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP27        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP28        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP29        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP30        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP33        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP34        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP35        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP36        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP37        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP38        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP43        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP44        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP45        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGGTTAATTCATTGATATC
VEP46        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGGTTAATTCATTGATATC
VEP47        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGGTTAATTCATTGATATC
VEP48        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP49        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP50        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGGTTAATTCATTGATATC
VEP51        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP52        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGGTTAATTCATTGATATC
VEP53        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP54        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
VEP55        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
SC198        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Viwlm03      CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vwilm04      CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vwilm06      CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vwilm07      CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vwilm10      CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
SC199        CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vimpa02      CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vimpa03      CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vimpa04      CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
Vimpa06      CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
IM420        CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
IM412        CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
IM423        CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
IM424        CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
IM426        CATTATGTATTATCTATAGGAGCAGTTTTTGCTATTATTACAAGATTAATTCATTGATATC
huntii       CATTACGTACTATCAATAGGAGCAGTTTTTGCTATTATTACAAGATTTATTCATTGATATC
vosnesenskii CATTATGTATTATCAATAGGAGCAGTTTTTGCTATTATTACTAGATTTATTCACTGATATC
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Appendix B. Sequence distance matrices. Matrices of Uncorrected “p” distances for sequence datasets.

CAD Distance Matrix

	VEP20	VEP45	VEP46	VEP47	VEP49	VEP03	VEP26	VEP12	VEP22	VEP37	VEP36	VEP13	VEP21	VEP34	VEP35	VEP05
VEP20																
VEP45	0.00242															
VEP46	0.00242	0														
VEP47	0.00242	0	0													
VEP49	0.00725	0.00483	0.00483	0.00483												
VEP03	0.00242	0	0	0	0.00483											
VEP26	0.00242	0	0	0	0.00483	0										
VEP12	0.00242	0	0	0	0.00483	0	0									
VEP22	0.00242	0	0	0	0.00483	0	0	0								
VEP37	0.00242	0	0	0	0.00483	0	0	0	0							
VEP36	0.00242	0	0	0	0.00483	0	0	0	0	0						
VEP13	0.00242	0	0	0	0.00483	0	0	0	0	0	0					
VEP21	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0				
VEP34	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0			
VEP35	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0		
VEP05	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	
VEP43	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	0
VEP29	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	0
VEP07	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	0
VEP25	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	0
VEP17	0.00366	0.00122	0.00122	0.00122	0.00121	0.00122	0.00122	0.00122	0.00122	0.00122	0.00122	0.00122	0.00122	0.00122	0.00122	0.00122
Viwlm04	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	0
Vwilm03	0.00242	0	0	0	0.00483	0	0	0	0	0	0	0	0	0	0	0
Vimpa02	0.00848	0.00847	0.00847	0.00847	0.00484	0.00847	0.00847	0.00847	0.00847	0.00847	0.00847	0.00847	0.00847	0.00847	0.00847	0.00847
Vimpa04	0.00363	0.00362	0.00362	0.00362	0.00846	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362
Vimpa06	0.00364	0.00362	0.00362	0.00362	0.00363	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362
huntii	0.00485	0.00485	0.00485	0.00485	0.00727	0.00485	0.00485	0.00485	0.00485	0.00485	0.00485	0.00485	0.00485	0.00485	0.00485	0.00485
vosnesenskii	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725	0.00725

Appendix B. (cont.)

	VEP43	**VEP29**	**VEP07**	**VEP25**	**VEP17**	**Vwilm04**	**Vwilm03**	**Vimpa02**	**Vimpa04**	**Vimpa06**	***huntii***
VEP20											
VEP45											
VEP46											
VEP47											
VEP49											
VEP03											
VEP26											
VEP12											
VEP22											
VEP37											
VEP36											
VEP13											
VEP21											
VEP34											
VEP35											
VEP05											
VEP43											
VEP29	0										
VEP07	0	0									
VEP25	0	0	0								
VEP17	0.00122	0.00122	0.00122	0.00122							
Viwlm04	0	0	0	0	0.00122						
Vwilm03	0	0	0	0	0.00122	0					
Vimpa02	0.00847	0.00847	0.00847	0.00847	0.00606	0.00847	0.00847				
Vimpa04	0.00362	0.00362	0.00362	0.00362	0.00365	0.00362	0.00362	0.00727			
Vimpa06	0.00362	0.00362	0.00362	0.00362	0.00244	0.00362	0.00362	0.00363	0.00242		
huntii	0.00485	0.00485	0.00485	0.00485	0.00489	0.00485	0.00485	0.0073	0.00606	0.00364	
vosnesenskii	0.00725	0.00725	0.00725	0.00725	0.00485	0.00725	0.00725	0.00726	0.00846	0.00483	0.00121

Appendix B. (cont.)

PEPCK Distance Matrix

	VEP01	VEP03	VEP05	VEP07	VEP09	VEP12	VEP17	VEP19	VEP21	VEP23	VEP25	VEP34	VEP35	VEP37	VEP44	VEP45
VEP01																
VEP03	0.00114															
VEP05	0	0.00114														
VEP07	0	0.00114	0													
VEP09	0.00228	0.00342	0.00228	0.00228												
VEP12	0	0.00114	0	0	0.00228											
VEP17	0	0.00114	0	0	0.00228	0										
VEP19	0	0.00114	0	0	0.00228	0	0									
VEP21	0	0.00114	0	0	0.00228	0	0	0								
VEP23	0	0.00114	0	0	0.00228	0	0	0	0							
VEP25	0	0.00114	0	0	0.00228	0	0	0	0	0						
VEP34	0.00114	0	0.00114	0.00114	0.00342	0.00114	0.00114	0.00114	0.00114	0.00114	0.00114					
VEP35	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114				
VEP37	0.00228	0.00114	0.00228	0.00228	0.00456	0.00228	0.00228	0.00228	0.00228	0.00228	0.00228	0.00114	0.00228			
VEP44	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228		
VEP45	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	
VEP46	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
VEP47	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
VEP48	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
VEP49	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
VEP52	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
VEP53	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
VEP54	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
SC198	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
Vwilm06	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
SC199	0	0.00114	0	0	0.00228	0	0	0	0	0	0	0.00114	0	0.00228	0	0
Vimpa03	0.00116	0.00231	0.00116	0.00116	0.00344	0.00116	0.00116	0.00116	0.00116	0.00116	0.00116	0.00231	0.00116	0.00346	0.00116	0.00116
SC060	0	0.00115	0	0	0.00228	0	0	0	0	0	0	0.00115	0	0.0023	0	0
huntii	0.00802	0.00917	0.00802	0.00802	0.0103	0.00802	0.00802	0.00802	0.00802	0.00802	0.00802	0.00804	0.00802	0.01032	0.00802	0.00802
vosnesenskii	0.00686	0.00802	0.00686	0.00686	0.00914	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00801	0.00686	0.00916	0.00686	0.00686

Appendix B. (cont.)

	VEP46	**VEP47**	**VEP48**	**VEP49**	**VEP52**	**VEP53**	**VEP54**	**SC198**	**Vwilm06**	**SC199**	**Vimpa03**	**SC060**	***huntii***
VEP01													
VEP03													
VEP05													
VEP07													
VEP09													
VEP12													
VEP17													
VEP19													
VEP21													
VEP23													
VEP25													
VEP34													
VEP35													
VEP37													
VEP44													
VEP45													
VEP46													
VEP47	0												
VEP48	0	0											
VEP49	0	0	0										
VEP52	0	0	0	0									
VEP53	0	0	0	0	0								
VEP54	0	0	0	0	0	0							
SC198	0	0	0	0	0	0	0						
Vwilm06	0	0	0	0	0	0	0	0					
SC199	0	0	0	0	0	0	0	0	0				
Vimpa03	0.00116	0.00116	0.00116	0.00116	0.00116	0.00116	0.00116	0.00116	0.00116	0.00116			
SC060	0	0	0	0	0	0	0	0	0	0	0		
huntii	0.00802	0.00802	0.00802	0.00802	0.00802	0.00802	0.00802	0.00802	0.00802	0.00802	0.00573	0.00458	
vosnesenskii	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00573	0.00458	0.00687

Appendix B. (cont.)

COI Distance Matrix

	VEP02	VEP09	VEP28	VEP18	VEP20	VEP23	VEP24	VEP27	VEP30	VEP44	VEP45	VEP46	VEP47	VEP48	VEP49	VEP50
VEP02																
VEP09	0															
VEP28	0	0														
VEP18	0	0	0													
VEP20	0	0	0	0												
VEP23	0.00123	0.00123	0.00123	0.00123	0.00123											
VEP24	0	0	0	0	0	0.00123										
VEP27	0	0	0	0	0	0.00123	0									
VEP30	0	0	0	0	0	0.00123	0	0								
VEP44	0.00986	0.00986	0.00986	0.00986	0.00986	0.0111	0.00986	0.00986	0.00986							
VEP45	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00863						
VEP46	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00986	0.00123					
VEP47	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00863	0	0.00123				
VEP48	0.00986	0.00986	0.00986	0.00986	0.00986	0.0111	0.00986	0.00986	0.00986	0	0.00863	0.00986	0.00863			
VEP49	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00123	0.00986	0.0111	0.00986	0.00123		
VEP50	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00863	0	0.00123	0	0.00863	0.00986	
VEP51	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00123	0.00986	0.0111	0.00986	0.00123	0	0.00986
VEP52	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00986	0.00123	0	0.00123	0.00986	0.0111	0.00123
VEP53	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00123	0.00986	0.0111	0.00986	0.00123	0	0.00986
VEP54	0.00863	0.00863	0.00863	0.00863	0.00863	0.00986	0.00863	0.00863	0.00863	0.00123	0.0074	0.00863	0.0074	0.00123	0.00247	0.0074
VEP55	0.00986	0.00986	0.00986	0.00986	0.00986	0.0111	0.00986	0.00986	0.00986	0.00247	0.00863	0.00986	0.00863	0.00247	0.00123	0.00863
VEP03	0.00991	0.00991	0.00991	0.00991	0.00991	0.01116	0.00991	0.00991	0.00991	0.00247	0.00869	0.00993	0.00869	0.00247	0.00124	0.00869
VEP14	0.00991	0.00991	0.00991	0.00991	0.00991	0.01115	0.00991	0.00991	0.00991	0.00497	0.00868	0.00993	0.00868	0.00497	0.00373	0.00868
VEP26	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00493	0.0111	0.01233	0.0111	0.00493	0.0037	0.0111
VEP05	0.0148	0.0148	0.0148	0.0148	0.0148	0.01603	0.0148	0.0148	0.0148	0.0074	0.01356	0.0148	0.01356	0.0074	0.00617	0.01356
VEP29	0.0148	0.0148	0.0148	0.0148	0.0148	0.01603	0.0148	0.0148	0.0148	0.0074	0.01356	0.0148	0.01356	0.0074	0.00617	0.01356
VEP43	0.01603	0.01603	0.01603	0.01603	0.01603	0.01726	0.01603	0.01603	0.01603	0.00863	0.0148	0.01603	0.0148	0.00863	0.0074	0.0148
VEP12	0.01356	0.01356	0.01356	0.01356	0.01356	0.0148	0.01356	0.01356	0.01356	0.00617	0.01233	0.01356	0.01233	0.00617	0.00493	0.01233
VEP22	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00493	0.0111	0.01233	0.0111	0.00493	0.0037	0.0111
VEP33	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00617	0.00986	0.0111	0.00986	0.00617	0.00493	0.00986

Appendix B. (cont.)

	VEP02	VEP09	VEP28	VEP18	VEP20	VEP23	VEP24	VEP27	VEP30	VEP44	VEP45	VEP46	VEP47	VEP48	VEP49	VEP50
VEP36	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00493	0.0111	0.01233	0.0111	0.00493	0.0037	0.0111
VEP37	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00493	0.0111	0.01233	0.0111	0.00493	0.0037	0.0111
VEP38	0.01235	0.01235	0.01235	0.01235	0.01235	0.01358	0.01235	0.01235	0.01235	0.0037	0.01111	0.01235	0.01111	0.0037	0.00247	0.01111
VEP01	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00493	0.0111	0.01233	0.0111	0.00493	0.0037	0.0111
VEP07	0.01356	0.01356	0.01356	0.01356	0.01356	0.0148	0.01356	0.01356	0.01356	0.00617	0.01233	0.01356	0.01233	0.00617	0.00493	0.01233
VEP25	0.01356	0.01356	0.01356	0.01356	0.01356	0.0148	0.01356	0.01356	0.01356	0.00617	0.01233	0.01356	0.01233	0.00617	0.00493	0.01233
VEP13	0.01356	0.01356	0.01356	0.01356	0.01356	0.0148	0.01356	0.01356	0.01356	0.00617	0.01233	0.01356	0.01233	0.00617	0.00493	0.01233
VEP21	0.01356	0.01356	0.01356	0.01356	0.01356	0.01233	0.01356	0.01356	0.01356	0.00617	0.01233	0.01356	0.01233	0.00617	0.00493	0.01233
VEP34	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.00493	0.0111	0.01233	0.0111	0.00493	0.0037	0.0111
VEP35	0.01356	0.01356	0.01356	0.01356	0.01356	0.0148	0.01356	0.01356	0.01356	0.00617	0.01233	0.01356	0.01233	0.00617	0.00493	0.01233
SC198	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.0074	0.0111	0.01233	0.0111	0.0074	0.00617	0.0111
VEP17	0.01233	0.01233	0.01233	0.01233	0.01233	0.01356	0.01233	0.01233	0.01233	0.0074	0.0111	0.01233	0.0111	0.0074	0.00617	0.0111
VEP19	0.0111	0.0111	0.0111	0.0111	0.0111	0.01233	0.0111	0.0111	0.0111	0.00617	0.00986	0.0111	0.00986	0.00617	0.00493	0.00986
SC199	0.00863	0.00863	0.00863	0.00863	0.00863	0.00986	0.00863	0.00863	0.00863	0.00863	0.00986	0.0111	0.00986	0.00863	0.0074	0.00986
Vwilm03	0.00864	0.00864	0.00864	0.00864	0.00864	0.00987	0.00864	0.00864	0.00864	0.00864	0.00987	0.0111	0.00987	0.00864	0.0074	0.00987
Vwilm04	0.00986	0.00986	0.00986	0.00986	0.00986	0.0111	0.00986	0.00986	0.00986	0.00986	0.0111	0.01233	0.0111	0.00986	0.00863	0.0111
Vwilm06	0.00864	0.00864	0.00864	0.00864	0.00864	0.00988	0.00864	0.00864	0.00864	0.00865	0.00988	0.0099	0.00988	0.00865	0.00741	0.00988
Vwilm07	0.00986	0.00986	0.00986	0.00986	0.00986	0.0111	0.00986	0.00986	0.00986	0.00986	0.0111	0.01233	0.0111	0.00986	0.00863	0.0111
Vwilm10	0.00986	0.00986	0.00986	0.00986	0.00986	0.0111	0.00986	0.00986	0.00986	0.00986	0.0111	0.01233	0.0111	0.00986	0.00863	0.0111
IM420	0.01977	0.01977	0.01977	0.01977	0.01977	0.021	0.01977	0.01977	0.01977	0.01853	0.01976	0.021	0.01976	0.01853	0.01856	0.01976
IM412	0.02343	0.02343	0.02343	0.02343	0.02343	0.02466	0.02343	0.02343	0.02343	0.02219	0.02343	0.02466	0.02343	0.02219	0.02343	0.02343
IM423	0.0222	0.0222	0.0222	0.0222	0.0222	0.02344	0.0222	0.0222	0.0222	0.02097	0.0222	0.02222	0.0222	0.02097	0.0222	0.0222
IM424	0.02096	0.02096	0.02096	0.02096	0.02096	0.02219	0.02096	0.02096	0.02096	0.01973	0.02096	0.02219	0.02096	0.01973	0.02096	0.02096
IM426	0.01976	0.01976	0.01976	0.01976	0.01976	0.02099	0.01976	0.01976	0.01976	0.01852	0.01976	0.02099	0.01976	0.01852	0.01855	0.01976
Vimpa03	0.02096	0.02096	0.02096	0.02096	0.02096	0.02219	0.02096	0.02096	0.02096	0.01973	0.02096	0.02219	0.02096	0.01973	0.02096	0.02096
Vimpa04	0.02219	0.02219	0.02219	0.02219	0.02219	0.02343	0.02219	0.02219	0.02219	0.02096	0.02219	0.02343	0.02219	0.02096	0.02219	0.02219
Vimpa02	0.01973	0.01973	0.01973	0.01973	0.01973	0.02096	0.01973	0.01973	0.01973	0.0185	0.01973	0.02096	0.01973	0.0185	0.01973	0.01973
Vimpa06	0.01973	0.01973	0.01973	0.01973	0.01973	0.02096	0.01973	0.01973	0.01973	0.0185	0.01973	0.02096	0.01973	0.0185	0.01973	0.01973
vosnesenskii	0.08385	0.08385	0.08385	0.08385	0.08385	0.08508	0.08385	0.08385	0.08385	0.08261	0.08261	0.08261	0.08261	0.08261	0.08385	0.08261
huntii	0.06412	0.06412	0.06412	0.06412	0.06412	0.06535	0.06412	0.06412	0.06412	0.06782	0.06782	0.06782	0.06782	0.06782	0.06905	0.06782

Appendix B. (cont.)

	VEP51	VEP52	VEP53	VEP54	VEP55	VEP03	VEP14	VEP26	VEP05	VEP29	VEP43	VEP12	VEP22	VEP33	VEP36	VEP37
VEP02																
VEP09																
VEP28																
VEP18																
VEP20																
VEP23																
VEP24																
VEP27																
VEP30																
VEP44																
VEP45																
VEP46																
VEP47																
VEP48																
VEP49																
VEP50																
VEP51																
VEP52	0.0111															
VEP53	0	0.0111														
VEP54	0.00247	0.00863	0.00247													
VEP55	0.00123	0.00986	0.00123	0.00123												
VEP03	0.00124	0.00993	0.00124	0.00371	0.00247											
VEP14	0.00373	0.00993	0.00373	0.00371	0.00247	0.00248										
VEP26	0.0037	0.01233	0.0037	0.0037	0.00247	0.00123	0.00124									
VEP05	0.00617	0.0148	0.00617	0.00617	0.00493	0.0037	0.0037	0.00247								
VEP29	0.00617	0.0148	0.00617	0.00617	0.00493	0.0037	0.0037	0.00247	0							
VEP43	0.0074	0.01603	0.0074	0.0074	0.00617	0.00497	0.00498	0.0037	0.00123	0.00123						
VEP12	0.00493	0.01356	0.00493	0.00493	0.0037	0.00247	0.00248	0.00123	0.0037	0.0037	0.00493					
VEP22	0.0037	0.01233	0.0037	0.0037	0.00247	0.00123	0.00124	0	0.00247	0.00247	0.0037	0.00123				
VEP33	0.00493	0.0111	0.00493	0.00493	0.0037	0.00124	0.00124	0.00123	0.0037	0.0037	0.00493	0.00247	0.00123			

Appendix B. (cont.)

	VEP51	VEP52	VEP53	VEP54	VEP55	VEP03	VEP14	VEP26	VEP05	VEP29	VEP43	VEP12	VEP22	VEP33	VEP36	VEP37
VEP36	0.0037	0.01233	0.0037	0.0037	0.00247	0.00123	0.00124	0	0.00247	0.00247	0.0037	0.00123	0	0.00123		
VEP37	0.0037	0.01233	0.0037	0.0037	0.00247	0.00123	0.00124	0	0.00247	0.00247	0.0037	0.00123	0	0.00123	0	
VEP38	0.00247	0.01235	0.00247	0.00371	0.00247	0	0.00124	0	0.00247	0.00247	0.0037	0.00123	0	0.00124	0	0
VEP01	0.0037	0.01233	0.0037	0.0037	0.00247	0.00123	0.00124	0	0.00247	0.00247	0.0037	0.00123	0	0.00123	0	0
VEP07	0.00493	0.01356	0.00493	0.00493	0.0037	0.00247	0.00247	0.00123	0.00123	0.00123	0.00247	0.00247	0.00123	0.00247	0.00123	0.00123
VEP25	0.00493	0.01356	0.00493	0.00493	0.0037	0.00247	0.00247	0.00123	0.00123	0.00123	0.00247	0.00247	0.00123	0.00247	0.00123	0.00123
VEP13	0.00493	0.01356	0.00493	0.00493	0.0037	0.00251	0.00251	0.00123	0.0037	0.0037	0.00493	0.00247	0.00123	0.00247	0.00123	0.00123
VEP21	0.00493	0.01356	0.00493	0.00493	0.0037	0.00248	0.00248	0.00123	0.0037	0.0037	0.00493	0.00247	0.00123	0.00247	0.00123	0.00123
VEP34	0.0037	0.01233	0.0037	0.0037	0.00247	0.00123	0.00124	0	0.00247	0.00247	0.0037	0.00123	0	0.00123	0	0
VEP35	0.00493	0.01356	0.00493	0.00493	0.0037	0.00248	0.00248	0.00123	0.0037	0.0037	0.00493	0.00247	0.00123	0.00247	0.00123	0.00123
SC198	0.00617	0.01233	0.00617	0.00617	0.00493	0.00373	0.00373	0.00493	0.0074	0.0074	0.00863	0.00617	0.00493	0.00617	0.00493	0.00493
VEP17	0.00617	0.01233	0.00617	0.00617	0.00493	0.00373	0.00373	0.00493	0.0074	0.0074	0.00863	0.00617	0.00493	0.00617	0.00493	0.00493
VEP19	0.00493	0.0111	0.00493	0.00493	0.0037	0.00249	0.00248	0.0037	0.00617	0.00617	0.0074	0.00493	0.0037	0.00493	0.0037	0.0037
SC199	0.0074	0.0111	0.0074	0.0074	0.00617	0.00621	0.00621	0.00863	0.0111	0.0111	0.01233	0.00986	0.00863	0.0074	0.00863	0.00863
Vwilm03	0.0074	0.0111	0.0074	0.00741	0.00617	0.00621	0.00621	0.00863	0.0111	0.0111	0.01233	0.00987	0.00863	0.0074	0.00863	0.00863
Vwilm04	0.00863	0.01233	0.00863	0.00863	0.0074	0.00744	0.00744	0.00986	0.01233	0.01233	0.01356	0.0111	0.00986	0.00863	0.00986	0.00986
Vwilm06	0.00741	0.0099	0.00741	0.00741	0.00618	0.00622	0.00622	0.00864	0.01111	0.01111	0.01234	0.00988	0.00864	0.00741	0.00864	0.00864
Vwilm07	0.00863	0.01233	0.00863	0.00863	0.0074	0.00744	0.00744	0.00986	0.01233	0.01233	0.01356	0.0111	0.00986	0.00863	0.00986	0.00986
Vwilm10	0.00863	0.01233	0.00863	0.00863	0.0074	0.00744	0.00744	0.00986	0.01233	0.01233	0.01356	0.0111	0.00986	0.00863	0.00986	0.00986
IM420	0.01856	0.021	0.01856	0.0173	0.01731	0.01613	0.01611	0.01981	0.02227	0.02227	0.02352	0.02104	0.01981	0.01856	0.01981	0.01981
IM412	0.02343	0.02466	0.02343	0.02096	0.02219	0.02103	0.02102	0.02466	0.02713	0.02713	0.02836	0.02589	0.02466	0.02343	0.02466	0.02466
IM423	0.0222	0.02222	0.0222	0.01974	0.02097	0.01981	0.0198	0.02344	0.0259	0.0259	0.02714	0.02467	0.02344	0.0222	0.02344	0.02344
IM424	0.02096	0.02219	0.02096	0.0185	0.01973	0.01855	0.01854	0.02219	0.02466	0.02466	0.02589	0.02343	0.02219	0.02096	0.02219	0.02219
IM426	0.01855	0.02099	0.01855	0.01729	0.0173	0.01611	0.01609	0.0198	0.02226	0.02226	0.02351	0.02103	0.0198	0.01855	0.0198	0.0198
Vimpa03	0.02096	0.02219	0.02096	0.0185	0.01973	0.01855	0.01854	0.02219	0.02466	0.02466	0.02589	0.02343	0.02219	0.02096	0.02219	0.02219
Vimpa04	0.02219	0.02343	0.02219	0.01973	0.02096	0.01978	0.01978	0.02343	0.02589	0.02589	0.02713	0.02466	0.02343	0.02219	0.02343	0.02343
Vimpa02	0.01973	0.02096	0.01973	0.01726	0.0185	0.01731	0.0173	0.02096	0.02343	0.02343	0.02466	0.02219	0.02096	0.01973	0.02096	0.02096
Vimpa06	0.01973	0.02096	0.01973	0.01726	0.0185	0.01731	0.0173	0.02096	0.02343	0.02343	0.02466	0.02219	0.02096	0.01973	0.02096	0.02096
vosnesenskii	0.08385	0.08261	0.08385	0.08138	0.08261	0.08172	0.08172	0.08261	0.08261	0.08261	0.08261	0.08138	0.08261	0.08261	0.08261	0.08261
huntii	0.06905	0.06782	0.06905	0.06658	0.06782	0.06793	0.06793	0.07028	0.07028	0.07028	0.07028	0.06905	0.07028	0.07028	0.07028	0.07028

Appendix B. (cont.)

	VEP38	VEP01	VEP07	VEP25	VEP13	VEP21	VEP34	VEP35	SC198	VEP17	VEP19	SC199	Vwilm03	Vwilm04	Vwilm06	Vwilm07
VEP36																
VEP37																
VEP38																
VEP01	0															
VEP07	0.00123	0.00123														
VEP25	0.00123	0.00123	0													
VEP13	0.00123	0.00123	0.00247	0.00247												
VEP21	0.00123	0.00123	0.00247	0.00247	0.00247											
VEP34	0	0	0.00123	0.00123	0.00123	0.00123										
VEP35	0.00123	0.00123	0.00247	0.00247	0.00247	0.00247	0.00123									
SC198	0.00494	0.00493	0.00617	0.00617	0.0037	0.00617	0.00493	0.00617								
VEP17	0.00494	0.00493	0.00617	0.00617	0.0037	0.00617	0.00493	0.00617	0.00247							
VEP19	0.00371	0.0037	0.00493	0.00493	0.00247	0.00493	0.0037	0.00493	0.00123	0.00123						
SC199	0.00865	0.00863	0.00986	0.00986	0.00986	0.00986	0.00863	0.00986	0.00863	0.00863	0.0074					
Vwilm03	0.00865	0.00863	0.00987	0.00987	0.00987	0.00987	0.00863	0.00987	0.00863	0.00863	0.0074	0				
Vwilm04	0.00988	0.00986	0.0111	0.0111	0.0111	0.0111	0.00986	0.0111	0.00986	0.00986	0.00863	0.00123	0			
Vwilm06	0.00866	0.00864	0.00988	0.00988	0.00988	0.00988	0.00864	0.00988	0.00864	0.00864	0.00741	0	0	0		
Vwilm07	0.00988	0.00986	0.0111	0.0111	0.0111	0.0111	0.00986	0.0111	0.00986	0.00986	0.00863	0.00123	0	0	0	
Vwilm10	0.00988	0.00986	0.0111	0.0111	0.0111	0.0111	0.00986	0.0111	0.00986	0.00986	0.00863	0.00123	0	0	0	0
IM420	0.01982	0.01981	0.02104	0.02104	0.02105	0.02104	0.01981	0.02103	0.01979	0.01979	0.01856	0.01853	0.01854	0.01978	0.01855	0.01978
IM412	0.02468	0.02466	0.02589	0.02589	0.02589	0.02589	0.02466	0.02466	0.02466	0.02466	0.02343	0.02343	0.02343	0.02466	0.02344	0.02466
IM423	0.02346	0.02344	0.02467	0.02467	0.02467	0.02467	0.02344	0.02344	0.02344	0.02344	0.0222	0.0222	0.02221	0.02344	0.02222	0.02344
IM424	0.02221	0.02219	0.02343	0.02343	0.02343	0.02343	0.02219	0.02219	0.02219	0.02219	0.02096	0.02096	0.02097	0.02219	0.02098	0.02219
IM426	0.01981	0.0198	0.02103	0.02103	0.02104	0.02103	0.0198	0.02101	0.01978	0.01978	0.01855	0.01852	0.01853	0.01977	0.01854	0.01977
Vimpa03	0.02221	0.02219	0.02343	0.02343	0.02343	0.02343	0.02219	0.02219	0.02219	0.02219	0.02096	0.02096	0.02097	0.02219	0.02098	0.02219
Vimpa04	0.02345	0.02343	0.02466	0.02466	0.02466	0.02466	0.02343	0.02343	0.02343	0.02343	0.02219	0.02219	0.0222	0.02343	0.02221	0.02343
Vimpa02	0.02098	0.02096	0.02219	0.02219	0.02219	0.02219	0.02096	0.02096	0.02096	0.02096	0.01973	0.01973	0.01974	0.02096	0.01975	0.02096
Vimpa06	0.02098	0.02096	0.02219	0.02219	0.02219	0.02219	0.02096	0.02096	0.02096	0.02096	0.01973	0.01973	0.01974	0.02096	0.01975	0.02096
vosnesenskii	0.08263	0.08261	0.08138	0.08138	0.08385	0.08385	0.08261	0.08385	0.08508	0.08508	0.08385	0.08385	0.08284	0.08261	0.08284	0.08261
huntii	0.0703	0.07028	0.06905	0.06905	0.07152	0.07152	0.07028	0.07152	0.07028	0.06905	0.06905	0.06658	0.06547	0.06535	0.06547	0.06535

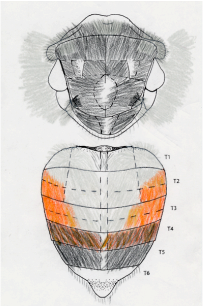
Appendix B. (cont.)

	Vwilm10	**IM420**	**IM412**	**IM423**	**IM424**	**IM426**	**Vimpa03**	**Vimpa04**	**Vimpa02**	**Vimpa06**	***vosnesenskii***
VEP36											
VEP37											
VEP38											
VEP01											
VEP07											
VEP25											
VEP13											
VEP21											
VEP34											
VEP35											
SC198											
VEP17											
VEP19											
SC199											
Vwilm03											
Vwilm04											
Vwilm06											
Vwilm07											
Vwilm10											
IM420	0.01978										
IM412	0.02466	0.00123									
IM423	0.02344	0	0.00123								
IM424	0.02219	0.00123	0.00247	0.00124							
IM426	0.01977	0.00123	0.00247	0.00124	0						
Vimpa03	0.02219	0.00123	0.00247	0.00124	0	0					
Vimpa04	0.02343	0.00248	0.0037	0.00247	0.00123	0.00123	0.00123				
Vimpa02	0.02096	0.00247	0.0037	0.00248	0.00123	0.00123	0.00123	0.00247			
Vimpa06	0.02096	0.00247	0.0037	0.00248	0.00123	0.00123	0.00123	0.00247	0		
vosnesenskii	0.08261	0.08395	0.08755	0.08631	0.08508	0.08394	0.08508	0.08385	0.08508	0.08508	
huntii	0.06535	0.06917	0.07275	0.07152	0.07028	0.06916	0.07028	0.07152	0.07028	0.07028	0.05302

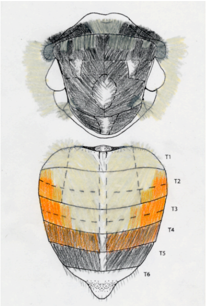
Appendix C. Specimen GPS coordinates. GPS coordinates for specimens used in this study, excluding *B. impatiens*.

Species	Voucher #	Latitude	Longitude
ephippiatus	SC198	16.140094	-92.777981
ephippiatus	VEP01	19.118402	-101.893329
ephippiatus	VEP02	9.564722	-83.742222
ephippiatus	VEP03	28.221098	-108.251971
ephippiatus	VEP05	17.474758	-100.178778
ephippiatus	VEP07	17.31736	-96.495108
ephippiatus	VEP09	10.28396	-84.75961
ephippiatus	VEP12	20.0085	-103.70833
ephippiatus	VEP13	21.17631	-99.57348
ephippiatus	VEP14	28.168724	-108.2131
ephippiatus	VEP17	15.117761	-92.107067
ephippiatus	VEP18	9.829227	-83.443688
ephippiatus	VEP19	15.120847	-92.096547
ephippiatus	VEP20	9.7	-83.9
ephippiatus	VEP21	21.13517	-99.63268
ephippiatus	VEP22	19.6143	-103.56765
ephippiatus	VEP23	9.564651	-83.707901
ephippiatus	VEP24	9.7	-83.9
ephippiatus	VEP25	17.31736	-96.495108
ephippiatus	VEP26	28.168724	-108.2131
ephippiatus	VEP27	9.4	-83.52
ephippiatus	VEP28	10.28396	-84.75961
ephippiatus	VEP29	17.474758	-100.178778
ephippiatus	VEP30	9.829227	-83.443688
ephippiatus	VEP34	21.13517	-99.63268
ephippiatus	VEP35	21.17631	-99.57348
ephippiatus	VEP36	19.6143	-103.56765
ephippiatus	VEP37	19.6143	-103.56765
ephippiatus	VEP38	19.6143	-103.56765
ephippiatus	VEP33	20.0085	-103.70833
ephippiatus	VEP43	17.474758	-100.178778
ephippiatus	VEP44	14.03055556	-87.08
ephippiatus	VEP45	14.03055556	-87.08
ephippiatus	VEP46	14.018834	-87.096436
ephippiatus	VEP47	14.018834	-87.096436
ephippiatus	VEP48	13.93166667	-86.87666667
ephippiatus	VEP49	13.93166667	-86.87666667
ephippiatus	VEP50	14.19444444	-87.12972222
ephippiatus	VEP51	14.19722222	-87.12583333
ephippiatus	VEP52	14.43611111	-87.56083333
ephippiatus	VEP53	14.4375	-87.56083333
ephippiatus	VEP54	15.49638889	-88.18083333
ephippiatus	VEP55	15.49222222	-88.22666667
wilmattae	Vwilm03	16.140094	-92.777981
wilmattae	Vwilm04	15.120847	-92.096547
wilmattae	Vwilm06	15.05	-92.283333
wilmattae	Vwilm07	15.05	-92.283333
wilmattae	Vwilm10	15.09036667	-92.28638333
wilmattae	SC199	16.140094	-92.777981

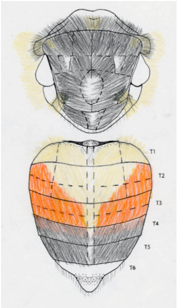
Appendix D. Color pattern drawings. Drawings by the author of *B. ephippiatus* and *B. wilmattae* color patterns. Drawings were used to determine morphological characters and character states for color pattern coding.



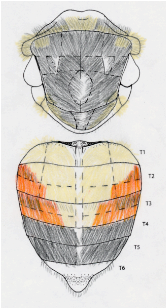
VEP03: Chihuahua, MX



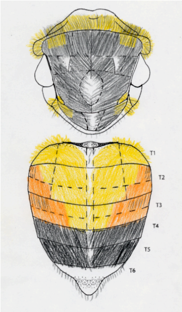
VEP12: Jalisco, MX



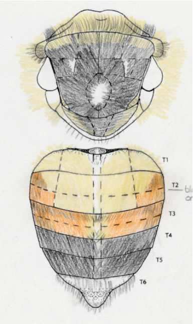
VEP05: Guerrero, MX



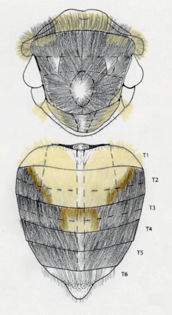
VEP07: Oaxaca, MX



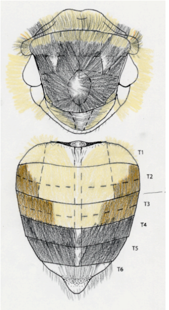
VEP17: Chiapas, MX



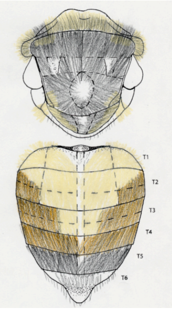
VEP44: R.B. El Uyuca, FM, HN



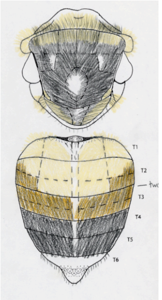
VEP45 R.B. El Uyuca, FM, HN



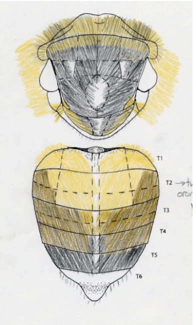
VEP46: Tatumbla, FM, HN



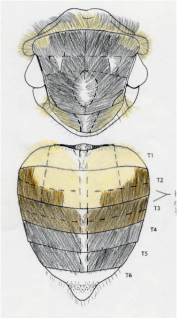
VEP47: Tatumbla, FM, HN



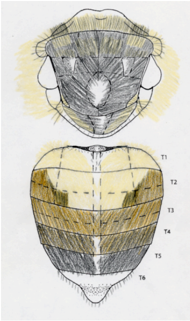
VEP23: Villa Mills, CR



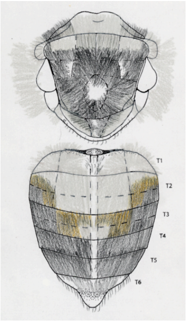
VEP15: Puntarenas, CR



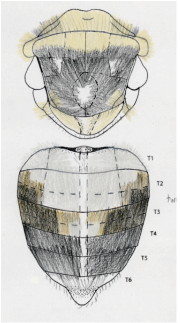
VEP09: Puntarenas, CR



VEP18: San Jose, CR



Vwilm04: Chiapas, MX



Vwilm05: Chiapas, MX