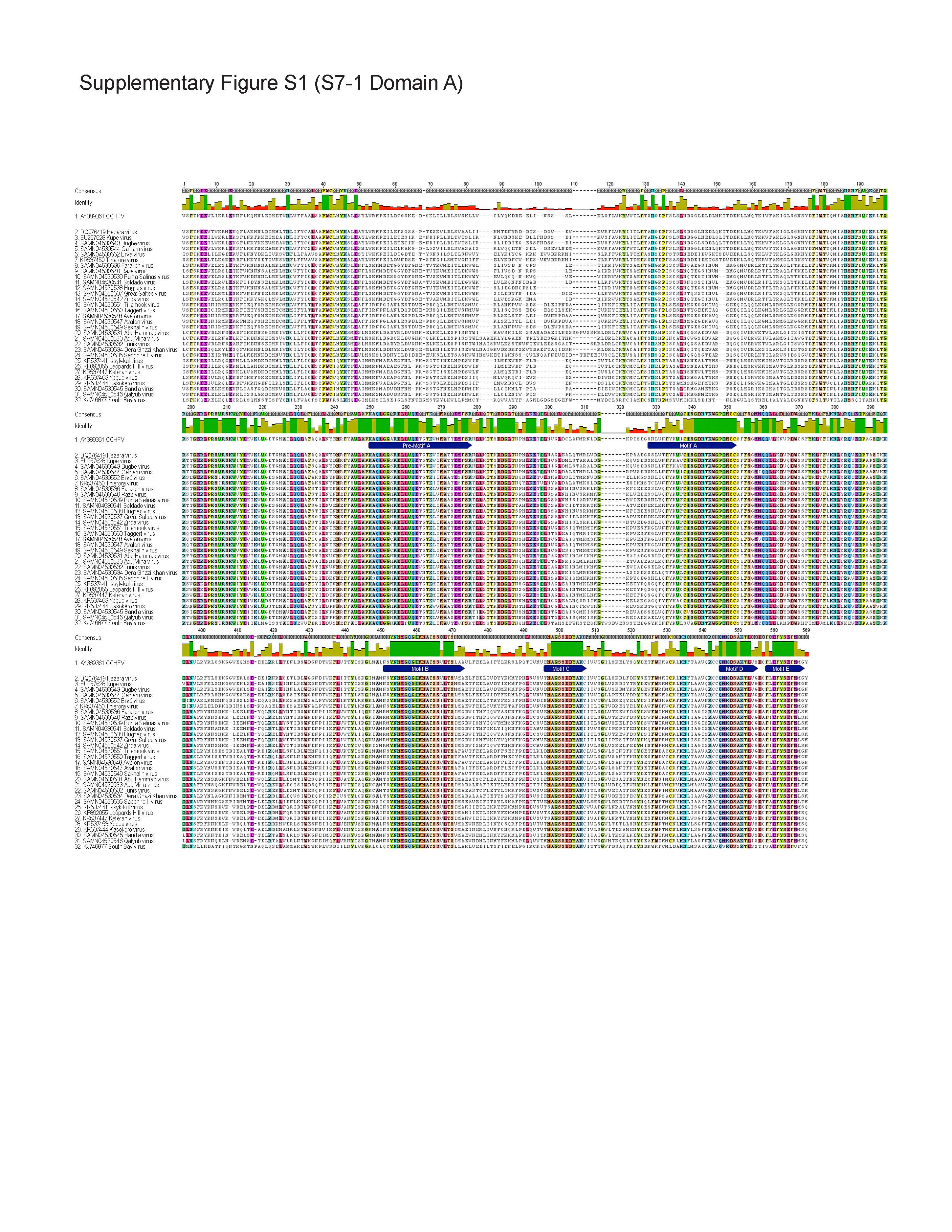
Supplementary material: Genomic Characterization of the Genus *Nairovirus* (Family *Bunyaviridae*)

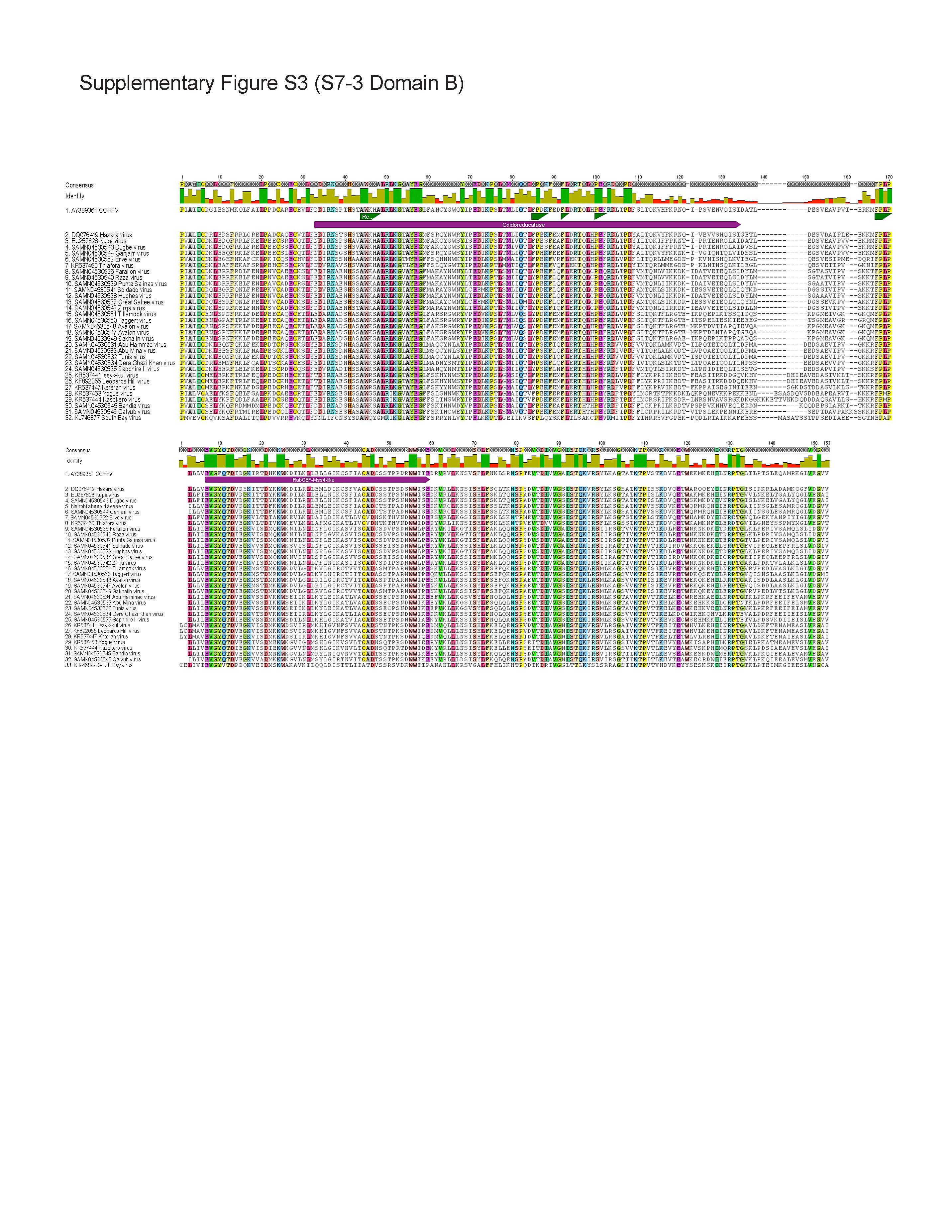
Jens H. Kuhn 1, Michael R. Wiley 2, Sergio E. Rodriguez 3, Yīmíng Bào 4, Karla Prieto 2,   
Amelia P. A. Travassos da Rosa 3, Hilda Guzman 3, Nazir Savji 5, Jason T. Ladner 2,   
Robert B. Tesh 3, Jiro Wada 1, Peter B. Jahrling 1, Dennis A. Bente 3 and Gustavo Palacios 2,\*



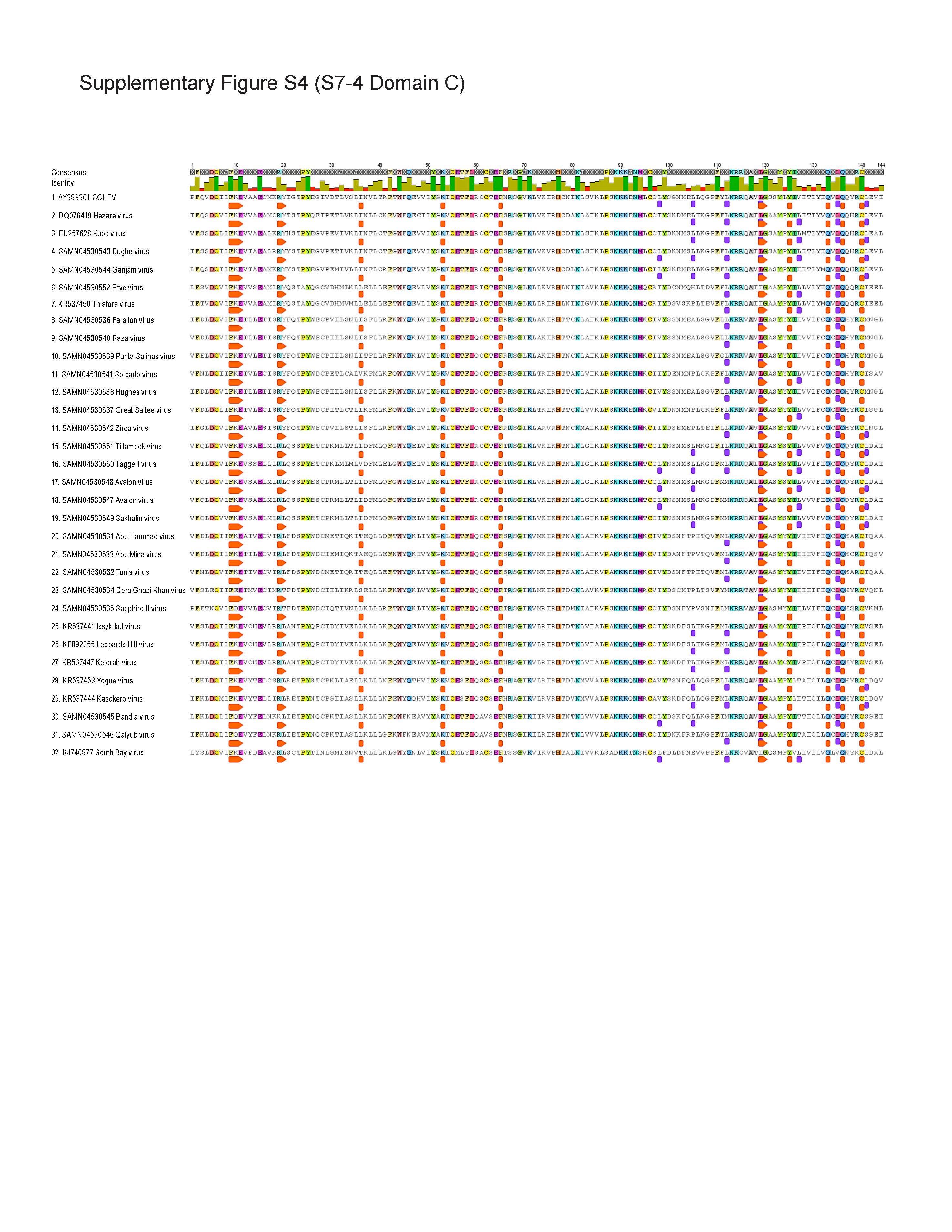
**Figure S1**: S7-1 Domain A



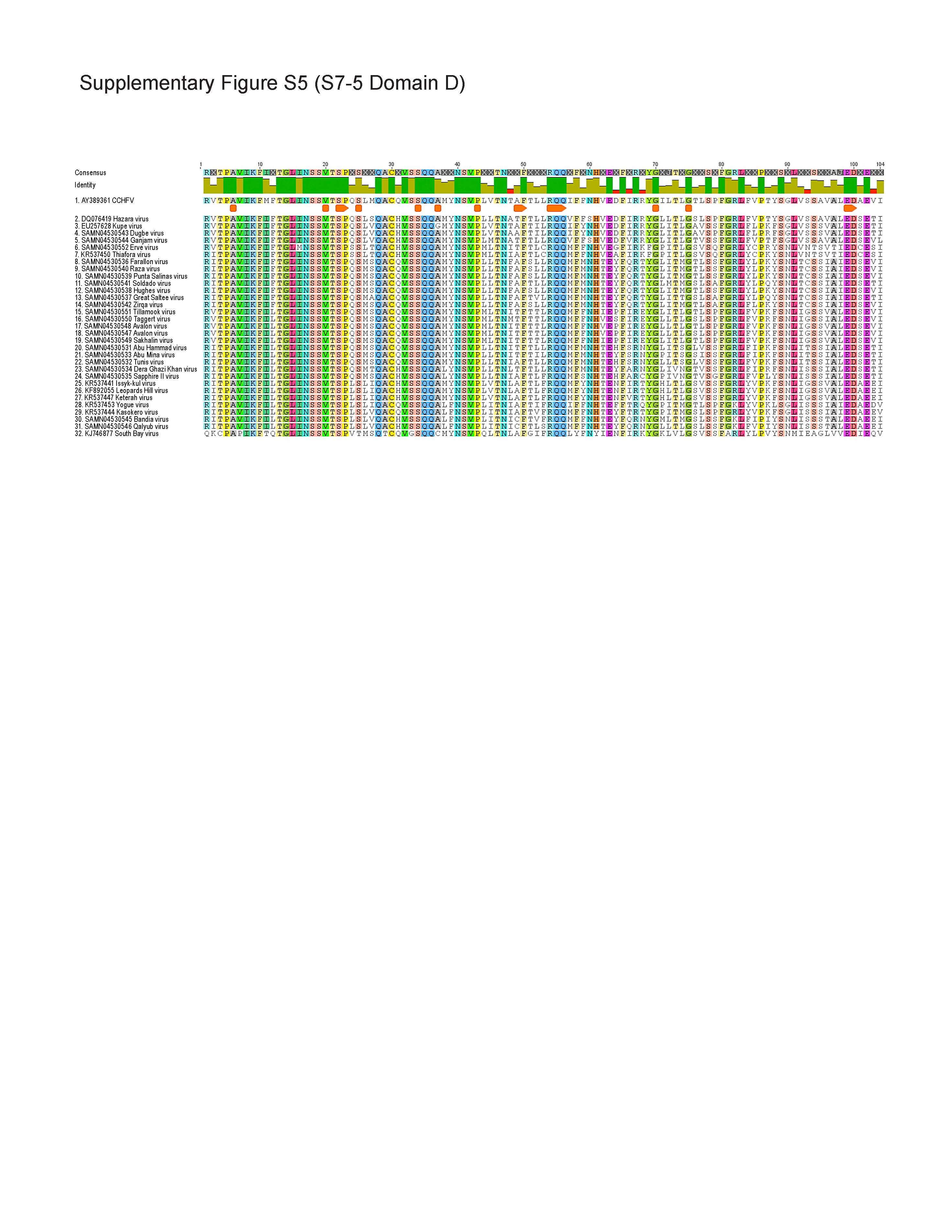
**Figure S2:** S7-2 OTU



**Figure S3:** S7-3 Domain B



**Figure S4:** S7-4 Domain C

****

**Figure S5:** S7-5 Domain D

**Table S1.** Nairovirus and nairo-like viruses and their deduced relationships prior to this study (based in part on [[1‒23](#_ENREF_1)]). a Genomic segments are representative complete or coding-complete sequences. NK, not known; NR, not recorded; TBD, to be determined.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Nairovirus Species and Virus Members (Abbreviations)** | **Virus Vector(s)** | **Virus Vertebrate Host(s)** | **Human infections** | **Genomic Segment Accession Numbers (RefSeq/GenBank)a** |
| **Species *Crimean-Congo hemorrhagic fever nairovirus*** |  |  |  |  |
| Crimean-Congo hemorrhagic fever virus (CCHFV) | Biting midges (*Culicoides* sp.)  Ticks (*Alveonasus lahorensis*, *Argas persicus*, *Amblyomma* spp., *Dermacentor dagestanicus*, *D. marginatus*, *Haemaphysalis punctata*, *Hyalomma anatolicum, H. asiaticum, H. detritum, H. excavatum*, *H. impeltatum*, *H. impressum*, *H. lusitanicum*, *H. marginatum*, *H. nitidum*, *H. punctatum*, *H. truncatum*, *Ixodes ricinus*, *Rhipicephalus annulatus*, *R.* *bursa*, *R. decoloratus*, *R. geigyi*, *R. microplus*, *R. pulchellus, R.* *pumilio*, *R.* *rossicus*, *R.* *sangineus*, *R. turanicus*) | Birds, camelids, cattle, eulipotyphla, humans, lagomorphs, rodents, sheep | Yes: Crimean-Congo hemorrhagic fever (frequently lethal) | S: NC\_005302.1  M: NC\_005300.2  L: NC\_005301.3 |
| Hazara virus (HAZV) | Ticks (*Ixodes redikorzevi*) | Royle’s mountain voles (*Alticola roylei*)? | NR | S: KP406725.1  M: KP406724.1  L: KP406723.1 |
| Tofla virus (TFLV) | Ticks (*Heamaphysalis flava* and *Heamaphysalis formsensis****)*** | Rodents? | NR | S: LC008510.1  M: LC008511.1  L: LC008512.1 |

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| --- | --- | --- | --- | --- |
| **Species *Dera Ghazi Khan nairovirus*** |  |  |  |  |
| Abu Hammad virus (AHV) | Ticks (*Argas* *hermanni*) | Pigeons? | NR | This study and [[23](#_ENREF_23)]:  S. KU343144.1  M: KU343143.1  L: KU343142.1 |
| Abu Mina virus (AMV) | Ticks (*Argas* *streptopelia*) | European turtle doves (*Streptopelia turtur*)? | NR | This study |
| Dera Ghazi Khan virus (DGKV) | Ticks (*Hyalomma dromedarii*) | Camelids? | NR | This study and [[23](#_ENREF_23)]:  S: KU343153.1  M: KU343152.1  L: KU343151.1 |
| Kao Shuan virus (KSV) | Ticks (*Argas* *robertsi*) | Night herons (*Nycticorax nycticorax*)? | NR | TBD |
| Pathum Thani virus (PTHV) | Ticks (*Argas* *robertsi*) | Open-billed storks (*Anastomus ascitans*)? | NR | TBD |
| Pretoria virus (PREV) | Ticks (*Argas* *africolumbae*) | Cape rock pigeons (*Columba guinea phaeonata*)?) | NR | TBD |
| Sapphire II virus (SAPV) | Ticks (*Argas cooley*) | Seabirds? | NR | This study and [[23](#_ENREF_23)]:  S: KU343165.1  M: KU343164.1  L: KU343163.1 |
| **Species *Dugbe nairovirus*** |  |  |  |  |
| Dugbe virus (DUGV) | Biting midges (*Culicoides* sp.)  Ticks (*Amblyomma variegatum*, *A. lepidum*, *Hyalomma truncatum*, *H. rufipes*, *Ixodes* sp., *Rhipicephalus decoloratus*,) | Cattle, giant pouched rats (*Cricetomys gambianus*) | Yes (rare): diarrhea, fever, headache, maculopapular rash, nausea, vomiting (non-lethal) | S: NC\_004157.1  M: NC\_004158.1  L: NC\_004159.1 |
| Ganjam virus (GANV) | Mosquitoes (*Culex vishnui*)  Ticks (*Haemaphysalis* *intermedia*, *H.* *wellingtoni*, *Rhipicephalus haemaphysaloides*) | Domestic sheep and goats | Yes (rare): fever (non-lethal) | Yadav *et al*. and this study:  S: AF504294.1  M: EU697950.1  L: EU697949.1 |
| Kupe virus (KUPEV) | Ticks (*Amblyomma gemma*, *Rhipicephalus pulchellus*) | Livestock? | NR | S: EU257626.1  M: EU257627.1  L: EU257628.1 |
| Nairobi sheep disease virus (NSDV) | Ticks (*Amblyomma variegatum*, *Haemaphysalis intermedia*, *Rhipicephalus* *appendiculatis*, *R. pulchellus*, *R. simus*) | Domestic sheep and goats | Yes (rare): abdominal pain, fever, headache, myalgia (non-lethal) | S: KM464724.1  M: KM464725.1  L: KM464726.1 |
| **Species *Hughes nairovirus*** |  |  |  |  |
| Caspiy virus (CASV) | Ticks (*Carios capensis*) | Common terns (*Sterna hirundo*), European herring gulls (*Larus argentatus*) | NR | Not yet deposited |
| Elliðaey virus ELL 81-3b | Ticks (*Ixodes uriae*) | Atlantic puffins (*Fratercula arctica*)? | NR | TBD |
| Farallon virus (FARV) | Ticks (*Carios denmarki*) | Western gulls (*Larus occidentalis*)? | NR | This study and [[23](#_ENREF_23)]:  S: KU343156.1  M: KU343155.1  L: KU343154.1 |
| Fraser Point virus (FPV) | NK | NK | NR | TBD |
| Foula virus F 80-1 | Ticks (*Ixodes uriae*) | Common murees (*Uria aalge*)? | NR | TBD |
| Great Saltee virus (GRSV) | Ticks (*Carios maritimus*, *Ixodes uriae*) | Black-legged kittiwakes (*Rissa tridactyla*), European shags (*Phalacrocorax aristotelis*), Razorbills (*Alca torda*)? | NR | This study |
| Grímsey virus GRIMS82-1b | Ticks (*Ixodes uriae*) | Atlantic puffins (*Fratercula arctica*)? | NR | TBD |
| Hughes virus (HUGV) | Ticks (*Carios denmarki*) | Brown noddies (*Anous stolidus*), sooty terns (*Sterna fuscata*)? | NR | This study |
| Inner Farne Island virus IF 80-3, IF80-4 | Ticks (*Ixodes uriae*) | Common murees (*Uria aalge*)? | NR | TBD |
| Island of May virus IM81 | Ticks (*Ixodes uriae*) | Common murees (*Uria aalge*)? | NR | TBD |
| Mykines virus M82-2 | Ticks (*Ixodes uriae*) | Atlantic puffins (*Fratercula arctica*)? | NR | TBD |
| Puffin Island virus (PIV) | Ticks (*Carios maritimus*) | Seabirds? | NR | TBD |
| Punta Salinas virus (PSV) | Ticks (*Argas arboreus*, *Carios amblus*) | Guanay cormorants (*Phalacrocorax bougainvillii*), Peruvian boobies (*Sula variegata*)? | NR | This study and [[23](#_ENREF_23)]:  S: KU343159.1  M: KU343158.1  L: KU343157.1 |
| Raza virus (RAZAV) | Ticks (*Carios denmarki*) | Seabirds? | NR | This study |
| Soldado virus (SOLV) | Ticks (*Amblyomma loculosum*, *Carios capensis*, *C. denmarki*) | Brown noddies (*Anous stolidus*), Cape cormorants (*Phalacrocorax capensis*), great cormorants (*Phalacrocorax carbo*), grey-headed gulls (*Chroicocephalus cirrocephalus*), long-tailed cormorants (*Phalacrocorax africanus*), masked boobies (*Sula dactylatra*), sooty terns (*Sterna fuscata*)? | NR | This study |
| Zirqa virus (ZIRV) | Ticks (*Carios* *muesebecki*) | Ospreys (*Pandion haliaetus*), Socotra cormorants (*Phalacrocorax nigrogularis*)? | NR | This study and [[23](#_ENREF_23)]:  S: KU343171.1  M: KU343170.1  L: KU343169.1 |
| **Species *Qalyub nairovirus*** |  |  |  |  |
| Bakel virus (BAKV) | Ticks (*Ornithodoros sonrai*) | NK | NR | TBD |
| Bandia virus (BDAV) | Ticks (*Ornithodoros sonrai*) | Multimammate rats  (*Mastomys* sp.) | NR | This study and [[23](#_ENREF_23)]:  S: KU343150.1  M: KU343149.1  L: KU343148.1 |
| Chim virus (CHIMV) | Ticks (*Hyalomma asiaticum*, *Ornithodoros papillipes, O. tartakovskii*, *Rhipicephalus turanicus*) | Great gerbils (*Rhombomys opimus*)? | NR | Not yet deposited |
| Geran virus (GERV/GRNV) | Ticks (Ornithodoros verrucosus) | Libyan jirds (*Meriones lybicus*)? | NR | Not yet deposited |
| Omo virus (OMOV) | NK | Reddish-white mastomys (*Mastomys erythroleucus*) | NR | TBD |
| Qalyub virus (QYBV) | Ticks (*Carios erraticus*) | African arvicanthis (*Arvicanthis niloticus*), camelids, cattle, pigs, dogs, donkeys | NR | This study and [[23](#_ENREF_23)]:  S: KU343162.1  M: KU343161.1  L: KU343160.1 |
| **Species *Sakhalin nairovirus*** |  |  |  |  |
| Avalon virus (AVAV)= Paramushir virus (PRMV)? | Ticks (*Ixodes signatus*, *I.* *uriae*) | Atlantic puffins (*Fratercula arctica*), European herring gulls (*Larus argentatus*), Leach's storm petrels (*Oceanodroma leucorhoa*)? | NR | This study and [[23](#_ENREF_23)]:  S: KU343147.1  M: KU343146.1  L: KU343145.1 |
| Clo Mor virus (C[L]MV) | Ticks (*Ixodes* *uriae*) | Common murees (*Uria aalge*)? | NR | This study and [[23](#_ENREF_23)]:  S: KU343141.1  M: KU343140.1  L: KU343139.1 |
| Finch Creek virus (FINCV) | Ticks (*Ixodes uriae*) | Penguins? | NR | TBD |
| Kachemak Bay virus (KBV) | Ticks (*Ixodes signatus*) | Common murees (*Uria aalge*)? | NR | TBD |
| Sakhalin virus (SAKV) | Ticks (*Ixodes putus*, *I. signatus*, *I. uriae*) | Black-legged kittiwakes (*Rissa tridactyla*), common murees (*Uria aalge*), Northern fulmars (*Fulmaris flacialis*), red-necked phalaropes (*Phalaropus lobatus*), tufted puffins (*Lunda cirrhata*)? | NR | This study |
| Taggert virus (TAGB) | Ticks (*Ixodes* *uriae*) | Macaroni penguins (*Eudyptes chrysolophus*)? | NR | This study and [[23](#_ENREF_23)]:  S: KU343168.1  M: KU343167.1  L: KU343166.1 |
| Tillamook virus (TILLV) | Ticks (*Ixodes uriae*) | Seabirds? | NR | This study |
| **Species *Thiafora nairovirus*** |  |  |  |  |
| Erve virus (ERVEV) | NK | Greater white-toothed shrews (*Crocidura russula*) | Possibly: thunderclap headaches (non-lethal)? | S: JF911699.1  M: JF911698.1  L: JF911697.1 |
| Thiafora virus (TFAV) | NK | White-toothed shrews (*Crocidura* sp.) | NR | Coding-complete:  S: KR537452.1  M: KR537451.1  L: KR537450.1 |
| **Putative species “*Ahun nairovirus*”** |  |  |  |  |
| Ahun virus | NK | Common pipistrelles (*Pipistrellus pipistrellus*), whiskered myotis (*Myotis mystacinus*) | NR | TBD |

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| **Putative species “*Issyk-kul nairovirus/Keterah nairovirus*”** |  |  |  |  |
| Garm virus | NK | Common redstarts (*Phoenicurus phoenicurus*) | NR | TBD |
| Gossas virus (GOSV) | NK | Free-tailed bats (*Tadarida* sp.) | NR | Coding-complete:  S: KR534876.1  M: KR534877.1  L: KR534878.1 |
| Issyk-kul virus (ISKV) | Biting midges (*Culicoides schultzei*)  Horseflies (*Tabanus agrestis*)  Mosquitoes (*Aedes caspius*, *Anopheles hyrcanus*)  Ticks (*Argas vespertilionis, A. pusillus*, *Ixodes vespertilionis*) | Humans  Bats: noctules (*Nyctalus noctula*), lesser mouse-eared myotis (*Myotis blythii*), common serotines (*Eptesicus serotinus*), particolored bats (*Vespertilio murinus*), common pipistrelles (*Pipistrellus pipistrellus*), greater horseshoe bats (*Rhinolophus ferrumequinum*)  Birds: Spanish sparrows (*Passer hispaniolensis*), white wagtails (*Motacilla alba*), grey wagtails (*Motacilla cinerea*), common redstarts (*Phoenicurus phoenicurus*), house swallows (*Hirundo rustica*), wrynecks (*Jynx torquilla*), common kingfishers (*Alcedo atthis*) | Yes (rare): cough, fever, headache, nausea (non-lethal) | Complete:  S: KF892057.1  M: KF892056.1  L: KF892055.1 |
| Keterah virus (KTRV) | Ticks (*Argas pusillus*) | Asiatic yellow house bats (*Scotophilus kuhlii* *temminckii*) | NR | S: KR537449.1  M: KR537448.1  L: KR537447.1 |
| soft tick bunyavirus (STBV) | Ticks (*Argas vespertilionis*) | Bats? | NR | S: LC027467.1  M: LC027466.1  L: LC027465.1 |
| Uzun-Agach virus (UZAV) | NK | Lesser mouse-eared myotis (*Myotis blythii oxygnathus*) | NR | TBD |

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| **Putative species “*Kasokero nairovirus*”** |  |  |  |  |
| Leopards Hill virus (LPHV) | NK | Giant leaf-nosed bats (*Hipposideros gigas*) | NR | S: NC\_025833.1  M: NC\_025832.1  L: NC\_025831.1 |
| Kasokero virus (KAS[O]V) | NK | Egyptian rousettes (*Rousettus aegyptiacus*) | Yes (rare): mild to severe laboratory infections characterized by abdominal pain, diarrhea, fever, headache, and severe myalgia and arthralgia (nonlethal) | Coding-complete  S: KR537446.1  M: KR537445.1  L: KR537444.1 |
| Yogue virus (YOGV) | NK | Egyptian rousettes (*Rousettus aegyptiacus*) | NR | Coding-complete:  S: KR537455.1  M: KR537454.1  L: KR537453.1 |
| **Putative species “*Burana nairovirus*”** |  |  |  |  |
| Burana virus (BURV) | Ticks (*Haemaphysalis concinna*, *H. punctata*) | Domestic cows? | NR | Not yet deposited |
| Huángpí tick virus 1 (HTV-1) | Ticks (*Haemaphysalis doenitzi*) | NK | NR | S: KM817734.1  M: KM817706.1  L: KM817667.1 |
| Tǎchéng tick virus 1 (TTV-1) | Ticks (*Dermacentor marginatus*) | NK | NR | S: KM817743.1  M: KM817717.1  L: KM817683.1 |
| Tamdy virus (TDYV) | Ticks (*Haemaphysalis* *anatolicum*,  *H. asiaticum*, *H. concinna*, *Hyalomma marginatum*, *Rhipicephalus turanicus*) | Birds: white wagtails (*Motacilla alba*), European rollers (*Coracias garrulus*), hoopoes (*Upupa epops*), common starlings (*Sturnus vulgaris*), southern grey shrikes (*Lanius meriodinalis*)  Carnivores: steppe polecats (*Mustela eversmanni*)  Rodents: great gerbils (*Rhombomys opimus*)  Unspecified bats  Domestic sheep? | Yes (rare): arthralgia, fever, myalgia (nonlethal) | Not yet deposited |
| Wēnzhōu tick virus (WTV) | Ticks (*Haemaphysalis hystricis*) | NK | NR | S: KM817745.1  M: KM817718.1  L: KM817685.1 |
| **Putative ungrouped nairo-like viruses** |  |  |  |  |
| Artashat virus (ARTSV) | Ticks (*Ornithodoros alactagalis*, *O. verrucosus*) | Persian jirds (*Meriones persicus*), small five-toed jerboas (*Allactaga elater*)? | NR | TBD |
| Nàyǔn tick virus | Ticks (*Rhipicephalus* sp.) | NK | NR | TBD |
| Sānxiá water strider virus 1  (SWSV-1) | Water striders (gerrids) | NK |  | S: KM817737.1  M: KM817711.1  L: KM817674.1 |
| Shāyáng spider virus 1 | Spiders (*Neoscona nautica, Parasteatoda tepidariorum, Plexippus setipes*) | NK | NR | S: KM817738.1  M: KM817712.1  L: KM817676.1 |
| South Bay virus (SBV) | Ticks (*Ixodes scapularis*) | NK | NR | S: KM048321.1  L: KM048320.1 |
| Wǔhàn millipede virus 2 | Millipedes (polydesmids) | NK | NR | S: KM817757.1  L: KM817696.1 |
| Xīnzhōu spider virus (XSV) | Spiders (*Neoscona nautica, Parasteatoda tepidariorum*) | NK | NR | S: KM817762.1  M:KM817729.1 (incomplete)  L: KM817702.1 |

**Table S2. M-segment polyprotein descriptions. Each species column depicts averages of its members.** Sample sizes are: Crimean-Congo hemorrhagic fever   
nairovirus n = 1, “Hazara nairovirus” n = 2, Dugbe nairovirus n = 5, Sakhalin nairovirus n = 4, Thiafora nairovirus n = 2, “Kasokero nairovirus” n = 3, Qalyub nairovirus   
n = 2, “Keterah nairovirus” n = 2, Dera Ghazi Khan nairovirus n = 5, Hughes nairovirus n = 7, and “Burana nairovirus” n = 3. Averages for predicted characteristics were rounded up. Proposed new taxa are highlighted in red and placed in quotation marks.

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| Predicted Glycoprotein Precursor Processing | *Crimean-Congo hemorrhagic fever nairovirus* | *“Hazara nairovirus*” | *Dugbe nairovirus* | *Sakhalin nairovirus* | | *Thiafora nairovirus* | | “*Kasokero nairovirus*” | | *Qalyub nairovirus* | “*Keterah nairovirus*” | *Dera Ghazi Khan nairovirus* | *Hughes nairovirus* | “*Burana nairovirus*” |
| Polyprotein Mass (deduced kDa) | 187 | 158 | 173 | | 158 | | 144 | | 159 | 164 | 183 | 157 | 155 | 150φ |
| Glycoproteins¥ | 5 | 3 | 3 | | 3 | | 3 | | 2 | 4 | 4 | 3 | 2 | 3 |
| Conserved Cleavage Sites | RSKR, RKPL, RRLL, RKLL | RRLL, RKLL | RKPL, RRLL, RKLL | | RRLL, RKLL, RKPL | | RRLL, RKLL | | RRLL, RKLL | RKPL, RKLL | RKLL | RRLL, RKLL | RRLL, RKLL | RRLL, RKLL, RKPL |
| *O*-Linked Glycosylations | 100 | 29 | 38 | | 35 | | 33 | | 38 | 48 | 135 | 17 | 4 | 38 |
| *N*-Linked Glycosylations | 11 | 6 | 7 | | 17 | | 12 | | 12 | 12 | 20 | 12 | 12 | 9 |
| Transmembrane domains (TMDs) | 5 | 5 | 5 | | 3 | | 3 | | 4 | 2¤¤¤ | 3 | 3 | 4 | 3 |
| Glycosylated Regions/Mucin-like domains (MLDs) | 1 | 1 | 1 | | 1 | | 1 | | 1 | 1 | 2–3 | 1 | None | 1 |
| MLD Mass (deduced kDa) | 23 | 3–5 | 11 | | 3–10 | | 7 | | 8–11 | 10–12 | 8–37 | 3–5 | 0 | 8–11 |

¤¤¤A single member of this species group (*Qalyub nairovirus*) is predicted to contain only a single transmembrane region. ¥ No differentiation of structural versus non-structural glycoproteins. φ Two members of the species *Burana nairovirus* are predicted to have two open reading frames on the M-segment encoding a separate stand-alone glycoprotein next to the polyprotein (GPC).

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