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Bat Fauna of Hin Nam No National Protected Area (HNN NPA), Khammouan, Laos

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Integrated Nature Conservation and Sustainable Resource Management in the Hin Nam No Region (HNN)

Chormphet Village, Thakhek District, Khammouan Province

PO Box: 555

T +856 51 214175

F +856 51 214175

Email: giz-laos@giz.de

www.giz.de/laos (EN); www.giz.de/laos-la (LAO)

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Bounmee Maokhamphiou

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Contributions of the contractors, Dr. Neil M. Furey and Dr. Bounsavane Douangboubpha, do not necessarily represent the position of GIZ.

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EXECUTIVE SUMMARY

Hin Nam No National Protected Area (NPA) covers ≈ 820 km² of mainly limestone landscape in Boualapha District, Khammouan Province, central Laos where the Central Indochina Limestone meets the Annamite Mountain Chain. Assisted by the German government, the Lao government is preparing a proposal to nominate the site as a Natural World Heritage Site (WHS). Because proof that the site possesses Outstanding Universal Value (criterion x) is required to this end, a bat survey was undertaken to contribute to such information for Hin Nam No in May 2017.

The aim of the assessment was to generate unequivocal information regarding bat assemblages at the site, with an emphasis on surface-dwelling species. The field survey encompassed seven areas within the NPA: Xe Bang Fai, Pak Xe Nue, Huoy Salong, Thong Xam, Tham Nam Ork, Ban Dou and Nam Cum. Survey methods included cave explorations and use of mist nets, four-bank harp traps and acoustic sampling. Seventeen trap nights representing 7,883.4 m² mist-net-hours and 631.2 m² harp-trap-hours were achieved at 88 discrete points during the field survey, comprising 86 forest locations and two points in Tham Bing cave. Trapping elevations ranged from 164–462 m asl and one hour of acoustic sampling was conducted from dusk onwards on all but two trap nights, resulting in 15 hours of recordings.

This resulted in the live-capture of 788 bats representing 34 species arranged in six families. These included one globally Vulnerable bat species (*Hipposideros scutinares*) and three species—*Rhinolophus microglobosus*, *Murina feae* and *Murina fionae*—which have yet to be evaluated by the IUCN Red List. Most female insectivorous bats captured during the survey period were lactating, indicating that the annual birth peak for insectivorous bat species primarily occurs in April–May each year. Seventeen species were distinguished in the acoustic sampling, including five horseshoe and four leaf-nosed bat species. The remainder were eight distinct phonic types which could not be assigned with certainty to species, although all represent aerial insectivores within the Vespertilionidae, Molossidae and/or Miniopteridae and emitted a mixture of broadband signals dominated by the fundamental harmonic.

Fourteen bat species captured during the field survey were new records for Hin Nam No. As a consequence, 41 bat species are now confirmed to occur at the NPA, including the above species and one globally Near-Threatened taxon (*Myotis pilosus*). This represents 43% of the known bat fauna of Laos and matches levels of bat species richness documented at Phong Nha – Ke Bang WHS (40 bat species), despite the latter having received greater survey effort. It also exceeds the documented bat species richness of Phou Hin Boun NPA (38 species) and Nakai Nam Theun NPA (26 species), although these figures undoubtedly reflect differing survey effort at each site. Consistent with patterns throughout mainland SE Asia, numbers of globally threatened taxa are low (2–3 spp.) at each site and none of the bat species currently documented are site-endemic.

Excellent potential remains for discovering additional bat species at Hin Nam No for several reasons, including: a) the occurrence of many other bat species in nearby and contiguous areas which have yet to be documented at the site, b) the limited representation of diverse genera and absence of ubiquitous taxa in the latest species list for the NPA, c) the relatively low survey

effort and coverage achieved at the site to date, and d) because acoustic data suggest that additional bat species occur there. As such and though already significant, the conservation importance of Hin Nam No NPA for bats is almost certainly greater than presently documented.

Hin Nam No NPA constitutes a major part of one of the largest limestone karst plateaus in Southeast Asia, which includes the NPA and the contiguous Phong Nha – Ke Bang WHS in Vietnam. Because nearly all of the Lao portion of the karst plateau is included within the NPA and the site includes enormous tracts of karst forest and extensive cave networks which collectively support an ecologically diverse array of bat species representing at least 43% of the Lao bat fauna, the *wholeness* of the property in supporting a speciose and representative assemblage of Indochinese bats is assured.

The highly-dissected topography of Hin Nam No, its limited accessibility and few areas with agricultural potential has meant that, apart from peripheral margins and river valleys, most of the site has been subjected to low development pressure. Though cross-border logging raises an issue which is being addressed through increased patrol effort, extensive tracts of forest deep in the karst remain in excellent condition and provide optimal habitat for a diverse complement of bat species. The same cannot be said for some areas in the vicinity of major river valleys, and to lesser extent, former logging concessions, though those visited in the present study showed few signs of recent large-scale disturbance and appeared to be regenerating well.

While the present survey emphasized surface-dwelling bat species, literature review coupled with correspondence with bio-speleologists familiar with the NPA suggest that caves in Hin Nam No are little disturbed due to their remoteness, lack of trails and surface water within the site interior, plus the large size of systems with peripheral entrances such as Xe Bang Fai (which effectively prohibits hunting). Though cave tourism is increasing at sites such as the latter, this has apparently yet to become an issue and potential future impacts are already being addressed. As a consequence, the *intactness* of the property regarding its cave- and surface-dwelling bat assemblages can also be asserted with confidence.

The report concludes with a summary of future considerations for bat conservation and research at Hin Nam No NPA and the authors would be pleased to provide further information as desired.

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ການສຳຫຼວດສັດຈຳພວກເຈຍ ປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມຫໍ່

ດຣ. Neil M. Furey¹ &

ດຣ. ປົວສະຫວັນ ດວງບຸບຜາ

¹ Email: neil.m.furey@gmail.com

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ບົດສະຫຼຸບຫຍໍ້

ປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ກວມເອົາເນື້ອທີປະມານ 82,000 ເຮັກຕາ ເຊິ່ງຝື່ນທີສ່ວນໃຫຍ່ແມ່ນຜູ້ຫີນປູນໃນເມືອງ ປົວລະຟາ, ແຂວງ ຄຳມ່ວນ, ພາກກາງຂອງປະເທດລາວ ເຊິ່ງເປັນຈຸດຕັດກັນລະຫວ່າງຜູ້ຫີນປູນອິນໂດຈີນ ກັບສາຍພູຫຼວງ. ໃນປະຈຸບັນທາງລັດຖະບານລາວໄດ້ຮັບການຊ່ວຍເຫຼືອຈາກລັດຖະບານເຢຍລະມັນທີ່ກຳລັງມີການກະກຽມບົດສະເໜີເພື່ອທີ່ສະເໜີເອົາຝື່ນທີ່ນີ້ເປັນມໍລະດົກໂລກທາງດ້ານທຳມະຊາດ ເຊິ່ງຈຳເປັນຕ້ອງມີຫຼັກຖານພິສູດວ່າຝື່ນທີ່ນີ້ມີຄຸນຄ່າຄວາມເປັນເອກະລັກສະເພາະທີ່ໂດດເດັ່ນຂອງໂລກ (ມາດຖານ X) ເພື່ອໃຫ້ບັນລຸໃນການສະເໜີການເຂົ້າເປັນມໍລະດົກໂລກ ສະນັ້ນ ການສຳຫຼວດເຈຍໄດ້ດຳເນີນເພື່ອໃຫ້ຂໍ້ມູນດັ່ງກ່າວໃຫ້ກັບປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ໃນເດືອນ ພຶດສະພາ 2017.

ຈຸດປະສົງຂອງການປະເມີນນີ້ແມ່ນການສ້າງຂໍ້ມູນທີ່ລະອຽດຊັດເຈນກ່ຽວກັບຊຸມຊົນຂອງເຈຍ/ຝູງເຈຍພາຍໃນຝື່ນທີ່ໂດຍແນ່ໃສ່ຊະນິດພັນເຈຍທີ່ອາໄສຢູ່ເທິງໜ້າດິນ. ການສຳຫຼວດພາກສະໜາມປະກອບມີ 7 ບ່ອນໃນຝື່ນທີ່ປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ຄື: ຖ້ຳນ້ຳລອດເຊບັ້ງໄຟ, ປາກເຊເໜືອ, ຫວັຍສະລອງ, ທົ່ງຊ້ຳ, ຖ້ຳນ້ຳອອກ, ບ້ານ ດູ ແລະ ນ້ຳຊຸ່ມ.

ວິທີການສຳຫຼວດປະກອບມີ ການສຳຫຼວດພາຍໃນຖ້ຳ ແລະ ນຳໃຊ້ເລດາດັກຈັບທົ່ວໄປ (mist nets), ເລດາດັກຈັບແບບມີຂາຕັ້ງພ້ອມດ້ວຍເສົາຕັ້ງ (four-bank harp traps) ແລະ ຕົວຢ່າງຂອງສຽງ. ການດັກຈັບ 17 ຄົນພາຍໃນເນື້ອທີ່ດັກຈັບ 7,883.4 ຕາລາງແມັດ/ເລດາທົ່ວໄປ/ຊົ່ວໂມງ ແລະ ເນື້ອທີ່ 631.2 ຕາລາງແມັດ/ເລດາແບບຂາຕັ້ງ/ຊົ່ວໂມງ ໄດ້ສຳເລັດພາຍໃນ 88 ຈຸດໃນຊ່ວງໄລຍະການສຳຫຼວດພາກສະໜາມ ປະກອບມີ ຝື່ນທີ່ປ່າໄມ້ 86 ບ່ອນ ແລະ ສອງຈຸດໃນເຂດຖ້ຳປິ້ງ. ລະດັບຄວາມສູງຂອງການຕິດຕັ້ງເລດາດັກຈັບຂະໜາດປະມານ 164-462 ແມັດຈາກໜ້ານ້ຳທະເລ ແລະ ດຳເນີນການນຳໃຊ້ສຽງຕົວຢ່າງປະມານ 1 ຊົ່ວໂມງແຕ່ຕອນຄ່ຳເປັນຕົ້ນໄປ ທຸກໆເລດາດັກຈັບໄດ້ຕິດຕັ້ງສອງຄັ້ງຕໍ່ຄືນໂດຍໃຊ້ເວລາການບັນທຶກ 15 ຊົ່ວໂມງ.

ນີ້ສິ່ງຜົນໃຫ້ມີການຈັບຕົວເຈຍຍັງບໍ່ທັນຕາຍໄດ້ຈຳນວນ 788 ໂຕ ເຊິ່ງມີ 32 ຊະນິດພັນໄດ້ຖືຈັດເຂົ້າໃນບັນດາ 6 ຕະກູນຂອງຊະນິດພັນເຈຍ. ບັນດາຊະນິດພັນເຫຼົ່ານີ້ເປັນໜຶ່ງໃນຊະນິດພັນເຈຍທີ່ມີຄວາມສ່ຽງຢູ່ໃນໂລກ (ຊື່ວິທະຍາສາດ: *Hipposideros scutinares*) ແລະ 3 ຊະນິດພັນປະກອບມີຊະນິດພັນ *Rhinolophus microglobosus*, ຊະນິດພັນ *Murina feae* ແລະ ຊະນິດພັນ *Murina fionae* ເຊິ່ງຍັງບໍ່ທັນໄດ້ມີການປະເມີນຢູ່ໃນບັນຊີແດງຂອງອົງການ *IUCN*. ສັງເກດເຫັນວ່າເຈຍໂຕແມ່ສ່ວນໃຫຍ່ຈັບໄດ້ໃນຊ່ວງໄລຍະການສຳຫຼວດທີ່ພວກມັນກຳລັງໃຫ້ນ້ຳນົມລູກຂອງພວກມັນ ເຊິ່ງສະແດງໃຫ້ເຫັນວ່າຈຳນວນການເກີດຫຼາຍສຸດຂອງປີສຳລັບຊະນິດພັນເຈຍເຫຼົ່ານີ້ແມ່ນເກີດຂຶ້ນຢູ່ໃນຊ່ວງລະຫວ່າງເດືອນເມສາ ຫາ ເດືອນ ພຶດສະພາຂອງແຕ່ລະປີ. ໄດ້ພົບເຫັນແລະຈຳແນກ 17 ຊະນິດພັນເຂົ້າໃນການສຸມຕົວຢ່າງສຽງ ປະກອບມີ ຊະນິດພັນເຈຍ horseshoe (5 ຊະນິດ) ແລະ ຊະນິດພັນເຈຍ leaf-nosed (4 ຊະນິດ). ສ່ວນທີ່ເຫຼືອເປັນຊະນິດພັນທີ່ແຕກຕ່າງຈາກ 8 ຊະນິດພັນ ເຊິ່ງບໍ່ສາມາດກຳນົດເຖິງຄວາມແນ່ນອນໃຫ້ກັບຊະນິດພັນໄດ້ ເຖິງແມ່ນວ່າຊະນິດພັນທັງໝົດຈະເປັນຕົວແທນຂອງເຈຍທີ່ກິນແມງໄມ້ເທິງໜ້າດິນພາຍ

ໃນຕະກຸນເຈຍຊື່ Vespertilionidae, Molossidae ແລະ/ຫຼື Miniopteridae ແລະ ມີການປະສົມປະສານຂອງ ສັນຍານການສື່ສານທີ່ຄວບຄຸມໂດຍຜືນຖານຢ່າງສອດຄ່ອງກັນ.

ນອກຈາກກໍ່ຍັງໄດ້ພົບເຫັນຊະນິດຜັນເຈຍ 14 ຊະນິດທີ່ໄດ້ຈັບໄດ້ໃນຊ່ວງໄລຍະການສຳຫຼວດພາກສະໜາມ ເຊິ່ງພວກມັນເປັນຊະນິດຜັນທີ່ຄົ້ນພົບໃໝ່ສຳລັບຫີນໜາມໜໍ່ ເຊິ່ງລວມເຖິງຊະນິດເຈຍ 41 ຊະນິດທີ່ໄດ້ຮັບການຮັບຮອງທີ່ພົບເຫັນໃນປ່າສະຫງວນແຫ່ງຊາດ ລວມທັງບັນດາຊະນິດຜັນທີ່ກ່າວມາຂ້າງເທິງ ແລະ ປະເພດຊະນິດຜັນໜຶ່ງທີ່ໃກ້ຖືກໄພຂົ່ມຂູ່ໃນໂລກ (ຊື່ວິທະຍາສາດ: *Myotis pilosus*) ເຊິ່ງສະແດງໃຫ້ເຫັນເຖິງ 43% ຂອງສັດປ່າປະເພດເຈຍທີ່ຮັບຮູ້ໃນປະເທດລາວ ແລະ ກົງກັບລະດັບຄວາມອຸດົມສົມບູນຂອງຊະນິດຜັນເຈຍທີ່ໄດ້ບັນທຶກໄວ້ໃນຜືນທີ່ມໍລະດົກໂລກຝອງຍາແກບ່າງ (40 ຊະນິດຜັນ). ເຖິງແມ່ນວ່າຈະໄດ້ຮັບຄວາມພະຍາຍາມໃນການສຳຫຼວດຄັ້ງໃຫຍ່ ນອກນີ້ມັນກໍ່ພົບເຫັນຊະນິດຜັນເຈຍຫຼາຍກວ່າຄວາມອຸດົມສົມບູນຂອງຊະນິດຜັນເຈຍໃນປ່າສະຫງວນແຫ່ງຊາດພູຫີນປູນ (38 ຊະນິດຜັນ) ແລະ ປ່າສະຫງວນແຫ່ງຊານາກາຍນ້ຳເທີນ (26 ຊະນິດຜັນ). ເຖິງແມ່ນວ່າຈຳນວນຕົວເລກເຫຼົ່ານີ້ຈະສະທ້ອນເຖິງຄວາມພະຍາຍາມໃນການສຳຫຼວດທີ່ແຕກຕ່າງກັນໃນແຕ່ລະຜືນທີ່.

ສອດຄ່ອງກັບຮູບແບບການຕ່າງໆທົ່ວທັງໝົດຜືນທີ່ອາຊີຕາເວັນອອກສຽງໃຕ້ ຈຳນວນປະເພດຊະນິດຜັນເຈຍທີ່ຖືກໄພຂົ່ມຂູ່ໂລກແມ່ນຕ່ຳ (2-3 ຊະນິດຜັນ) ໃນແຕ່ລະຜືນທີ່ ແລະ ບໍ່ມີຊະນິດຜັນເຈຍທີ່ໄດ້ບັນທຶກເປັນຊະນິດຜັນສະເພາະຖິ່ນຂອງຜືນທີ່.

ຍັງຄົງມີຄວາມເປັນໄປໄດ້ສຳລັບການຄົ້ນພົບຊະນິດຜັນເຈຍໃໝ່ເພີ່ມອີກໃນເຂດປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ ເນື່ອງຈາກມີຫຼາຍສາເຫດ ລວມທັງ: ກ) ການປະກົດຕົວຂອງຊະນິດຜັນເຈຍອື່ນໆທີ່ຫຼາກຫຼາຍໃນເຂດຜືນທີ່ໃກ້ຄຽງ ແລະ ຕິດກັບຜືນທີ່ຕ່າງໆທີ່ຍັງບໍ່ທັນໄດ້ມີການບັນທຶກໄວ້ໃນສະຖານທີ່, ຂ) ການເປັນຕົວແທນທີ່ມີຢູ່ຈຳກັດສຳລັບຈຳພວກທີ່ຫຼາກຫຼາຍ ແລະ ປະເພດທີ່ຍັງບໍ່ທັນພົບເຫັນຢູ່ໃນລາຍຊື່ຊະນິດຜັນເຈຍທີ່ພົບເຫັນລ່າສຸດຂອງປ່າສະຫງວນແຫ່ງຊາດ, ຄ) ຄວາມພະຍາຍາມການສຳຫຼວດທີ່ຂ້ອນຂ້າງຕ່ຳ ແລະ ຜືນທີ່ປົກຄຸມໜ້ອຍທີ່ປະສົບຜົນສຳເລັດໃນການສຳຫຼວດໃນຜືນທີ່ໃນປະຈຸບັນ ແລະ ງ) ເນື່ອງຈາກວ່າຂໍ້ມູນທາງດ້ານສຽງແນະນຳວ່າຍັງມີຊະນິດຜັນເຈຍເພີ່ມອີກໃນທີ່ນັ້ນ ແລະ ເຖິງແມ່ນວ່າຈະມີຄວາມສຳຄັນຢູ່ແລ້ວ ແຕ່ຄວາມສຳຄັນໃນການອະນຸລັກຂອງປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ສຳລັບຊະນິດຜັນເຈຍກໍ່ຈະຫຼາຍກວ່າເອກະສານທີ່ໄດ້ມີການບັນທຶກໄວ້ໃນປະຈຸບັນ.

ປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ເປັນພາກສ່ວນໜຶ່ງທີ່ສຳຄັນຂອງຜູ້ຝຽງຫີນປູນຂະໜາດກວ້າງທີ່ສຸດໃນອາຊີຕາເວັນອອກສຽງໃຕ້ ເຊິ່ງລວມທັງປ່າສະຫງວນແຫ່ງຊາດ ແລະ ຕິດກັບອຸທິຍາດແຫ່ງຊາດຝອງຍາແກບ່າງທີ່ເປັນແຫຼ່ງມໍລະດົກໂລກທາງດ້ານທຳມະຊາດໃນປະເທດຫວຽດນາມ ເນື່ອງຈາກວ່າຜືນທີ່ເກືອບທັງໝົດຂອງຜູ້ຝຽງຫີນປູນຂອງລາວນີ້ໄດ້ກວມເອົາພາຍໃນເຂດປ່າສະຫງວນແຫ່ງຊາດ ແລະ ຜືນທີ່ດັ່ງກ່າວປະກອບມີເຂດຜືນທີ່ປ່າຫີນປູນທີ່ເກົ່າແກ່ ແລະ ເຄື່ອນຄາຍຖ້າຂະໜາດໃຫຍ່ທີ່ຮັບຮອງເອົາການແຜ່ຜັນຂອງເຈຍທີ່ກໍ່ໃຫ້ເກີດມີຄວາມລາກຫຼາຍທາງດ້ານນິເວດວິທະຍາຢ່າງໜ້ອຍ 43% ຂອງສັດຈຳພວກເຈຍໃນລາວ, ຄວາມອຸດົມສົມບູນຂອງຜືນທີ່ໃນການສະໜອງບ່ອນອາໄສຂອງປະຊາກອນເຈຍ ແລະ ເປັນກຸ່ມປະຊາກອນເຈຍໃນເຂດອິນດູຈີນທີ່ປອດໄພ.

ພູມມິສາດຂອງຫົນໜາມໜ່ວຍທີ່ມີການສູງຊັນທີ່ແຫຼມຄົມ ເຮັດໃຫ້ການເຂົ້າເຖິງໄດ້ຍາກ ແລະ ມີພຽງຝື່ນທີ່ສ່ວນໜ້ອຍທີ່ມີທ່າແຮງໃນການເຮັດກະສິກໍາບໍ່ຫຼາຍ ໝາຍຄວາມວ່ານອກເໜືອຈາກຂອບດ້ານນອກ ແລະ ກວນທີ່ມີແມ່ນ້ຳແລ້ວ ຝື່ນທີ່ສ່ວນໃຫຍ່ຍັງຄົງມີຄວາມກົດດັນດ້ານການພັດທະນາຕໍ່າ ເຖິງແມ່ນວ່າການຕັດໄມ້ລະຫວ່າງຊາຍແດນຈະກໍ່ໃຫ້ເກີດມີບັນຫາເຊິ່ງຈະຕ້ອງໄດ້ມີການແກ້ໄຂໂດຍຄວາມພະຍາຍາມໃນການລາດຕະເວນເພີ່ມຂຶ້ນໃນຝື່ນທີ່ປ່າໄມ້ທີ່ຢູ່ເລິກເຂົ້າໃນປ່າພູຫີນປູນທີ່ຍັງຄົງຢູ່ໃນສະພາບທີ່ອຸດົມສົມບູນ ແລະ ເປັນຝື່ນທີ່ຢູ່ອາໄສທີ່ເໝາະສົມສໍາລັບການສືບພັນຂອງຊະນິດພັນເຈຍຕ່າງໆໃນເຂດບໍລິເວນໃກ້ຄຽງກັບເຂດກວນທີ່ມີແມ່ນ້ຳໃຫຍ່ ແລະ ໃນເຂດຝື່ນທີ່ອື່ນໆທີ່ບໍ່ເຄີຍໄດ້ຮັບການສໍາປະທານການຕັດໄມ້ກ່ອນໜ້ານີ້ ດັ່ງນັ້ນສະຖານທີ່ທີ່ໄດ້ສໍາຫຼວດໃນການສຶກສາຄົ້ນຄ້ວາປະຈຸບັນສະແດງໃຫ້ເຫັນວ່າມີສັນຍານລົບກວນຂະໜາດໃຫຍ່ພຽງໜ້ອຍດຽວ ແລະ ອາດຈະມີການເກີດຂຶ້ນອີກເຊັ່ນດຽວກັນ.

ໃນຂະນະທີ່ການສໍາຫຼວດນີ້ໄດ້ແນ່ໃສ່ຊະນິດພັນເຈຍທີ່ອາໄສຕາມເທິງໜ້າດິນ, ທົບທວນວະລະສານຄວບຄູ່ໄປກັບການຕິດຕໍ່ກັບນັກຊີວະວິທະຍາສາດທີ່ຄຸ້ນເຄີຍກັບປ່າສະຫງວນ ແນະນຳວ່າບັນດາຖ້ຳຕ່າງໆໃນປ່າສະຫງວນແຫ່ງຊາດຫົນໜາມໜ່ວຍແມ່ນບໍ່ໄດ້ມີສິ່ງລົບກວນ ເນື່ອງຈາກຄວາມຫ່າງໄກ ແລະ ບໍ່ມີເສັ້ນທາງເຂົ້າເຖິງ ແລະ ນ້ຳທີ່ບໍ່ພຽງພໍພາຍໃນຝື່ນທີ່ອີກຢ່າງລະບົບຂະໜາດໃຫຍ່ທີ່ມີທາງເຂົ້າເຊັ່ນຖ້ຳນ້ຳລອດເຊບັ້ງໄຟ (ເຊິ່ງເປັນເຂດຫວ່າງຫ້າມໃນການລ່າທີ່ມີປະສິດທິພາບ). ເຖິງແມ່ນວ່າການທ່ອງທ່ຽວພາຍໃນຖ້ຳແຫ່ງນີ້ກໍາລັງມີຈຳນວນນັກທ່ອງທ່ຽວເພີ່ມຂຶ້ນຄືກັນກັບເມື່ອກ່ອນ ແຕ່ເລື່ອງນີ້ເບິ່ງແລ້ວອາດຈະຍັງບໍ່ມີບັນຫາ ແລະ ບັນດາຜົນກະທົບທີ່ອາດຈະເກີດຂຶ້ນໃນຕໍ່ໜ້າກໍ່ກໍາລັງມີການແກ້ໄຂກ່ອນແລ້ວ ເຊິ່ງເປັນຜົນກໍ່ໃຫ້ຄວາມອຸດົມສົມບູນຂອງຝື່ນທີ່ກ່ຽວກັບບັນດາເຈຍທີ່ອາໄສພາຍໃນຖ້ຳ ແລະ ເທິງໜ້າດິນຍັງສາມາດຍືນຍັນດ້ວຍຄວາມໝັ້ນໃຈ.

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1. INTRODUCTION

1.1 CONTEXT FOR THIS DOCUMENT

Hin Nam No National Protected Area (NPA) covers $\approx 820 \text{ km}^2$ of mainly limestone landscape in Boualapha District, Khammouan Province, central Laos where the Central Indochina Limestone meets the Annamite Mountain Chain. The German Government supported Hin Nam No Project assists the Hin Nam No NPA authorities in developing a co-management system, where local communities share responsibilities for and share benefit from sustainable management of the biodiversity and other resources of the NPA.

The Department of Forest Resource Management of the Lao Ministry of Natural Resources and Environment is preparing a proposal to UNESCO to nominate Hin Nam No NPA as a Natural World Heritage Site. Proof that the site possesses Outstanding Universal Value(s) is required to support the nomination process and certain knowledge gaps need to be addressed to this end. These include knowledge gaps regarding the bat diversity at Hin Nam No and with respect to world heritage criterion x (namely: “*Contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of Outstanding Universal Value from the point of view of science or conservation*”).

This document consequently presents the results of a dedicated assessment of the bat fauna of Hin Nam No NPA in May 2017 using a variety of internationally-accepted methods.

1.2 BACKGROUND TO BATS IN SE ASIA & LAOS

Bats are divided into two suborders: the Yinpterochiroptera (Rhinolophoid bats and old world fruit bats) and Yangochiroptera (all other bats), whose ability to perceive their surroundings using echolocation, together with powered flight, has allowed them to master the night skies and exploit a wide range of niches worldwide (Schnitzler et al. 2001, Jones & Teeling 2006). Around 1,300 bat species are currently recognized, many of which feed on nectar and fruit, and this figure continues to grow each year with the discovery of new species, particularly in SE Asia (Tsang et al. 2016). Fruit bats are the main pollinators of many economically and ecologically important plants (Fujita & Tuttle 1991, Bumrungsri et al. 2013), and as many species carry seeds over long distances, make a significant contribution to reforestation of cleared areas (Sritongchuay et al. 2014). Most echolocating bats are insectivorous and these are the primary consumers of nocturnal insects (Nowak 1994), including economically significant quantities of major agricultural pests (Wanger et al. 2014) and important vectors of disease e.g., mosquitoes (Reiskind & Wund 2009).

Bats form a critical component of the SE Asia’s mammal fauna, as the group constitutes ca. 30% of the region’s mammal species, and can comprise as many as half of all mammal species in tropical rainforests (Kingston et al. 2006). Southeast Asia is also pivotal area for global bat conservation as it supports over 25% of the world’s bat fauna and as >197 of the 342 species known from the region are endemic to it (Kingston 2010). Despite the economic and conservation

importance of bats (Kunz et al. 2011), the composition and biogeography of the Lao bat fauna is poorly known. Though knowledge has increased in recent years, only 96 bat species are currently documented for the country (Kruskop & Borisenko 2013, Thomas et al. 2013, Son et al. 2013, Douangboubpha et al. 2014, Gorfol et al. 2014, Soisook et al. 2016), a figure which lags behind that for neighbouring Vietnam (≈ 120 species: Kruskop 2013) and Thailand (119 species: Bumrungsri et al. 2006). Correspondingly little is also known about the natural history of Lao bats, although as elsewhere in SE Asia, the group is particularly threatened by hunting (especially where this is for trade) and habitat loss, with forests being cleared for agriculture, plantations and dam construction (Thomas et al. 2013).

Beyond their intrinsic significance, the importance of cave-roosting bats for the subterranean invertebrates that depend on their guano is increasingly recognized. Due to the absence of primary production and general scarcity of food underground, most life in caves is invertebrate and largely dependent on energy sources from the surface such as penetrating tree roots and organic debris washed in by percolating waters or floods (Gillieson 1996). While bat guano appears to be less significant for cave-restricted invertebrates in the temperate zone, a considerable proportion of the terrestrial fauna in tropical caves depends upon its continued deposition (Deharveng & Bedos 2012). The significance of this lies in the fact that subterranean invertebrates are globally diverse and caves are thought to rank among the hottest of biodiversity hotspots (*sensu* Myers et al. 2000) worldwide in terms of their levels of species endemism and threat (Gilbert & Deharveng 2002, Whitten 2009). This poses a distinct concern in Laos as large bat colonies are at risk of extirpation in many parts of the country due to hunting (Francis et al. 1999) and these otherwise common species are paradoxically the most important for cave invertebrates because they produce the most guano (Furey & Racey, 2016a).

1.3 BATS STUDIES IN CENTRAL INDOCHINA AND COMPARATIVE ANALYSIS

While many studies have been conducted on the biodiversity of Hin Nam No NPA, dedicated surveys of bats at the site appear to be confined to a single study commissioned by the Wildlife Conservation Society (Francis & Khoonmy, 1998). Preliminary data from this study were included in Francis et al. (1999) and later reviewed by Thomas et al. (2013). Records of bat species at Hin Nam No NPA were also made during cave surveys by Steiner (2011, 2016). These collectively indicate the occurrence of at least 27 bat species at the site, including one listed as globally Near-Threatened by IUCN (2017): *Myotis pilosus*.

Prior to the present survey, it was assumed that additional bat species might exist at Hin Nam No NPA for several reasons, including:

- The relatively low survey effort and coverage achieved at the site to date, coupled with its size ($\approx 82,000$ ha), relative intactness and tendency for moderate-sized to large areas of forested karst in Indochina to support significantly greater bat species richness (Furey et al. 2010);

- The limited representation of diverse genera (e.g., *Hipposideros*, *Myotis*, *Pipistrellus*, *Murina* spp.) and absence of commonplace taxa (e.g., *Hesperoptenus* spp., *Scotophilus* spp.) that occur throughout the Indochinese region upon the existing bat species list for the site.

Other bat studies in Khammouan province have included surveys at Phou Hin Boun (formerly Khammouan Limestone) by Francis & Vongkhamheng (1998) and Robinson & Webber (2000), and at Nakai-Nam Theun by Francis et al. (1996). Records and specimen material from these studies were reviewed by Thomas et al. (2013), who also included details of bat species recorded in the Khammouan, Bolikhamxai and Savannakhet provinces which are held in overseas museums. As such, the latter was an important source of data for comparative analysis.

Although a large collection of bats was made in eastern Savannakhet province in late 2008 and deposited in the Australian National Wildlife Collection, details were not available for the otherwise exhaustive review of Thomas et al. (2013). Because species information presented in the preliminary report for this work (CNS & WCS, 2009) is equivocal¹, information for Savannakhet province was necessarily confined to two records detailed in Thomas et al. (2013) and records made by Furey & Douangboubpha (2015).

Finally, the comparative analysis incorporated information for Phong Nha – Ke Bang (Quang Binh province, Vietnam) from Hendrichsen et al. (2001) and Vu et al. (2012), and for Vu Quang (Ha Tinh province, Vietnam) from Borisenko & Kruskop (2003), as corrected by Kruskop (2013).

1.4 SURVEY OBJECTIVES AND SCHEDULE

The overall aim of the survey was to generate current and unequivocal information regarding the bat fauna of Hin Nam No NPA. In accordance with the associated terms of reference, the specific survey objectives were to:

- Provide a current baseline for the bat fauna of the Hin Nam No NPA
- Provide special insights into surface-dwelling bat species at Hin Nam No NPA
- Add new species to existing the bat inventory for Hin Nam No NPA

Prior to the field survey, a literature review (pre-study) was undertaken to synthesize published and other available data regarding the occurrence of bat species in Hin Nam No NPA, nearby sites (e.g., Nakai-Nam Theun, Phou Hin Boun, Phong Nha – Ke Bang) and central Indochina.

The field survey was undertaken from 9–29 May 2017 and encompassed seven areas in Hin Nam No NPA: Xe Bang Fai (9–10 May), Pak Xe Nue (11–15 May), Huoy Salong (17–19 May), Thong Xam (21 May); Tham Nam Ork (22–24 May), Ban Dou (25 May) and Nam Cum (26–28 May) (Fig. 1).

¹ As (1) some taxa recorded were not identified to species, (2) many were detected acoustically only (such that their identity remains unverified), (3) details are lacking as to what species were represented by captures (or specimens).

Following this, laboratory examination of voucher specimen was undertaken at the National University of Laos (NUoL) in Vientiane from 29 May to 2 June. A full schedule of activities during the survey is given in Appendix 1.

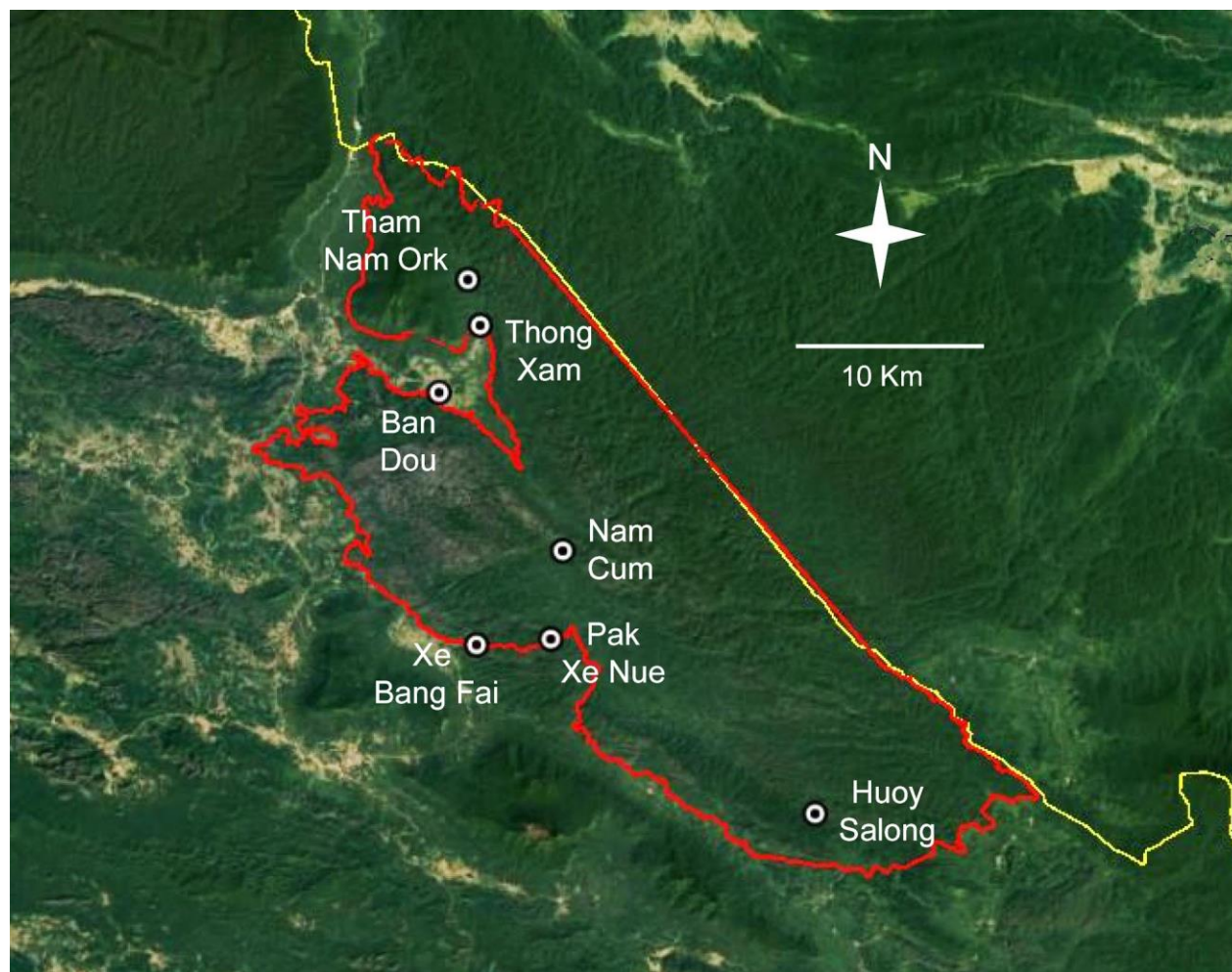


Fig. 1: Areas sampled during the bat survey at Hin Nam No NPA in May 2017

2. METHODS

2.1 SURFACE LIVE-SAMPLING

Outside of cave roosts, the success of live-sampling efforts in any bat survey are largely determined by the extent to which the habitat and terrain concentrate commuting bats into discreet flyways. Selection of sampling locations consequently focused on perceived flyways within the widest range of characteristic vegetation types in-situ, including ecotones and the interior (e.g.,

trails, watercourses and natural linear breaks) and edge of each (plus any water stationary features). Geo-coordinates and standard habitat data were recorded at all study sites.

Because bat species vary in their relative susceptibility to capture with mist nets and harp traps (Francis 1989, Berry et al. 2004) and our aim was to maximize inventory completeness, both capture devices were employed. An assortment of mist net sizes were used depending on local topography (e.g. 7x3m, 9x3.6m, 10x3m, 12x2.5m), all of which were 70 denier nets (Fig. 2). Two four-bank harp traps were also employed, each with a capture surface of 2.4 m² (Fig. 3). To standardize units of sampling effort between these traps per Furey et al. (2010), sampling effort for mist nets was calculated as m² of net multiplied by the hours for which they are set (m²mnh), while harp trap effort was calculated as m² multiplied by the hours of use (m²hth).

Mist nets were employed from 1800–2100 hrs each night, except where heavy rain prohibited live trapping. Harp traps were typically used from 1800–0600 hrs and checked for captures every 30 minutes between 1800–2100 hrs, then again the following morning. Mist nets were attended constantly while in use and disabled after each trapping session. Live-sampling was avoided on consecutive nights at the same location to avoid trap familiarity, and following processing, bats captured were released the same night. Field guides were interviewed to elicit information on roosts or specific foraging sites (e.g., water features) at the onset of fieldwork.



Fig. 2: Four-bank harp trap



Fig. 3: Mist net (70 denier)

2.2 CAVE SAMPLING

Daytime searches were undertaken to assess bat roosts. As the emphasis of the survey was on surface-dwelling bats, these were confined to two caves in Hin Nam No NPA: Tham Bing and

Tham Nam Ork. Because many bat species use caves on a transient basis, either seasonally as maternity roosts or nocturnally as feeding roosts, their absence during a single visit does not necessarily mean that a site is unused or abandoned. Past and present use by bats and people was therefore determined by exploring the caves during the daytime to:

- Directly observe and census the bats at roost. While many bat species prefer to roost in clusters, some species roost singly while others prefer to roost in crevices which can be easily overlooked. Ultrasound detectors (see below) were used to detect and identify both types.
- Search for guano. Fresh guano is the most obvious evidence of recent use by bats and the size of guano deposits can give a rough idea of population size and length of occupancy (provided it has not been harvested). Fruit bats and insectivorous bats also produce different guano and this was used to determine which were present.
- Assess past bat use. This was determined by searching for remains of bats on floors (Fig. 4) and stains on walls and ceilings from bat skin oils and urine.
- Assess human use. Evidence typically includes footprints, garbage, graffiti, rock scratches, fire pits and religious items such as burnt incense and other offerings. For instance, the presence of long sticks and fishing net fragments typically indicates bat hunting has occurred.

Following internal cave assessments, live-trapping and acoustic sampling was conducted at each cave to determine its bat species composition. Live-trapping was undertaken using mist nets nearby cave entrances during the evening emergence. Acoustic methods are detailed below.

2.3 ACOUSTIC SAMPLING

Acoustic sampling with ultrasound (bat) detectors is extensively used in temperate regions and an important complement to conventional capture methods (e.g., mist nets and harp traps) for bat species inventories in the tropics (MacSwiney et al. 2008, Furey et al. 2009a). This is because traditional methods typically fail to record insectivorous species that habitually fly in open areas and at higher altitudes outside the range of ground-based live-traps and so are less than comprehensive, even in the most intensive studies (Furey et al. 2009a).

During the above-ground surveys, recordings were made each night using a D980 bat detector (Pettersson Elecktronic AB) and stored on an Edirol HR09 digital recorder (Roland) (Fig. 5). In each instance, a continuous recording was made for 60 minutes beginning at sunset. While recording, the bat detector was set to repeatedly record three seconds of real time and time-expand (x10) the recordings. To minimize call variability and changes in detection due to habitat structure, calls were recorded in the most open space available at all sites. Because taxa within the Murininae and Kerivoulininae produce calls of very low intensity and are thus difficult to sample with bat detectors, live-trapping was alone used to sample members of these groups.

During internal cave assessments, recordings were made of all stationary and flying bats observed using D240x bat detectors (Pettersson Elecktronic AB) and stored on an Edirol HR09 digital

recorder. During live-trapping nearby cave entrances, continuous recordings were also made at the cave entrances using the same equipment & methods as in the above-ground surveys.

All recordings were digitized for analysis using Bat Sound software (ver. 3.31, Pettersson Electronic AB) at a sampling rate of 44.1 kHz, with 16 bits/sample. Spectrograms were examined using a 512-size Fast Fourier Transformation and a Hanning window. Only search phase calls of sufficient intensity for measurement were considered for analysis. A reference collection of calls was constructed from captured rhinolophid and hipposiderid bats (of known identity) to facilitate identification of bats registered in the acoustic sampling. Other taxa were reviewed against call descriptions in the literature.



Fig. 4: *Rousettus* sp. skull in cave



Fig. 5: Acoustic sampling equipment

2.4 SPECIES IDENTIFICATION

Bats captured during live-sampling were measured, photographed and identified in the field using the appropriate field guides/monographs for Laos (e.g., Francis 2008, Kruskop 2013) and released at the same night. Echolocation calls were recorded from each released individual using the appropriate species-specific methods for reference in analysis of acoustic data.

To verify species identifications, a minimum number of non-reproductively active adult males were retained as voucher specimens in 80% ethanol (in practice, this usually meant two specimens for each species). Skulls of selected voucher specimens were extracted for measurement and comparative examination of cranio-dental features and a variety of other characters at the National University of Laos with reference to recent taxonomic literature.

External measurements were taken from ethanol preserved specimens to the nearest 0.1mm, while cranio-dental measurements were taken to the nearest 0.01 mm using digital calipers under a stereo

microscope. Measurements included only those taken from non-juveniles, as indicated by the presence of fully ossified metacarpal-phalangeal joints.

All voucher specimens collected during the field sampling are permanently deposited in the zoological collections of Faculty of Environmental Science at NUoL. Taxonomy follows Simmons (2005), with recent modifications (e.g., Bates et al. 2007, Soisook et al. 2008, Furey et al., 2009b; Francis & Eger 2012).

2.5 REPRODUCTIVE ASSESSMENT

Bat populations take a relatively long time to recover from population losses associated with human activities due to their low annual reproductive rates (Racey & Entwistle 2000). This poses a particular problem for cave-dwelling bats, as any intrusion into the relatively small and confined spaces that caves provide tends to affect the entire aggregation (McCracken 1989). Because disturbance during pregnancy, lactation and weaning is widely recognized as highly detrimental to recruitment in bat populations (McCracken 1989, Sheffield et al. 1992, Juberthie 2000, Mitchell-Jones et al. 2007), identification of these critical periods is consequently central to site-based assessments and species conservation.

All bats captured during the survey were examined to diagnose their sex, age and reproductive status following Furey et al. (2011). Young bats were classified as non-volant young if still attached to their mother, while juveniles were classified as volant individuals lacking fully ossified and fused metacarpal-phalangeal epiphyses. Genitalia were examined to determine the status of non-juvenile males and individuals were classified as reproductively immature if they lacked enlarged testes and/or distended caudae epididymides, or mature if these were enlarged or distended. Non-juvenile females were classified as nulliparous or parous, and, reproductively inactive, pregnant and/or lactating using a variety of anatomical criteria.

These data were aggregated to determine the timing of critical reproductive periods, the degree of reproductive synchronicity between species, and congruence with multi-year datasets and literature held by the authors for Laos and neighbouring Indochinese region.

2.6 ANALYSIS

2.6.1 Assemblage structure

Bats respond to habitat alterations in a species-specific manner, with the result that abundances of some species can be expected to increase (tolerant species), while others decrease (intolerant species) and yet others are seemingly unaffected. As forest interiors are spatially complex, bat species which primarily forage in these ‘cluttered’ airspaces require greater manoeuvrability than those that forage in less cluttered or open airspaces. This is reflected in their wing morphology which is consequently a significant independent predictor of extinction risk for insectivorous

species (Jones *et al.* 2003, Safi & Kerth 2004), as it determines their foraging preferences, home range area and dispersal abilities (Norberg & Rayner 1987).

Recognition that bats foraging in similar habitats have similar wing morphology has prompted several classifications (e.g., Aldridge & Rautenbach 1987, Crome & Richards 1988, Fenton 1990). These were categorized by McKenzie *et al.* (1995) as:

- Strategy I: Insectivorous species that forage in the highly cluttered airspace within the forest interior (or forest-interior specialists);
- Strategy II: Insectivorous species that forage in partially cluttered spaces such as clearings, streams or other tunnels within the forest or just above the canopy (edge and gap foragers);
- Strategy III: Insectivorous bats that forage in unobstructed airspaces found in large clearings or high above the forest canopy (open-space foragers);
- Strategy IV: fruit and nectar-eating bats that fly into the partially cluttered air-spaces between tree canopies, roost in small numbers and forage locally; and,
- Strategy V: Fruit and nectar-eating bats that fly in unobstructed air-spaces, roost in large colonies and forage over large areas.

All species recorded during the survey were classified per the above schema on the basis of wing-morphology analyses of Indochinese bats by Furey *et al.* (2016b) and associated publications. Finally, assemblage evenness ($E_{1/D}$) was calculated by dividing the reciprocal form of Simpson's Index index values by S (number of species). Values for $E_{1/D}$ range from 0–1, reflecting increasing evenness in the distribution of relative abundances of species.

2.6.2 Inventory completeness

To quantitatively determine the completeness of sampling effort, true species richness (S_{max}) was estimated following Furey *et al.* (2010) using abundance data and multinomial methods developed by Solow and Polasky (1999) and Shen *et al.* (2003). To create upper and lower bound estimates of species richness, predictions were based upon a quadrupling of sampling effort and inventory completeness was calculated as the ratio of species observed (S_{obs}) to those estimated i.e. $S_{obs}/S_{max} \times 100$.

To determine the potential for further discoveries and thus the probable bat species richness of Hin Nam No NPA, these quantitative analyses were refined with reference to a synthesis of published and unpublished data held by the authors regarding the distribution and occurrence of bat species in nearby sites, wider Indochina and mainland SE Asia.

2.6.3 Biological significance

Biological significance was assessed for all species using an aggregate of the following measures: conservation status, rarity, distribution (incl. endemism) and specialization.

Conservation Status: Although Duckworth et al. (1999) categorized the national conservation status of bat species in Laos, many of these classifications have been made redundant by subsequent progress in the field. National conservation status for bat species was therefore assessed with reference to Francis & Eger (2012), Thomas et al. (2013), Douangboubpha et al. (2014) and recent field research (e.g., Furey & Douangboubpha 2015). Global conservation status was assessed with reference to the IUCN Red List of Threatened Species (www.iucnredlist.org/).

Rarity & Distribution: Species representing <0.5% of total captures in the live-trapping (only, because acoustic sampling cannot be used to determine abundance) were defined as ‘locally rare’, following Furey et al. (2010). Distributions (global rarity / endemism) for each species were defined on the basis of literature for Laos (e.g., Francis & Eger 2012, Thomas et al. 2013, Douangboubpha et al. 2014, Furey & Douangboubpha 2015) and wider SE Asian mainland.

Specialization: Each species recorded during the study was defined on the basis of its roosting, trophic (dietary), locomotory and perceptual specializations (foraging strategy).

3. RESULTS

3.1 SAMPLING EFFORT

Over the course of the field survey, 17 trap nights of live-trapping representing 7,883.4 m²mnh (mist-net-hours) and 631.2 m²hth (harp-trap-hours) were achieved at 88 discrete points in Hin Nam No NPA. These comprised 86 forest locations and two points within Tham Bing cave. Trapping elevations ranged from 164–462 m asl. One hour of simultaneous acoustic sampling (from ≈1800–1900 hrs) was undertaken on all but two trap nights (12 May and 25 May, due to rain and equipment malfunction respectively), resulting in 15 hours of recordings. Live-trapping and acoustic sampling effort is summarized in Table 1 and full details of effort and geo-coordinates for sampling sites are provided in Appendix 2.

Table 1: Sampling effort during the bat survey at Hin Nam No NPA, May 2017

Area	Trap nights	Trap points (site codes)	m ² mnh	m ² hth	Acoustic sampling hrs (location)
Xe Bang Fai	2	8 (F#1-8)	608.4	12	2 (C#1-2)
Pak Xe Nue	5	27 (F#9-35)	1,470.6	244.8	4 (C#3,F#18,24,31)
Huoy Salong	3	18 (F#36-53)	918	129.6	3 (F#38,44,49)
Thong Xam	1	3 (F#54-56)	243	0	1 (F#54)
Tham Nam Ork	2	10 (F#57-64,C#4.1-4.2)	554.4	115.2	2 (C#4,F#57)
Ban Dou	1	4 (F#65-68)	220.8	0	-
Nam Cum	3	18 (F#69-86)	3,868.2	129.6	3 (F#69,74,81)
Total	17		7,883.4	631.2	15

Rain was experienced on 11 days during the survey period, but only prohibited live-trapping on a single evening (24 May). Weather conditions were otherwise dry and variably clear for the remainder of the survey. Temperature and relative humidity ranges were 20.2–38.0°C and 63.0–98.9% respectively. Daily meteorological data for the survey period are provided in Appendix 3.

3.2 SPECIES COMPOSITION

A total of 788 bats representing 34 species arranged in six families were captured in live-traps during the survey period (Table 2). Sixty voucher specimens were collected representing all but one of these species (*Cynopterus sphinx*). To verify identifications, skulls of 30 specimens were extracted for examination and measurement at the NUoL laboratory. A full list of specimen material collected during the survey is given in Appendix 4 and biometric data in Appendix 5 & 6.

Seventeen species were distinguished in the acoustic sampling, including five horseshoe and four leaf-nosed bat species (Table 2). The remainder were eight distinct phonic types (PT 1–8) which could not be assigned with certainty to species, although all were aerial insectivores within the Vespertilionidae, Molossidae and/or Miniopteridae and emitted a mixture of broadband signals dominated by the fundamental harmonic. Emballonurids also represent a possibility, though this is less likely as these typically emit signals characterized by multiple harmonics (Jones & Teeling 2006). Two additional signal types, one belonging to a rhinolophid and another to a hipposiderid were also registered in many survey areas, but could not assigned to a specific taxon due to overlap in call frequencies emitted by several species. Characteristic echolocation signals recorded from insectivorous bat species during the survey are shown in Fig. 6.

Fourteen bat species captured during the survey represent new records for Hin Nam No NPA: Leschenault's rousette *Rousettus leschenaulti*, cave nectar bat *Eonycteris spelaea*, Greater long-tongued nectar bat *Macroglossus sobrinus*, Siamese horseshoe bat *Rhinolophus siamensis*, lesser brown horseshoe bat *R. microglobosus*, ashy leaf-nosed bat *Hipposideros cineraceus*, grand leaf-

nosed bat *H. grandis*², intermediate leaf-nosed bat *H. larvatus*, shield-nosed bat *H. scutinares*, Mount Popa pipistrelle *Pipistrellus paterculus*, greater bamboo bat *Murina huttoni*, Fiona's tube-nosed bat *M. fionae*, grey-headed tube-nosed bat *M. feae* and Kachin woolly bat *Kerivoula kachinensis* (Fig. 7, Table 2).

One bat species captured during the survey is listed by IUCN (2017) as globally Vulnerable (*Hipposideros scutinares*), whereas three others have yet to be evaluated: *R. microglobosus*, *M. fionae* and *M. feae* (Fig. 7, Table 2). The remaining species are all considered as Least Concern and are variably common within their respective ranges.

Table 2: Bat species recorded at Hin Nam No NPA, May 2017

* = New record for Hin Nam No NPA. NE = Not evaluated; VU = Vulnerable (IUCN, 2017). Sh-FM = Shallow frequency-modulated signal; St-FM = Steep frequency-modulated signal. A = Verified from carcasses collected at Tham Bing cave; B = Registered acoustically (use of square brackets indicates taxa that cannot be unequivocally distinguished due to overlapping frequencies at Hin Nam No e.g., *H. diadema* vs. *H. scutinares* and *R. malayanus* vs. *R. siamensis* vs. *R. thomasi*; these are excluded from species totals).

#	Family / Species	Xe Bang Fai	Pak Xe Nue	Houy Salong	Thong Xam	Tham Nam Ork	Ban Dou	Nam Cum
Old world fruit bats, Pteropodidae								
1	<i>Cynopterus sphinx</i>		1				5	
2	<i>Cynopterus horsfieldi</i>		2				4	1
3	<i>Eonycteris spelaea</i> *		1					
4	<i>Macroglossus sobrinus</i> *		2					
5	<i>Rousettus amplexicaudatus</i>	1 ^A						
6	<i>Rousettus leschenaulti</i> *	A						
False vampire bats, Megadermatidae								
7	<i>Megaderma lyra</i>	7	2	1			1	
8	<i>Megaderma spasma</i>	1	3				3	
Horseshoe bats, Rhinolophidae								
9	<i>Rhinolophus malayanus</i>	2	12 ^[B]		[B]	3 ^[B]	1	1 ^[B]
10	<i>Rhinolophus siamensis</i> *		14 ^[B]	1	[B]	[B]		[B]
11	<i>Rhinolophus microglobosus</i> * NE		1	1				1 ^B
12	<i>Rhinolophus paradoxolophus</i>		1 ^B					1
13	<i>Rhinolophus pearsonii</i>		2 ^B	4		8 ^B		3 ^B
14	<i>Rhinolophus pusillus</i>		27 ^B	4		5		1
15	<i>Rhinolophus thomasi</i>	3	7 ^[B]	54	1 ^[B]	57 ^[B]	2	11 ^[B]
Leaf-nosed bats, Hipposideridae								
16	<i>Hipposideros armiger</i>		B	6 ^B	12	1 ^B		6

² Distinguished from *H. larvatus* per Kruskop (2013).

#	Family / Species	Xe Bang Fai	Pak Xe Nue	Houy Salong	Thong Xam	Tham Nam Ork	Ban Dou	Nam Cum
17	<i>Hipposideros cineraceus</i> *					4	1	
18	<i>Hipposideros diadema</i>	5 ^[B]	[B]		1 ^[B]	[B]		
19	<i>Hipposideros grandis</i> *			1 ^B	2	15 ^B		5 ^B
20	<i>Hipposideros larvatus</i> *	1	7 ^B	75 ^B		58	1	14
21	<i>Hipposideros pomona</i>		26	16		45		2
22	<i>Hipposideros scutinares</i> * ^{VU}	12 ^[B]	2 ^[B]		[B]	2 ^[B]	3	
23	<i>Aselliscus stoliczkanus</i>	3	92 ^B	3		51 ^B		1
Evening bats, Vespertilionidae								
24	<i>Myotis siligorensis</i>			2				
25	<i>Pipistrellus paterculus</i> *		2					1
26	<i>Tylonycteris malayana</i>					1		
27	<i>Kerivoula kachinensis</i> *		2					1
28	<i>Kerivoula hardwickii</i>		6	6		5		
29	<i>Kerivoula titania</i>		1			1		5
30	<i>Harpiocephalus harpia</i>			2				9
31	<i>Murina huttoni</i> *							4
32	<i>Murina feae</i> * ^{NE}		1					
33	<i>Murina fionae</i> * ^{NE}							2
Bent-winged bats, Miniopteridae								
34	<i>Miniopterus magnater</i>							1
Phonic types (Pt)								
35	PT-1 (Sh-FM 19.4 kHz)	B	B		B	B		B
36	PT-2 (St-FM 28.1 kHz)	B			B	B		
37	PT-3 (St-FM 35.4 kHz)	B						
38	PT-4 (Sh-FM 44.6 kHz)			B	B			
39	PT-5 (St-FM 45.1 kHz)					B		
40	PT-6 (St-FM 53.3 kHz)		B			B		
41	PT-7 (St-FM 62.0 kHz)					B		
42	PT-8 (St-FM 68.3 kHz)	B				B		
Total (bats)		35	214	176	16	256	21	70
Total (species)		14	25	15	7	20	9	20

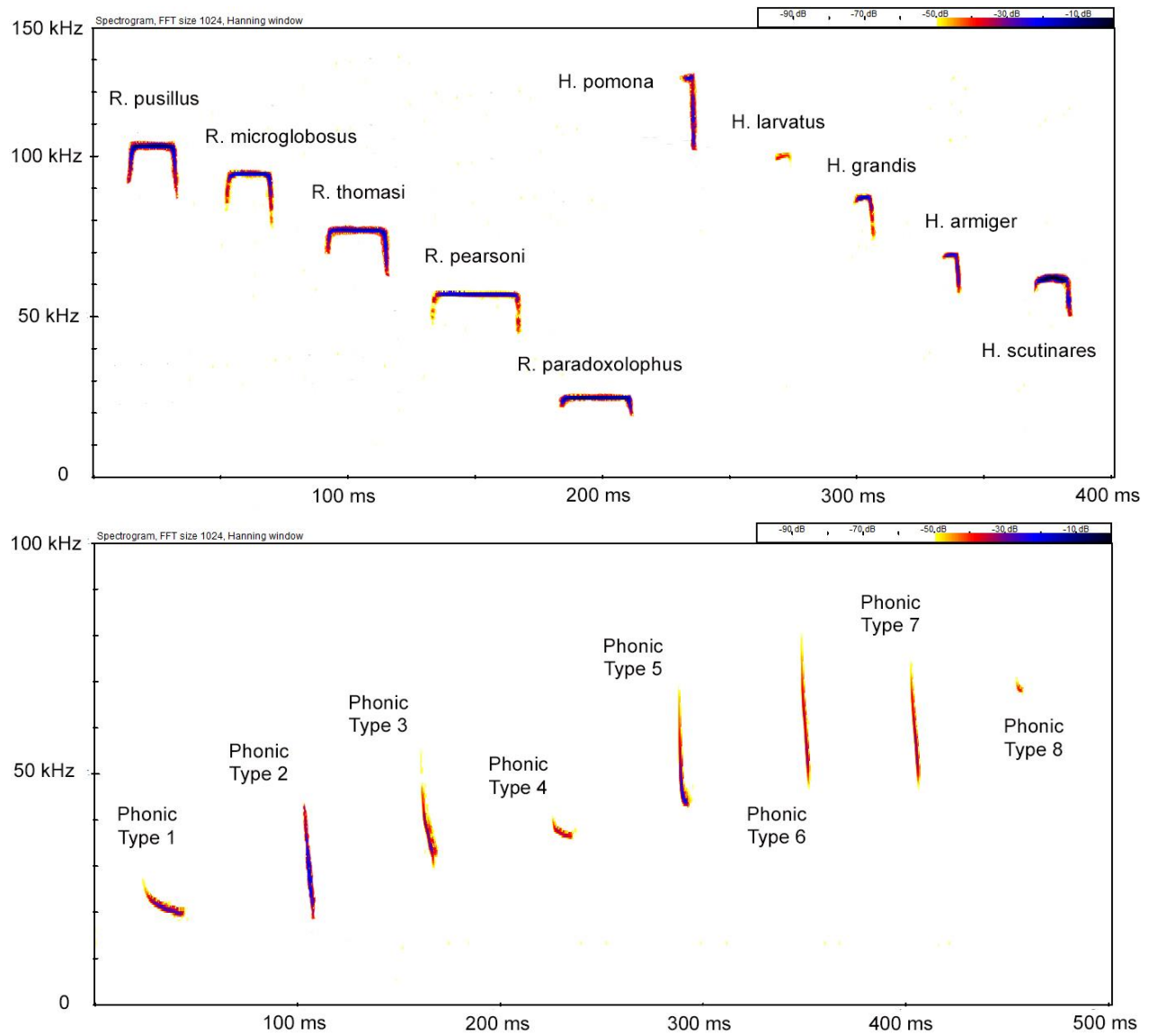


Fig. 6: Echolocation calls of selected species recorded at Hin Nam No NPA, May 2017

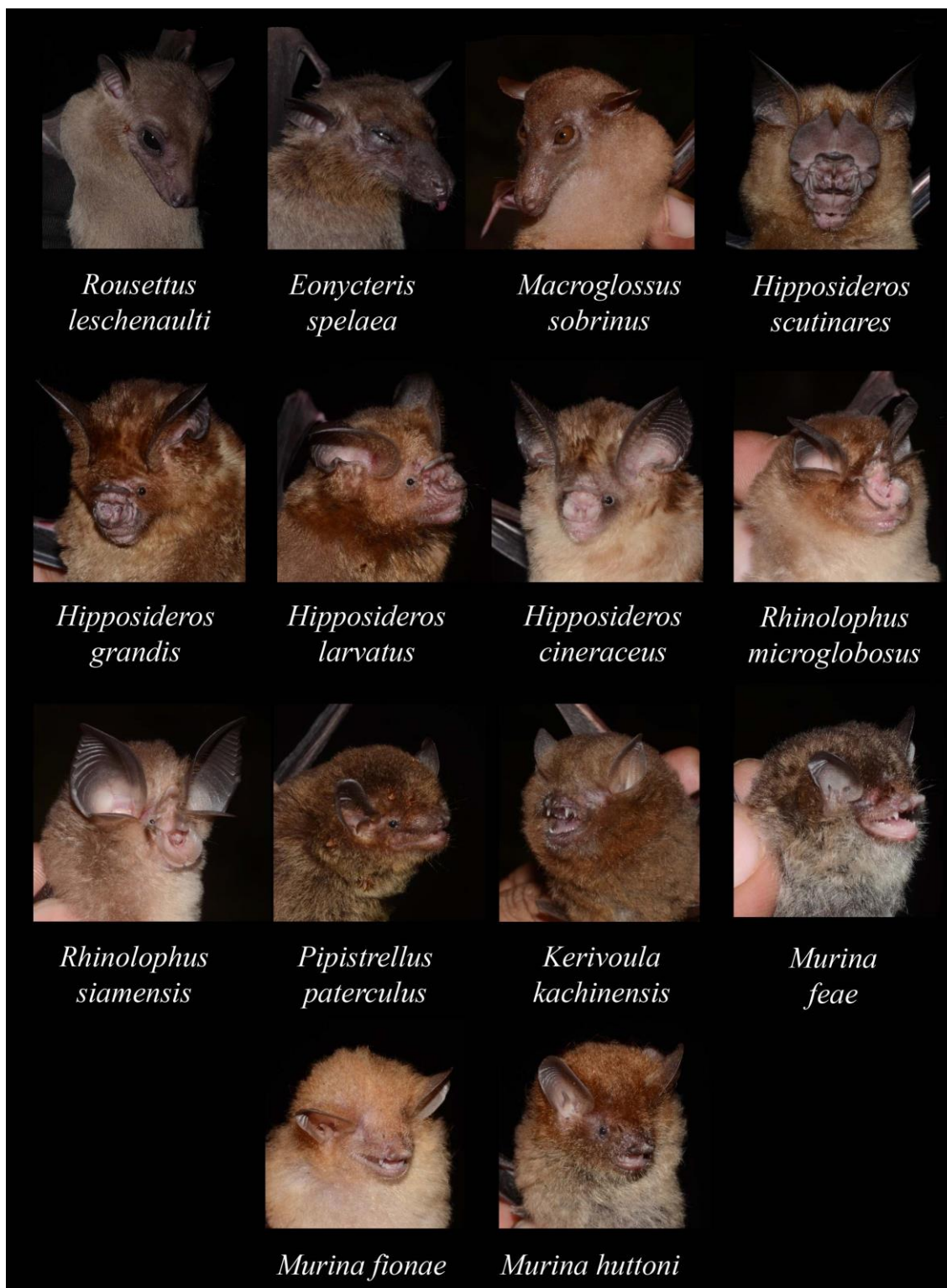


Fig. 7: Bat species first recorded at Hin Nam No NPA in May 2017. Not to scale.

3.3 ASSEMBLAGE STRUCTURE

Per live-capture data, evening bats (Vespertilionidae) were best represented in species richness with ten species (=6.5% of captures, 51/788 bats), followed by leaf-nosed bats (Hipposideridae) with eight species (60%, 473/788), horseshoe bats (Rhinolophidae) with seven species (28.9%, 228/788), old world fruit bats (Pteropodidae) with six species (2.2%, 17/788), false vampire bats (Megadermatidae) with two species (2.3%, 18/788) and bent-winged bats (Miniopteridae) with one species (0.1%, 1/788) (Table 2). Assemblage evenness was low at 0.238, reflecting dramatic differences in relative species abundances e.g., several hyper-abundant species and many taxa represented by very few individuals (Fig. 8).

The single most abundant species was *Hipposideros larvatus* which represented 19.8% of captures (156 bats), followed by trident leaf-nosed bat *Aselliscus stoliczkanus* (19%, 150) and Thomas's horseshoe bat *Rhinolophus thomasi* (17.1%, 135). All three species are cave-dwelling insectivores and common with their respective ranges. Eleven taxa were 'locally rare' in representing <0.5% of captures (e.g., <4 bats): *Eonycteris spelaea*, *Macroglossus sobrinus*, *Rhinolophus microglobosus*, Bourret's horseshoe bat *Rhinolophus paradoxolophus*, small-toothed myotis *Myotis siligorensis*, *Pipistrellus paterculus*, *Tylonycteris malayana*, *Kerivoula kachinensis*, *Murina fuae*, *M. fionae* and large bent-winged bat *Miniopterus magnater* (Fig. 8).

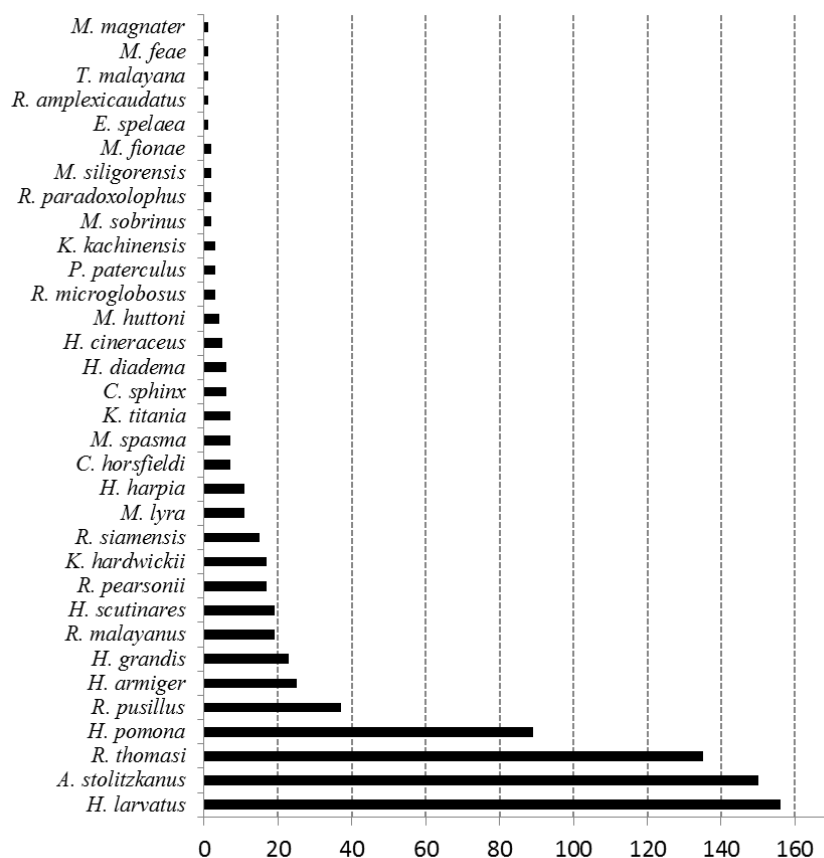


Fig. 8: Relative abundances of bat species recorded at Hin Nam No NPA, May 2017

Of the 28 animalivorous bats captured during the survey (false-vampire, horseshoe, leaf-nosed, evening and bent-winged bats), 15 were forest-interior specialists (strategy I species), whereas 12 were edge and gap foragers (strategy II species, including two taxa that use both habitats) and the remaining species (*M. magnater*) was an open space forager (strategy III) (Table 3).

As such, a large proportion of bat fauna recorded during the survey (44%, 15/34 spp.) is vulnerable to declines as a result of forest loss and degradation. This concern is exacerbated for species that dwell in caves (e.g., most rhinolophid and hipposiderid taxa), because these roost sites are inherently vulnerable to disturbance (Furey & Racey 2016a). The latter issue also affects three cave-dwelling fruit bat taxa (strategy V species: *Eonycteris spelaea*, *Rousettus amplexicaudatus* and *Rousettus leschenaulti*) which are often targeted by hunters for bush meat consumption.

Table 3: Characteristics of bat species recorded at Hin Nam No NPA, May 2017

Superscript annotations: NE=Not evaluated; VU=Vulnerable (IUCN, 2017). ¹ S-I=Forest-interior specialist; S-II=Edge and gap specialist; S-III=Open-space forager; S-IV=Frugivores that roost in small numbers and forage locally; S-V=Frugivores that roost in large numbers and forage over large areas. Use of the word ‘region’ refers to mainland SE Asia. Distribution data is taken from Francis (2008), Francis & Eger (2012), Kruskop (2013), Thomas et al. (2013) and Furey & Douangboubpha (2015).

#	Family / species	Characteristics ¹
Old world fruit bats, Pteropodidae		
1	Greater short-nosed fruit bat <i>Cynopterus sphinx</i>	Foliage-dweller and frugivore (S-IV). Widespread in region and Laos. LC
2	Horsfield's fruit bat <i>Cynopterus horsfieldi</i>	Foliage-dweller and frugivore (S-IV). Widespread in region, although hitherto only three localities recorded for Laos. LC
3	Cave nectar bat <i>Eonycteris spelaea</i> *	Cave-dweller and colonial nectarivore (S-V). Widespread in region and Laos. Often targeted by hunters. LC
4	Greater long-tongued nectar bat <i>Macroglossus sobrinus</i>	Foliage-dweller and nectarivore (S-IV). Widespread in region, though most records to date for Laos are in north and centre. LC
5	Geoffroy's rousette <i>Rousettus amplexicaudatus</i>	Cave-dweller and colonial frugivore (S-V). Widespread in region and Laos. Often targeted by hunters. LC
6	Leschenault's rousette, <i>Rousettus leschenaultia</i>	Cave-dweller and colonial frugivore (S-V). Widespread in region and Laos. Often targeted by hunters. LC
False vampire bats, Megadermatidae		
7	Greater false vampire bat <i>Megaderma lyra</i>	Forest-interior/edge & gap and insectivore/carnivore (S-I/II). Roosts in caves and tunnels. Widespread in region and Laos. LC
8	Lesser false vampire bat <i>Megaderma spasma</i>	Forest-interior/edge & gap and insectivore/carnivore (S-I/II). Roosts in caves and trees. Widespread in region and Laos. LC
Horseshoe bats, Rhinolophidae		
9	Malayan horseshoe bat <i>Rhinolophus malayanus</i>	Forest-interior insectivore and cave-dweller (S-I). Widespread in region and Laos. LC
10	Siamese horseshoe bat <i>Rhinolophus siamensis</i>	Forest-interior insectivore. Likely a cave-dweller (S-I). Occurs in north Indochina, north Thailand and Laos. LC
11	Lesser brown horseshoe bat <i>Rhinolophus microglobosus</i> ^{NE}	Forest-interior insectivore and cave-dweller (S-I). Recorded from north, central and south Laos. NE
12	Bourret's horseshoe bat <i>Rhinolophus paradoxolophus</i>	Forest-interior insectivore and cave-dweller (S-I). Restricted to N. Indochina & Thailand. Most Lao records hitherto from centre. LC

13	Pearson's horseshoe bat <i>Rhinolophus pearsonii</i>	Edge and gap insectivore and cave-dweller (S-II). Widespread in region and Laos. LC
14	Least horseshoe bat <i>Rhinolophus pusillus</i>	Forest-interior insectivore (S-I). Roosts in caves and foliage. Widespread in region and Laos. LC
15	Thomas's horseshoe bat <i>Rhinolophus thomasi</i>	Forest-interior insectivore and cave-dweller (S-I). Widespread in north & central SE Asian mainland, including Laos. LC
Leaf-nosed bats, Hipposideridae		
16	Great leaf-nosed bat <i>Hipposideros armiger</i>	Edge and gap insectivore and cave-dweller (S-II). Widespread in region and Laos. LC
17	Ashy leaf-nosed bat <i>Hipposideros cineraceus</i>	Forest-interior insectivore and cave-dweller (S-I). Widespread in region and Laos. LC
18	Diadem leaf-nosed bat <i>Hipposideros diadema</i>	Edge and gap insectivore and cave-dweller (S-II). Widespread in south & central SE Asian mainland, including Laos. LC
19	Grand leaf-nosed bat <i>Hipposideros grandis</i>	Edge and gap insectivore and cave-dweller (S-II). Widespread in region, status in Laos is unclear. LC
20	Intermediate leaf-nosed bat <i>Hipposideros larvatus</i>	Edge and gap insectivore and cave-dweller (S-II). Widespread in region and Laos. LC
21	Large-eared leaf-nosed bat <i>Hipposideros pomona</i>	Forest-interior specialist and cave-dweller (S-I). Widespread in region and Laos. LC
22	Shield-nosed bat <i>Hipposideros scutinares</i> ^{VU}	Edge and gap insectivore and cave-dweller (S-II). Currently recorded only in relatively small area of central Indochina. VU
23	Trident leaf-nosed bat <i>Aselliscus stoliczkanus</i>	Forest-interior insectivore and cave-dweller (S-I). Widespread in north SE Asian mainland, including north & central Laos. LC
Evening bats, Vespertilionidae		
24	Small-toothed myotis <i>Myotis siligorensis</i>	Edge and gap insectivore and cave-dweller (S-II). Widespread in region and Laos. LC
25	Mount Popa pipistrelle <i>Pipistrellus paterculus</i>	Edge and gap insectivore and cave-dweller (S-II). North and central Indochina & Myanmar, with only few records for southern Laos. LC
26	Greater bamboo bat <i>Tylonycteris malayana</i>	Edge and gap insectivore (S-II). Roosts in bamboo stems. Widespread in Indochina, P. Malaysia and Laos. LC
27	Kachin woolly bat <i>Kerivoula kachinensis</i>	Forest-interior insectivore and foliage-dweller (S-I). Scattered records for region, including north to south Laos. LC
28	Hardwicke's woolly bat <i>Kerivoula hardwickii</i>	Forest-interior insectivore and foliage-dweller (S-I). Widespread in region and Laos. LC
29	Titania's woolly bat <i>Kerivoula titania</i>	Forest-interior insectivore and foliage-dweller (S-I). Widespread in region, though hitherto very few records for Laos. LC
30	Hairy-winged bat <i>Harpiocephalus harpia</i>	Edge and gap specialist and foliage-dweller (S-II). Relatively widespread, including north to south Laos. LC
31	Hutton's tube-nosed bat <i>Murina huttoni</i>	Forest-interior insectivore and foliage-dweller (S-I). Scattered records in region, but in Laos hitherto known only from one locality. LC
32	Grey-headed tube-nosed bat <i>Murina fuae</i> ^{NE}	Forest-interior insectivore and foliage-dweller (S-I). Widespread in region and Laos. NE
33	Fiona's tube-nosed bat <i>Murina fionae</i> ^{NE}	Forest-interior insectivore and foliage-dweller (S-I). Currently known only from very few localities in central and south Indochina, including type locality in Khammouan, Laos. NE
Bent-winged bats, Miniopteridae		
34	Large bent-winged bat <i>Miniopterus magnater</i>	Open-space insectivore and cave-dweller (S-III). Widespread in region and Laos. LC

3.4 REPRODUCTIVE ACTIVITY

The overwhelming majority of female insectivorous bat species captured during the survey period were lactating, indicating that these had given birth in the recent past. This is consistent with predictions for the seasonal tropics (Racey & Entwistle 2000) and recent data for the SE Asian mainland (e.g., Nu Nu Aye 2006, Furey et al. 2011, Khin Min Min Tun et al. 2015, Furey et al. unpublished data) and is to be expected because insect biomass and thus food availability are optimal for ensuring reproductive success during the wet season (May to October).

Among the six fruit bat species recorded, live-captures included one juvenile of *Rousettus* sp.; five juveniles, one lactating female and one female in early pregnancy of greater short-nosed fruit bat *C. sphinx*; one juvenile and one lactating female of Horsfield's fruit bat *C. horsfieldi*; and one female of *M. sobrinus* which was carrying an offspring. Unlike most insectivorous bats in mainland SE Asia which bear a single young per year, *Rousettus* spp. and *Cynopterus* spp. bear two cohorts of young each year and the timing of parturition is regulated by food availability e.g., flowering and fruiting phenology of local food plants (Bumrungsri et al. 2007, Furey et al. 2011).

3.5 INVENTORY COMPLETENESS

Based on live-trapping results, both quantitative estimates of true bat species richness (S_{max}) at Hin Nam No NPA were 36.1, suggesting an overall inventory completeness ratio of 91%. Because 14 bat species recorded during the survey are new site records, which in turn means that 41 bat species are now known to occur at the NPA (Table 4), this is clearly an underestimate.

Further, excellent potential remains for discovering additional bat species at Hin Nam No NPA for several reasons, including:

- The occurrence of at least 64 species in Khammouan province and at least 40 species at the contiguous Phong Nha – Ke Bang WHS in Vietnam, the latter including 13 taxa which have yet to be recorded at Hin Nam No;
- The limited representation of diverse genera (e.g., *Myotis*, *Pipistrellus*) and absence of several commonplace taxa (e.g., *Hesperoptenus* spp., *Scotophilus* spp.) that occur throughout the Indochinese region on the combined bat species list for the NPA;
- The relatively low survey effort and coverage achieved at the site to date (compared to areas such as Phong Nha – Ke Bang) and because acoustic data recorded in the May 2017 study suggest that additional bat species occur at the site.

As a consequence, further sampling would undoubtedly reveal additional bat species. Because multi-year sampling in Vietnam suggests that sampling during both seasons is critical to inventory completeness (Furey et al. 2010), such work should encompass the dry and wet seasons and employ multiple detection methods e.g., cave exploration, live-trapping and acoustic sampling.

Table 4: Bat species recorded at Hin Nam No NPA and nearby areas in central Indochina

Sites: HNN = Hin Nam No, PHB = Phou Hin Boun (formerly Khammouan Limestone), NNT = Nakai Nam Theun, KHA-PROV = Khammouan Province, BOL-PROV = Bolikhamxai Province, SAV-PROV = Savannakhet Province, PNKB = Phong Nha Ke Bang (Quang Binh Province), VUQ = Vu Quang (Ha Tinh Province).

Superscript annotations: * = New record for Hin Nam No NPA; DD = Data Deficient; NE = Not evaluated; NT = Near Threatened; VU = Vulnerable (per IUCN, 2017).

#	Family / Species	LAOS					VIETNAM		
		HNN	PHB	NNT	KHA-PROV	BOL-PROV	SAV-PROV	PNKB	VUQ
	Pteropodidae								
1	<i>Pteropus</i> sp.					2			
2	<i>Rousettus amplexicaudatus</i>	1,3	2,4		1,2,3,4				
3	<i>Rousettus leschenaultii</i> *	1	2,4		1,2,4	2	5	7	
4	<i>Cynopterus sphinx</i>	1,2	2,4		1,2,4	2		6,7,8	8
5	<i>Cynopterus horsfieldii</i>	1,2			1,2		5		
6	<i>Megaerops niphanae</i>	2	2,4	2	2,4	2	5	7	8
7	<i>Sphaerias blanfordi</i>							6	8
8	<i>Eonycteris spelaea</i> *	1	2,4		1,2,4		5	7,8	8
9	<i>Macroglossus sobrinus</i> *	1		2	1,2	2	5	6,7,8	8
	Emballonuridae								
10	<i>Taphozous theobaldi</i>	3	2,4		2,3,4				
11	<i>Taphozous melanopogon</i>							6	
	Megadermatidae								
12	<i>Megaderma lyra</i>	1,2	2,4		1,2,4	2	5	6,7	
13	<i>Megaderma spasma</i>	1,2	2,4		1,2,4		5	6,7	
	Rhinolophidae								
14	<i>Rhinolophus luctus</i>		2,4		2,4		5	7	8
15	<i>Rhinolophus macrotis</i>		4		2,4	2		6	
16	<i>Rhinolophus siamensis</i> *	1			1		5		
17	<i>Rhinolophus paradoxolophus</i>	1,2	2,4	2	1,2,4	2		6,7,8	
18	<i>Rhinolophus marshalli</i>						5		
19	<i>Rhinolophus coelophyllus</i>					2			
20	<i>Rhinolophus shameli</i>				2	2	5		
21	<i>Rhinolophus pusillus</i>	1,2	2,4		1,2,4	2	5	6,7	8
22	<i>Rhinolophus affinis</i>			2	2	2	5	7	8
23	<i>Rhinolophus microglobosus</i> * ^{NE}	1	2,4	2	1,2,4	2	2, 5		
24	<i>Rhinolophus malayanus</i>	1,2	2,4	2	1,2,4	2	5		
25	<i>Rhinolophus chaseni</i> ^{NE}					2			
26	<i>Rhinolophus thomasi</i>	1,2	2,4	2	1,2,4	2		6,7,8	
27	<i>Rhinolophus pearsonii</i>	1,2	2,4	2	1,2,4	2	5	6,7,8	
	Hipposideridae								
28	<i>Hipposideros pomona</i>	1,2	2,4	2	1,2,4	2	5	6,7,8	8
29	<i>Hipposideros cineraceus</i> *	1	2,4	2	1,2,4	2		6,8	8
30	<i>Hipposideros rotalis</i>			2	2	2			

#	Family / Species	LAOS			VIETNAM				
		HNN	PHB	NNT	KHA- PROV	BOL- PROV	SAV- PROV	PNKB	VUQ
31	<i>Hipposideros khaokhouayensis</i> ^{VU}					2			
32	<i>Hipposideros galeritus</i>						5		
33	<i>Hipposideros grandis</i> *	1			1				
34	<i>Hipposideros larvatus</i> *	1	2,4	2	1,2,4	2		6,7,8	
35	<i>Hipposideros diadema</i>	1,3	2,4		1,2,3,4				
36	<i>Hipposideros armiger</i>	1,2,3	2,4	2	1,2,3,4	2	5	6,7,8	8
37	<i>Hipposideros scutinares</i> * ^{VU}	1	2	2	1,2			6,7,8	
38	<i>Coelops frithii</i>					2			8
39	<i>Aselliscus stoliczkanus</i>	1,2	2,4	2	1,2,4	2		6,7	
	Vespertilionidae								
40	<i>Myotis cf. muricola</i>		2	2	2	2	5		8
41	<i>Myotis chinensis</i>							7	
42	<i>Myotis cf. montivagus</i>			2	2	2			8
43	<i>Myotis annectans</i>				2				
44	<i>Myotis horsfieldii</i>			2	2	2		7	8
45	<i>Myotis pilosus</i> ^{NT}	2	2,4	2	2,4			7	
46	<i>Myotis ater</i>							7	
47	<i>Myotis siligorensis</i>	1,2	2,4		1,2,4	2		6,7,8	
48	<i>Myotis laniger</i>				2	2			
49	<i>Myotis annamiticus</i> ^{DD}		9		2,9			8	
50	<i>Pipistrellus javanicus</i>				2			7	8
51	<i>Pipistrellus coromandra</i>				2				
52	<i>Pipistrellus abramus</i>								8
53	<i>Pipistrellus tenuis</i>		2,4		2,4			8	
54	<i>Pipistrellus paterculus</i> *	1			1				
55	<i>Glischropus bucephalus</i> ^{NE}					2			
56	<i>Hypsugo pulveratus</i>	2	2,4	2	2,4			6,7,8	
57	<i>Hypsugo cardornae</i>				2				
58	<i>Arielulus aureocollaris</i>								8
59	<i>Arielulus circumdatus</i>								8
60	<i>Eptesicus cf. serotinus</i>				2				
61	<i>Ia io</i>	2	2,4		2,4			6,7	
62	<i>Hesperoptenus blanfordi</i>		2,4		2,4				
63	<i>Hesperoptenus tickelli</i>					2			
64	<i>Scotomanus ornatus</i>	2			2			7,8	8
65	<i>Scotophilus kuhlii</i>						2		
66	<i>Tyloncteris malayana</i>	1,2	2,4		1,2,4				
67	<i>Tyloncteris fulvida</i>			2	2	2	5		
68	<i>Murina cyclotis</i>	2	2,4	2	2,4	2	5	6,7	
69	<i>Murina huttoni</i> *	1			1,2				
70	<i>Murina harrisoni</i>							6	
71	<i>Murina annamitica</i> ^{NE}			2	2	2			
72	<i>Murina fionae</i> * ^{NE}	1			1,2			8	
73	<i>Murina eleryi</i> ^{NE}				2	2		6	

#	Family / Species	LAOS			VIETNAM				
		HNN	PHB	NNT	KHA-PROV	BOL-PROV	SAV-PROV	PNKB	VUQ
74	<i>Murina feae</i> * ^{NE}	1			1,2	2	5	6	
75	<i>Harpiocephalus harpia</i>	1,2	2,4		1,2,4	2		7	
76	<i>Kerivoula papillosa</i>					2			
77	<i>Kerivoula kachinensis</i> *	1			1	2	5		
78	<i>Kerivoula hardwickii</i>	1,2	2,4	2	1,2,4	2	5		
79	<i>Kerivoula titania</i>	1,2			1,2		5		
80	<i>Phoniscus jagorii</i>		4	2	2,4				
	Miniopteridae								
81	<i>Miniopterus magnater</i>	1,2	2,4		1,2,4	2		7	
82	<i>Miniopterus fuliginosus</i>		4	2	2,4				
83	<i>Miniopterus pusillus</i>				2	2			
	TOTAL	41	38	26	64	43	27	40	20

Data sources (with various corrections reflecting recent taxonomic revisions): 1 = This study; 2 = Thomas et al. (2013); 3 = Steiner (2016), Appendix 2– Included *Hipposideros pratti* + *Rousettus* sp., both excluded here; 4 = Robinson & Webber (2000)– Included *Rhinolophus ?subadius*, *Chaerephon ?plicatus*, three *Hipposideros* spp. (A, B & C) and *Murina* sp., all excluded here; 5 = Furey & Douangboubpha (2015); 6 = Vu et al. (2012)– Included *Megaerops ecaudatus*, *Rhinolophus* sp. and *Murina* sp., all excluded here; 7 = Hendrichsen et al. (2001)– Included *Harpiocephalus mordax*, rejected here as this taxon is conspecific with *H. harpia*; 8 = Borisenko & Kruksop (2003), as later confirmed by Kruskop (2013); 9 = Douangboubpha et al. (2014).

4. COMPARATIVE ANALYSIS

4.1 SPECIES RICHNESS

On current data for Khammouan province (Table 4), Hin Nam No NPA ranks first in terms of documented bat species richness with 41 species, followed by Phou Hin Boun with 38 species and Nakai Nam Theun with 26 species. However, because these figures undoubtedly reflect differences in survey effort and coverage at each site, they must be viewed with caution and cannot be regarded as true species richness. Notwithstanding this, it is notable that bat species richness recorded at Hin Nam No matches that of Phong Nha – Ke Bang WHS (40 bat species; Table 4), despite the latter having received greater survey effort. Given the strong potential for discovering additional species at the NPA (section 3.5), coupled with the fact that it supports at least 43% of the known bat fauna of Laos (41/96 spp.), the species richness of bats at Hin Nam No NPA is clearly significant and undoubtedly somewhat greater than presently documented.

4.2 ENDEMISM

Patterns of endemism in bats typically concern species that occur on oceanic islands and potential cases of genuine site-level endemism are rare in continental Southeast Asia. In a growing number of cases, even the few bat species long known only from a single country in the region have

subsequently been found elsewhere. For instance, Wroughton's free-tailed bat *Otomops wroughtoni* was known only from a single cave in the Western Ghats (India) for >85 years until it was found ca. 3,200 km away in Cambodia (Walston & Bates, 2001). Thus even in the absence of other records, there is no compelling reason to assume that any bat species currently known only from Laos e.g., *Hipposideros rotalis*, are nationally endemic and consequently less reason to think that any bat species at Hin Nam No, Phong Nha – Ke Bang or other area might be site-endemic.

4.3 RED-LISTED AND RARELY-RECORDED TAXA

At present, four bat species documented in the central Indochina region are inscribed on the IUCN Red List (2017) in categories other than Least Concern: *Hipposideros khaokhouayensis* (Vulnerable), *Hipposideros scutinares* (Vulnerable), *Myotis pilosus* (Near-Threatened) and *Myotis annamiticus* (Data Deficient) (Table 4). Two of these taxa are confirmed to occur at Hin Nam No and Nakai Nam Theun (*H. scutinares* & *M. pilosus*) and three at Phou Hin Boun and Phong Nha – Ke Bang (*H. scutinares*, *M. pilosus* & *M. annamiticus*). Although relatively common at Hin Nam No, *H. scutinares* is notable as existing data suggest the species is confined to an unusually small area of central Indochina (Vietnam & Laos) (Table 2, 3).

Six additional species in the region have yet to be evaluated by IUCN: *Rhinolophus microglobosus*, *Glischropus bucephalus*, *Murina annamitica*, *Murina eleryi*, *Murina feae* and *Murina fionae* (Table 4). Three of these taxa are confirmed for Hin Nam No—*R. microglobosus*, *M. feae* and *M. fionae*—although the former two would not qualify for a globally threatened category, being widespread in mainland SE Asia and Laos.

Two insectivorous bat species at Hin Nam No are notable for other reasons. Though scattered records exist for the region, *Murina huttoni* was hitherto known from only one other locality in Laos (Pha Deng, Khammouan Province). The species is foliage-dwelling forest-interior specialist and seldom recorded. Second, *Murina fionae*, described from the same area in 2012 and a similar species ecologically, is currently known only from very few localities in central and southern Indochina. Three additional species at Hin Nam No are also currently known from very few localities in Laos (*Cynopterus horsfieldi*, *Pipistrellus paterculus* & *Kerivoula titania*), but because these are relatively widespread in the region, they likely occur in many areas of the country.

4.4 STATEMENT OF INTEGRITY

Hin Nam No NPA constitutes a major part of one of the largest limestone karst plateaus in Southeast Asia, which includes the NPA and the contiguous Phong Nha – Ke Bang WHS in Vietnam. Nearly all of the Lao portion of the karst plateau is included within the ~820 km² NPA, whereas in Vietnam, the karst plateau encompasses a further ~2,000 km², ~1,260 km² of which is included within Phong Nha – Ke Bang. Much of Hin Nam No NPA consists of forested limestone which is uninhabited and largely inaccessible. In comprising enormous tracts of karst forest and extensive cave networks which collectively support an ecologically diverse array of bat species

that represent at least 43% of the known Lao bat fauna, the *wholeness* of the property in supporting a speciose and representative assemblage of Indochinese bats is assured.

The highly-dissected topography of Hin Nam No, its limited accessibility and few areas with agricultural potential has meant that, apart from peripheral margins and river valleys, most of the site has been subjected to low development pressure to date. Though illegal cross-border logging raises an issue which is being addressed through increased patrol effort, extensive tracts of forest deep in the karst remain in excellent condition (e.g., Nam Cum area) and provide optimal habitat for a diverse complement of bat species. The same cannot be said for disturbed forest areas in the vicinity of major river valleys (e.g., Tham Nam Ork area), and to a lesser extent, former logging concessions (e.g., Huoy Salong area), although those observed during the present study contained few signs of extensive recent disturbance and appeared to be regenerating well.

Because the present study emphasized surface-dwelling bat species, only two caves were partially explored during the field survey. However, literature review coupled with correspondence with bio-speleologists familiar with the site also suggest that the caves of Hin Nam No are little disturbed due to their remoteness, lack of trails and surface water within the site interior, and the large size of systems with peripheral entrances such as Xe Bang Fai (which effectively prohibit hunting). This contrasts with Phong Nha – Ke Bang where disturbance of cave roosts is widespread and presents a serious threat³. Though cave tourism is increasing at sites such as Xe Bang Fai, this has yet to become an issue and potential future impacts are being addressed by the site authorities and GIZ project. As a consequence, the *intactness* of the property regarding its surface- and cave-dwelling bat assemblages can also be asserted with confidence.

5. FUTURE CONSIDERATIONS

The following points summarize important considerations for future bat conservation and research at Hin Nam No NPA and the authors would be pleased to provide further information as needed.

- A large proportion of the insectivorous bat fauna at Hin Nam No is particularly susceptible to declines as a result of forest loss and degradation, being poorly adapted to foraging in open areas. This issue is exacerbated for the species that also dwell in caves (e.g., most rhinolophid and hipposiderid taxa), because these roosts are inherently vulnerable to human disturbance.
- As foliage-dwelling bats are rarely affected by hunting, forest protection alone is sufficient for their conservation. Although detailed recommendations regarding the site-based actions necessary to achieve this are beyond the scope of the present study, forest stands that encompass surface waters are particularly important foraging areas and should be accorded special attention (also for the benefit of other wildlife).

³ Vu et al. (2012).

- Because cave-dwelling bats are highly susceptible to human disturbance during late pregnancy through lactation until weaning each year, March–July/August constitutes the critical period for protection of maternity colonies of insectivorous bats at Hin Nam No. This should be considered in all future plans for development and management of cave tourism at the NPA.
- To the extent practicable, all caves supporting significant bat colonies warrant protection from incidental and deliberate disturbance. This prohibition need not extend to guano collection (should this occur at the site now or in future) however, because this could be encouraged to support livelihoods and conservation objectives, so long as sustainable harvesting techniques (e.g., IUCN SSC 2014) are adhered to.
- While hunting of cave-dwelling bats has not yet been reported at Hin Nam No NPA, this gravely threatens cave bat colonies throughout Laos and could easily become an issue in future. Effective law enforcement and public education regarding the economic and societal benefits of retaining bat biodiversity (e.g., via ecosystem services such bio-control of agricultural pests, pollination of economically significant and ecologically important plant species, and regeneration of deforested areas) are consequently vital.
- Strong potential remains for discovering additional bat species at Hin Nam No. Should further surveys be undertaken, these should ideally focus on unsurveyed interior areas near the international border (though this would be challenging) and employ multiple detection methods. Because little is known about the bat fauna of flagship caves such as Xe Bang Fai and Tham Bing, dedicated bat surveys including acoustic sampling are desirable at these sites.

6. REFERENCES

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APPENDIXES:

APPENDIX 1: SCHEDULE FOR BAT SURVEY AT HIN NAM NO NPA, MAY 2017

Date	Activities	Sample site codes ¹
8 May	Travel from Vientiane to Thakhek. Overnight at Thakhek.	
9 May	Travel to Nong Ping village. Sampling in Xe Bang Fai area.	C#1, F#1-3
10 May	Sampling at Tham Bing cave and in Xe Bang Fai area.	C#2, F#4-8
11 May	Travel to and sampling in Pak Xe Nue area.	C#3, F#9-12
12 May	Sampling in Pak Xe Nue area.	F#13-17
13 May	Sampling in Pak Xe Nue area.	F#18-23
14 May	Sampling in Pak Xe Nue area.	F#24-29
15 May	Sampling in Pak Xe Nue area.	F#30-35
16 May	Travel to Nong Ping to Nong Ma village. Overnight at Nong Ma.	
17 May	Travel to Houy Salong. Sampling in Huoy Salong area.	F#36-41
18 May	Sampling in Huoy Salong area.	F#42-47
19 May	Sampling in Huoy Salong area.	F#48-53
20 May	Travel to Nong Ma and Bulapha town. Overnight in Bulapha.	
21 May	Travel to Thong Xam village. Sampling in Thong Xam area.	F#54-56
22 May	Travel to Tham Nam Ork. Sampling in Tham Nam Ork area.	F#57-60
23 May	Sampling in Tham Nam Ork area.	C#4, F#61-64
24 May	Tham Nam Ork area, sampling cancelled due to heavy rain.	
25 May	Travel to Ban Dou village. Sampling at nearby karst isolates.	F#65-68
26 May	Travel to Nam Cum area. Sampling in Nam Cum area.	F#69-73
27 May	Sampling in Nam Cum area.	F#74-80
28 May	Sampling in Nam Cum area.	F#81-82
29 May	Travel to Ban Dou and Vientiane.	F#83-86
30 May	Laboratory processing at NUoL.	
31 May	Laboratory processing at NUoL.	
1 June	Laboratory processing at NUoL.	
2 June	Laboratory processing at NUoL.	

¹ Geo-coordinates for these sites are given in Appendix 2.

APPENDIX 2: GEO-COORDINATES AND LIVE-SAMPLING EFFORT AT HIN NAM NO NPA, MAY 2017

¹ MNH = m² mist-net-hours

² HTH = m² harp-trap-hours

Date	Sample site code	X	Y	Altitude (m asl)	MNH ¹	HTH ²	Location
9 May	C#1 / F#1-3	0588767	1921058	164	284.4		Xe Bang Fai cave / area
10 May	C#2 / F#4-5	0589387	1921055	323	162		Tham Bing cave / area
10 May	F#6-8	0589143	1921108	≈180	162	12	Xe Bang Fai area
11 May	C#3 / F#9-12	0593985	1921391	≈180	187.2	57.6	Xe Bang Fai cave / Pak Xe Nue area
12 May	F#13-17	0594283	1921442	186	207	57.6	Pak Xe Nue area
13 May	F#18-23	0594538	1921725	228	367.2	57.6	Pak Xe Nue area
14 May	F#24-26	0593940	1921552	202	153	28.8	Pak Xe Nue area
14 May	F#27-29	0593711	1921787	250	250.2	28.8	Pak Xe Nue area
15 May	F#30-32	0593940	1921552	202	153	7.2	Pak Xe Nue area
15 May	F#33-35	0594538	1921725	228	153	7.2	Pak Xe Nue area
17 May	F#36-38	0611981	1910154	413	153	28.8	Huoy Salong area
17 May	F#39-41	0611763	1909884	426	153	28.8	Huoy Salong area
18 May	F#42-44	0612839	1910397	411	153	28.8	Huoy Salong area
18 May	F#45-47	0612668	1910759	384	153	28.8	Huoy Salong area
19 May	F#48-50	0612142	1910222	406	153	7.2	Huoy Salong area
19 May	F#51-53	0611896	1909621	462	153	7.2	Huoy Salong area
21 May	F#54	0589356	1942299	194	90		Thong Xam village area
21 May	F#55-56	0589517	1942013	183	153		Thong Xam village area
22 May	F#57-58	0588687	1944706	256	180		Tham Nam Ork area
22 May	F#59-60	0588421	1944812	302		57.6	Tham Nam Ork area
23 May	C#4	0588631	1945029	270	187.2		Tham Nam Ork cave
23 May	F#61-64	0588837	1944522	315	187.2	57.6	Tham Nam Ork area
25 May	F#65-68	0586812	1937595	187	220.8		Ban Dou Village area
26 May	F#69-71	0595320	1927372	420	423	28.8	Nam Cum area
26 May	F#72-73	0595399	1927258	400	187.2	28.8	Nam Cum area
27 May	F#74-76, 80	0594939	1927142	420	1,440	28.8	Nam Cum area
27 May	F#77-79	0594379	1927428	372	1,200.6	28.8	Nam Cum area
28 May	F#81-82	0594896	1927360	398	270	7.2	Nam Cum area
28 May	F#83-86	0594379	1927428	372	347.4	7.2	Nam Cum area
					7,883.4	631.2	

APPENDIX 3: WEATHER CONDITIONS DURING THE BAT SURVEY AT HIN NAM NO NPA, MAY 2017

Date	Temperature (°C)		Relative Humidity (%)		Rainfall
	Min	Max	Min	Max	
9 May	25.8	33.1	80.1	84.2	Rain before sampling
10 May	24.4	31.4	81.6	86.4	Dry all day
11 May	24.7	31.8	69.1	>90.0	Dry all day
12 May	23.1	32.6	<70.0	>90.0	Rain during sampling
13 May	24.1	29.8	<70.0	>90.0	Rain during sampling
14 May	24.1	32.2	<70.0	>90.0	Rain before/after sampling
15 May	24.4	30.6	<70.0	>90.0	Rain throughout sampling
16 May	23.4	29.1	<70.0	>90.0	Dry all day
17 May	21.8	27.2	70.6	91.8	Dry all day
18 May	23.1	26.9	80.1	88.0	Rain in AM, dry in PM
19 May	23.1	27.2	81.6	94.6	Rain in AM
20 May	23.4	30.2	85.3	98.9	Dry all day
21 May	25.8	38.0	63.0	>90.0	Dry all day
22 May	24.7	28.7	87.5	>90.0	Rain in AM, dry in PM
23 May	24.7	28.3	<70.0	>90.0	Rain before sampling
24 May	23.1	29.4	<70.0	>90.0	Heavy rain, no sampling
25 May	23.4	28.3	<70.0	82.7	Rain in AM, dry in PM
26 May	21.1	26.5	74.8	89.7	Dry all day
27 May	20.2	26.9	55.5	91.8	Dry all day
28 May	20.2	25.8	70.6	94.6	Dry all day

APPENDIX 4: VOUCHER SPECIMENS COLLECTED AT HIN NAM NO NPA, MAY 2017

¹ A=Body in alcohol, S=Skull extracted.

Accession No.	Genus	Species	Sex	#	Preservation ¹
CBC02608	<i>Megaderma</i>	<i>lyra</i>	M	F#3	A
CBC02609	<i>Hipposideros</i>	<i>scutinares</i>	M	F#2	A
CBC02610	<i>Rhinolophus</i>	<i>malayanus</i>	F	F#3	A
CBC02611	<i>Hipposideros</i>	<i>scutinares</i>	M	F#2	A
CBC02612	<i>Rhinolophus</i>	<i>thomasi</i>	M	F#6	A
CBC02613	<i>Hipposideros</i>	<i>larvatus</i>	F	F#6	A,S
CBC02614	<i>Kerivoula</i>	<i>hardwickii</i>	F	F#12	A,S
CBC02615	<i>Rhinolophus</i>	<i>thomasi</i>	M	F#12	A
CBC02616	<i>Rhinolophus</i>	<i>malayanus</i>	M	F#12	A
CBC02617	<i>Hipposideros</i>	<i>pomona</i>	M	F#12	A
CBC02618	<i>Rhinolophus</i>	<i>paradoxolophus</i>	M	F#11	A
CBC02619	<i>Hipposideros</i>	<i>larvatus</i>	M	F#11	A,S
CBC02620	<i>Pipistrellus</i>	<i>paterculus</i>	F	F#11	A,S
CBC02621	<i>Rhinolophus</i>	<i>siamensis</i>	F	F#10	A
CBC02622	<i>Macroglossus</i>	<i>sobrinus</i>	M	F#9	A
CBC02623	<i>Rhinolophus</i>	<i>pusillus</i>	F	F#10	A
CBC02624	<i>Aselliscus</i>	<i>stolitzkanus</i>	M	F#10	A
CBC02625	<i>Hipposideros</i>	<i>scutinares</i>	F	F#14	A
CBC02626	<i>Pipistrellus</i>	<i>paterculus</i>	F	F#14	A,S
CBC02627	<i>Megaderma</i>	<i>spasma</i>	M	F#17	A
CBC02628	<i>Kerivoula</i>	<i>titania</i>	F	F#21	A,S
CBC02629	<i>Kerivoula</i>	<i>kachinensis</i>	M	F#21	A,S
CBC02630	<i>Rhinolophus</i>	<i>pearsoni</i>	M	F#23	A
CBC02631	<i>Eonycteris</i>	<i>spelaea</i>	M	F#19	A
CBC02632	<i>Cynopterus</i>	<i>horsfieldi</i>	F	F#20	A,S
CBC02633	<i>Kerivoula</i>	<i>hardwickii</i>	M	F#18	A,S
CBC02634	<i>Murina</i>	<i>feae</i>	M	F#18	A,S
CBC02635	<i>Hipposideros</i>	<i>pomona</i>	M	F#24	A
CBC02636	<i>Rhinolophus</i>	<i>pusillus</i>	F	F#24	A
CBC02637	<i>Kerivoula</i>	<i>kachinensis</i>	M	F#25	A,S
CBC02638	<i>Rhinolophus</i>	<i>siamensis</i>	M	F#24	A
CBC02639	<i>Rhinolophus</i>	<i>siamensis</i>	F	F#24	A
CBC02640	<i>Rhinolophus</i>	<i>pearsoni</i>	F	F#34	A
CBC02641	<i>Hipposideros</i>	<i>armiger</i>	M	F#37	A
CBC02642	<i>Hipposideros</i>	<i>larvatus</i>	F	F#39	A,S
CBC02643	<i>Harpiocephalus</i>	<i>harpia</i>	M	F#37	A
CBC02644	<i>Harpiocephalus</i>	<i>harpia</i>	F	F#37	A
CBC02645	<i>Rhinolophus</i>	<i>microglobosus</i>	M	F#42	A
CBC02646	<i>Kerivoula</i>	<i>titania</i>	F	F#47	A,S

Accession No.	Genus	Species	Sex	#	Preservation ¹
CBC02647	<i>Myotis</i>	<i>siligorensis</i>	F	F#42	A,S
CBC02648	<i>Myotis</i>	<i>siligorensis</i>	F	F#42	A,S
CBC02649	<i>Hipposideros</i>	<i>grandis</i>	F	F#56	A,S
CBC02650	<i>Hipposideros</i>	<i>diadema</i>	F	F#54	A
CBC02651	<i>Hipposideros</i>	<i>grandis</i>	F	F#60	A,S
CBC02652	<i>Hipposideros</i>	<i>larvatus</i>	M	F#60	A,S
CBC02653	<i>Tylonycteris</i>	<i>malayana</i>	F	F#57	A,S
CBC02654	<i>Hipposideros</i>	<i>cineraceus</i>	M	F#59	A
CBC02655	<i>Hipposideros</i>	<i>cineraceus</i>	F	F#60	A
CBC02656	<i>Hipposideros</i>	<i>larvatus</i>	F	C#4	A,S
CBC02657	<i>Hipposideros</i>	<i>larvatus</i>	F	C#4	A,S
CBC02658	<i>Rhinolophus</i>	<i>thomasi</i>	F	F#74	A,S
CBC02659	<i>Murina</i>	<i>huttoni</i>	F	F#78	A,S
CBC02660	<i>Murina</i>	<i>huttoni</i>	F	F#78	A,S
CBC02661	<i>Murina</i>	<i>fionae</i>	F	F#78	A,S
CBC02662	<i>Miniopterus</i>	<i>magnater</i>	F	F#78	A,S
CBC02663	<i>Pipistrellus</i>	<i>paterculus</i>	F	F#78	A,S
CBC02664	<i>Rhinolophus</i>	<i>microglobosus</i>	F	F#81	A
CBC02665	<i>Kerivoula</i>	<i>titania</i>	F	F#81	A,S
CBC02666	<i>Cynopterus</i>	<i>horsfieldi</i>	F	F#84	A,S
CBC02667	<i>Murina</i>	<i>fionae</i>	F	F#84	A,S

APPENDIX 5: EXTERNAL MEASUREMENTS OF SPECIMENS COLLECTED IN HIN NAM NO NPA

FA = forearm length – from the extremity of the elbow to the extremity of the carpus with the wings folded; T = tail length – from the anal opening to the tip of the tail; E = ear length – from the lower border of the external auditory meatus to the tip of the pinna, excluding any hair; TIB = tibia length – from the knee joint to the ankle; HF = hindfoot – from the tip of the longest digit, excluding the claw, to the extremity of the heel, behind the *os calcis*. All measurements are in mm.

Accession No.	Genus	Species	FA	T	E	TIB	HF
CBC02608	<i>Megaderma</i>	<i>lyra</i>	67.8	20.8	30.6	34.5	16.1
CBC02609	<i>Hipposideros</i>	<i>scutinares</i>	82.3	48.6	22.1	38.1	16.6
CBC02610	<i>Rhinolophus</i>	<i>malayanus</i>	42.4	19.7	16.4	16.2	7.0
CBC02611	<i>Hipposideros</i>	<i>scutinares</i>	80.0	54.5	26.5	39.2	18.4
CBC02612	<i>Rhinolophus</i>	<i>thomasi</i>	43.6	21.8	17.8	16.8	6.0
CBC02613	<i>Hipposideros</i>	<i>larvatus</i>	53.8	29.2	17.4	20.2	8.1
CBC02614	<i>Kerivoula</i>	<i>hardwickii</i>	32.6	43.2	11.4	16.6	5.8
CBC02615	<i>Rhinolophus</i>	<i>thomasi</i>	43.3	21.1	18.3	16.6	7.1
CBC02616	<i>Rhinolophus</i>	<i>malayanus</i>	41.7	19.8	16.3	17.4	6.2
CBC02617	<i>Hipposideros</i>	<i>pomona</i>	41.2	34.8	22.3	18.7	5.1
CBC02618	<i>Rhinolophus</i>	<i>paradoxolophus</i>	55.2	25.4	33.7	22.7	7.0
CBC02619	<i>Hipposideros</i>	<i>larvatus</i>	49.8	25.6	19.7	17.6	6.2
CBC02620	<i>Pipistrellus</i>	<i>paterculus</i>	33.4	39.7	11.2	15.0	4.3
CBC02621	<i>Rhinolophus</i>	<i>siamensis</i>	38.4	16.6	18.0	15.9	5.8
CBC02622	<i>Macroglossus</i>	<i>sobrinus</i>	50.2	-	16.2	20.4	10.0
CBC02623	<i>Rhinolophus</i>	<i>pusillus</i>	36.1	13.1	14.7	14.9	4.9
CBC02624	<i>Aselliscus</i>	<i>stolitzkanus</i>	42.2	35.5	9.6	18.9	5.6
CBC02625	<i>Hipposideros</i>	<i>scutinares</i>	80.2	41.9	26.4	36.4	16.5
CBC02626	<i>Pipistrellus</i>	<i>paterculus</i>	33.5	39.5	10.5	14.8	5.2
CBC02627	<i>Megaderma</i>	<i>spasma</i>	62.1	36.3	40.8	34.6	15.0
CBC02628	<i>Kerivoula</i>	<i>titania</i>	34.0	42.8	13.8	18.5	6.5
CBC02629	<i>Kerivoula</i>	<i>kachinensis</i>	40.0	50.0	14.0	21.9	6.5
CBC02630	<i>Rhinolophus</i>	<i>pearsoni</i>	48.6	17.7	23.4	24.8	8.9
CBC02631	<i>Eonycteris</i>	<i>spelaea</i>	74.3	15.4	19.3	35.5	15.8
CBC02632	<i>Cynopterus</i>	<i>horsfieldi</i>	66.7	11.5	21.0	26.0	12.5
CBC02633	<i>Kerivoula</i>	<i>hardwickii</i>	31.3	37.3	12.4	15.4	6.0
CBC02634	<i>Murina</i>	<i>feae</i>	28.2	32.1	12.6	17.0	5.0
CBC02635	<i>Hipposideros</i>	<i>pomona</i>	41.6	29.1	22.1	16.9	5.8
CBC02636	<i>Rhinolophus</i>	<i>pusillus</i>	35.1	14.3	14.6	13.7	5.3
CBC02637	<i>Kerivoula</i>	<i>kachinensis</i>	40.2	47.0	13.6	21.6	6.5
CBC02638	<i>Rhinolophus</i>	<i>siamensis</i>	38.7	16.1	22.5	15.9	5.5
CBC02639	<i>Rhinolophus</i>	<i>siamensis</i>	38.7	14.5	17.5	16.2	5.9
CBC02640	<i>Rhinolophus</i>	<i>pearsoni</i>	51.6	17.2	22.4	25.7	7.8
CBC02641	<i>Hipposideros</i>	<i>armiger</i>	88.3	52.5	28.9	39.7	13.3

Accession No.	Genus	Species	FA	T	E	TIB	HF
CBC02642	<i>Hipposideros</i>	<i>larvatus</i>	57.5	31.4	20.1	23.1	7.0
CBC02643	<i>Harpiocephalus</i>	<i>harpia</i>	48.4	48.7	18.6	21.5	10.5
CBC02644	<i>Harpiocephalus</i>	<i>harpia</i>	52.3	53.5	16.2	23.6	10.0
CBC02645	<i>Rhinolophus</i>	<i>microglobosus</i>	45.5	19.3	17.0	21.7	7.4
CBC02646	<i>Kerivoula</i>	<i>titania</i>	34.7	48.4	14.0	19.1	6.2
CBC02647	<i>Myotis</i>	<i>siligorensis</i>	34.3	35.3	12.6	14.0	5.0
CBC02648	<i>Myotis</i>	<i>siligorensis</i>	33.7	35.5	12.7	13.8	5.9
CBC02649	<i>Hipposideros</i>	<i>grandis</i>	60.9	40.8	20.4	25.8	7.4
CBC02650	<i>Hipposideros</i>	<i>diadema</i>	86.3	52.0	22.8	34.5	13.9
CBC02651	<i>Hipposideros</i>	<i>grandis</i>	61.3	44.4	19.8	24.0	7.6
CBC02652	<i>Hipposideros</i>	<i>larvatus</i>	58.8	37.0	19.5	23.1	7.5
CBC02653	<i>Tylonycteris</i>	<i>malayana</i>	25.3	26.4	11.3	11.4	4.8
CBC02654	<i>Hipposideros</i>	<i>cineraceus</i>	34.2	25.1	15.3	15.6	4.5
CBC02655	<i>Hipposideros</i>	<i>cineraceus</i>	34.5	22.2	17.7	15.0	5.0
CBC02656	<i>Hipposideros</i>	<i>larvatus</i>	56.6	37.3	21.3	22.4	7.4
CBC02657	<i>Hipposideros</i>	<i>larvatus</i>	57.3	35.7	20.8	24.1	7.6
CBC02658	<i>Rhinolophus</i>	<i>thomasi</i>	45.8	22.3	18.2	17.4	6.0
CBC02659	<i>Murina</i>	<i>huttoni</i>	33.3	41.2	14.9	17.1	6.6
CBC02660	<i>Murina</i>	<i>huttoni</i>	32.7	34.6	15.0	16.4	6.7
CBC02661	<i>Murina</i>	<i>fionae</i>	36.7	44.4	18.5	20.3	7.4
CBC02662	<i>Miniopterus</i>	<i>magnater</i>	48.9	55.4	14.4	19.6	8.8
CBC02663	<i>Pipistrellus</i>	<i>paterculus</i>	34.8	38.5	12.1	15.3	5.4
CBC02664	<i>Rhinolophus</i>	<i>microglobosus</i>	43.6	18.0	16.7	20.0	6.5
CBC02665	<i>Kerivoula</i>	<i>titania</i>	36.2	52.3	14.3	20.7	6.8
CBC02666	<i>Cynopterus</i>	<i>horsfieldi</i>	72.3	12.0	24.1	27.2	12.1
CBC02667	<i>Murina</i>	<i>fionae</i>	34.9	40.3	18.6	19.4	6.7

APPENDIX 6: CRANIODENTAL MEASUREMENTS OF SPECIMENS COLLECTED IN HIN NAM NO NPA

GTL = greatest length of skull – greatest antero-posterior length of the skull, taken from the most projecting point at each extremity; CBL = condylobasal length – from the exoccipital condyle to the anterior rim of the alveolus of the first upper incisor; CCL = condylo-canine length – from the exoccipital condyle to the most anterior part of the canine; ZYW = zygomatic width – the greatest width of the skull across the zygomatic arches; MA = mastoid width – the greatest distance across the mastoid region; IOW = inter-orbital width – least distance across the constriction posterior to the orbits; CM³ = maxillary tooththrow length – from the front of upper canine to the back of the crown of the third molar; C¹C¹ = width across the upper canines – greatest width, taken across the outer borders of upper canines; M³M³ = width across the upper molars – greatest width, taken across the outer crowns of the last upper molars; ML = mandible length – from the anterior rim of the alveolus of the first lower incisor to the most posterior part of the condyle; CM₃ = mandibular tooththrow length – from the front of the lower canine to the back of the crown of the third lower molar; CPH = least height of the coronoid process – from the tip of the coronoid process to the apex of the indentation on the inferior surface of the ramus adjacent to the angular process. All measurements are in mm.

Accession No.	Genus	Species	GTL	CBL	CCL	ZYW	MA	IOW	CM ³	C ¹ C ¹	M ³ M ³	ML	CM ₃	CPH
CBC02613	<i>Hipposideros</i>	<i>larvatus</i>	21.59	19.00	18.58	11.80	10.36	2.94	7.75	4.56	7.71	13.94	8.29	4.82
CBC02614	<i>Kerivoula</i>	<i>hardwickii</i>	14.46	13.16	12.57	8.29	7.37	3.31	5.12	3.37	5.18	9.78	5.68	3.55
CBC02619	<i>Hipposideros</i>	<i>larvatus</i>	20.62	18.10	17.58	11.38	10.24	3.14	7.42	4.36	7.44	13.65	8.20	5.07
CBC02620	<i>Pipistrellus</i>	<i>paterculus</i>	12.65	11.50	11.64	8.44	7.17	3.53	4.68	3.92	5.58	9.00	4.91	2.61
CBC02626	<i>Pipistrellus</i>	<i>paterculus</i>	12.74	11.95	11.94	8.56	7.18	-	4.80	4.05	5.76	8.99	4.97	2.85
CBC02628	<i>Kerivoula</i>	<i>titania</i>	15.49	14.29	13.66	8.88	7.98	3.33	5.94	3.61	5.55	10.44	6.07	3.25
CBC02629	<i>Kerivoula</i>	<i>kachinensis</i>	17.64	16.01	15.85	10.46	8.76	3.69	6.78	4.39	6.57	11.99	7.27	3.75
CBC02632	<i>Cynopterus</i>	<i>horsfieldi</i>	31.55	30.11	29.85	21.19	12.90	5.81	10.93	6.72	9.86	23.77	12.12	12.05
CBC02633	<i>Kerivoula</i>	<i>hardwickii</i>	13.99	12.92	12.36	8.11	6.99	3.07	5.20	3.14	5.05	9.54	5.49	3.34
CBC02634	<i>Murina</i>	<i>feae</i>	15.49	14.09	13.42	8.50	7.47	4.12	4.86	3.58	4.96	10.39	5.23	3.64
CBC02637	<i>Kerivoula</i>	<i>kachinensis</i>	17.74	15.67	15.66	10.05	9.01	3.44	6.82	4.18	5.99	12.01	7.24	3.73
CBC02642	<i>Hipposideros</i>	<i>larvatus</i>	22.75	20.04	19.28	12.42	10.89	3.18	8.12	4.98	8.48	14.68	8.80	5.38
CBC02646	<i>Kerivoula</i>	<i>titania</i>	15.67	14.39	13.76	9.29	8.24	3.45	5.88	3.73	5.62	10.48	6.28	3.79

Accession No.	Genus	Species	GTL	CBL	CCL	ZYW	MA	IOW	CM ³	C ¹ C ¹	M ³ M ³	ML	CM ₃	CPH
CBC02647	<i>Myotis</i>	<i>siligorensis</i>	12.39	11.35	10.79	7.22	6.58	2.94	4.43	3.02	4.82	8.82	4.70	2.05
CBC02648	<i>Myotis</i>	<i>siligorensis</i>	12.52	11.44	10.82	7.29	6.43	3.01	4.57	3.02	4.82	8.87	4.75	2.17
CBC02649	<i>Hipposideros</i>	<i>grandis</i>	23.31	20.64	19.78	12.60	10.95	3.15	8.59	5.23	8.69	15.38	9.33	5.22
CBC02651	<i>Hipposideros</i>	<i>grandis</i>	23.42	20.38	19.86	12.85	11.04	3.36	8.48	4.74	8.75	15.32	9.09	5.66
CBC02652	<i>Hipposideros</i>	<i>larvatus</i>	22.96	20.07	19.52	12.72	11.22	3.25	8.57	5.09	8.59	15.08	9.06	5.05
CBC02653	<i>Tylonycteris</i>	<i>malayana</i>	12.39	11.60	11.36	9.05	7.71	3.71	4.09	4.22	5.77	8.68	4.28	2.62
CBC02656	<i>Hipposideros</i>	<i>larvatus</i>	22.27	19.74	19.25	12.62	10.96	3.29	8.20	4.89	8.30	14.72	8.75	5.25
CBC02657	<i>Hipposideros</i>	<i>larvatus</i>	23.20	20.38	19.94	12.84	11.05	3.36	8.21	5.09	8.52	15.49	9.02	5.36
CBC02658	<i>Rhinolophus</i>	<i>thomasi</i>	19.11	17.00	16.16	9.55	8.91	2.57	6.83	4.30	7.11	12.46	7.15	3.10
CBC02659	<i>Murina</i>	<i>huttoni</i>	17.13	15.29	14.94	9.27	8.07	4.32	5.60	4.07	5.39	11.09	6.23	3.81
CBC02660	<i>Murina</i>	<i>huttoni</i>	16.57	15.23	14.79	9.04	7.96	4.33	5.42	4.20	5.55	11.31	6.21	4.24
CBC02661	<i>Murina</i>	<i>fionae</i>	19.32	16.96	16.77	11.45	9.17	4.87	6.45	4.96	6.77	12.62	7.02	4.92
CBC02662	<i>Miniopterus</i>	<i>magnater</i>	16.89	15.88	14.94	9.38	8.89	4.14	6.84	4.93	7.38	12.11	7.36	2.82
CBC02663	<i>Pipistrellus</i>	<i>paterculus</i>	12.79	11.82	11.79	8.53	7.23	3.60	4.64	4.06	5.79	8.92	4.93	2.62
CBC02665	<i>Kerivoula</i>	<i>titania</i>	16.03	14.81	14.24	9.36	7.99	3.48	6.18	3.49	5.75	10.98	6.56	3.82
CBC02666	<i>Cynopterus</i>	<i>horsfieldi</i>	32.40	30.54	29.89	21.51	13.27	6.22	10.55	6.76	9.36	24.60	11.61	12.38
CBC02667	<i>Murina</i>	<i>fionae</i>	17.62	15.90	15.54	10.00	8.31	4.29	5.49	4.18	5.58	11.94	6.05	4.50