STATUS OF KEY SPECIES IN KEO SEIMA WILDLIFE SANCTUARY 2010–2020

ស្ថានភាពនៃប្រភេទសត្វព្រៃសំខាន់ៗនៅក្នុងដែនជម្រកសត្វព្រៃកែវសីមាឆ្នាំ ២០១០-២០២០

WCS Cambodia
September 2020

ACKNOWLEDGEMENTS

Surveys conducted between 2010 and 2016 were approved and supported by the Ministry of Agriculture, Forestry and Fisheries in Seima Protection Forest. Following a transfer of management and renaming of the protected area, surveys from 2016 to 2020 were approved and supported by the Ministry of Environment in Keo Seima Wildlife Sanctuary.

Technical Advisors who have implemented these surveys are Hannah O'Kelly, Matt Nuttall, and Olly Griffin.

Wildlife Monitoring Team Coordinator was Nut Menghor and is now Sot Vandouen.

Field team leaders for each survey year are listed below.

2010
Nut Menghor
Houen Seang Lay
Orn Samart
Phok Sopanha
Sot Vandoeun

2011
Nut Menghor
Sorn Borey
Houen Seang Lay
Orn Samart
Phok Sopanha
Sot Vandoeun

2013
Nut Menghor
Sot Vandoeun
Orn Samart
Phok Sopanha
Toeu Bann

2014
Nut Menghor
Sot Vandoeun
Orn Samart
Phok Sopanha
Sorn Chanthoeun
Toeu Bann
Vorn Vuth

2016
Nut Menghor
Sot Vandoeun
Noeun Bunthenh
Orn Samart
Phok Sopanha
Sorn Chanthoeun
Toeu Bann
Vorn Vuth

2018
Sot Vandoeun
Khny Sokry
Orn Samart
Phok Sopanha
Sorn Chanthoeun
Toeu Bann

2020
Sot Vandoeun
Khny Sokry
Noeun Bunthenh
Orn Samart
Phok Sopanha
Toeu Bann

Local community members from villages in and around KSWS have played a vital role in supporting these surveys; thanks to all those who have contributed to the successful implement-ation of this montoring program.

Acronyms

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CR	Critically Endangered on the IUCN Red List of Threatened Species
DOI	Digital Object Identifier
EN	Endangered on the IUCN Red List of Threatened Species
GAM	Generalized Additive Model
IUCN	International Union for Conservation of Nature
KDE	Kernel Density Estimation
KSWS	Keo Seima Wildlife Sanctuary
LC	Least Concern on the IUCN Red List of Threatened Species
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoE	Ministry of Environment
NT	Near Threatened on the IUCN Red List of Threatened Species
VU	Vulnerable on the IUCN Red List of Threatened Species
WCS	Wildlife Conservation Society

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Cover photo: Northern red muntjac seen in KSWS during the 2020 surveys, Toeu Bann/WCS Cambodia

Contents

EXECUTIVE SUMMARY

- Keo Seima Wildlife Sanctuary (KSWS) was established with three main purposes, the first of which is to "protect and maintain wildlife habitat and ecosystems as well as to fulfill the necessary conditions for all kinds of wildlife species, plants and biodiversity".

- Effectiveness of conservation measures and progress towards this goal can only be measured by objective and robust biodiversity monitoring. Here, we report on one aspect of this monitoring program: the populations and distributions within KSWS of 13 key species.

- Population trends for six monitored primate species are reassuring, with **three primate species showing stable populations** (black-shanked douc langur, yellow-cheeked crested gibbon, long-tailed macaque), and **one species showing an increasing population** (pig-tailed macaque). Maintaining stable populations of Critically Endangered, Endangered, and Vulnerable primate species is a significant conservation success. However, the **population of two primate species are declining** (stump-tailed macaque and Germain's silver langur) in KSWS.

- **Green peafowl populations are increasing within KSWS**; as an Endangered species with a contracting range and significant population loss globally, this is a great success.

- Ungulate population trends are concerning. **Five out of six monitored ungulate species either show significant population declines,** or have been assessed by experts as being in decline within KSWS. Wild pig populations naturally fluctuate, so are considered to be stable in this analysis. **Northern red muntjac, a species typically considered robust to hunting, shows a 50 % decline between 2014 and 2020.** Since 2010, Eld's deer and sambar have been at densities too low to monitor with line transects. Banteng and gaur are now at such low densities that future monitoring with line transects will not give robust population estimates. **All four large ungulates are declining within KSWS.**

- **Population trends for eight of ten key species meet or improve upon the anticipated REDD+ *with*-project scenario**, and all exceed the anticipated *without*-project scenario, demonstrating the positive impact of the KSWS project.

- These results highlight both successes in conservation and protection in KSWS, and areas where significant, urgent improvements are required to meet the goal of maintaining wildlife populations. Rates of decline in KSWS are likely to be significantly slower than outside protected areas. However, **protection and conservation efforts must be increased to prevent the total loss of large ungulates, and to reverse the decline of northern red muntjac.**

Primates

1 increasing population
- ⬆ Pig-tailed macaque

3 stable populations
- ➡ Black-shanked douc langur
- ➡ Yellow-cheeked gibbon
- ➡ Long-tailed macaque

2 decreasing populations
- ⬇ Stump-tailed macaque
- ⬇ Germain's silver langur

Birds

1 increasing population
- ⬆ Green peafowl

Ungulates

1 stable population
- ➡ Wild pig

5 decreasing populations
- ⬇ Red muntjac
- ⬇ Banteng
- ⬇ Gaur
- ⬇ Eld's deer
- ⬇ Sambar
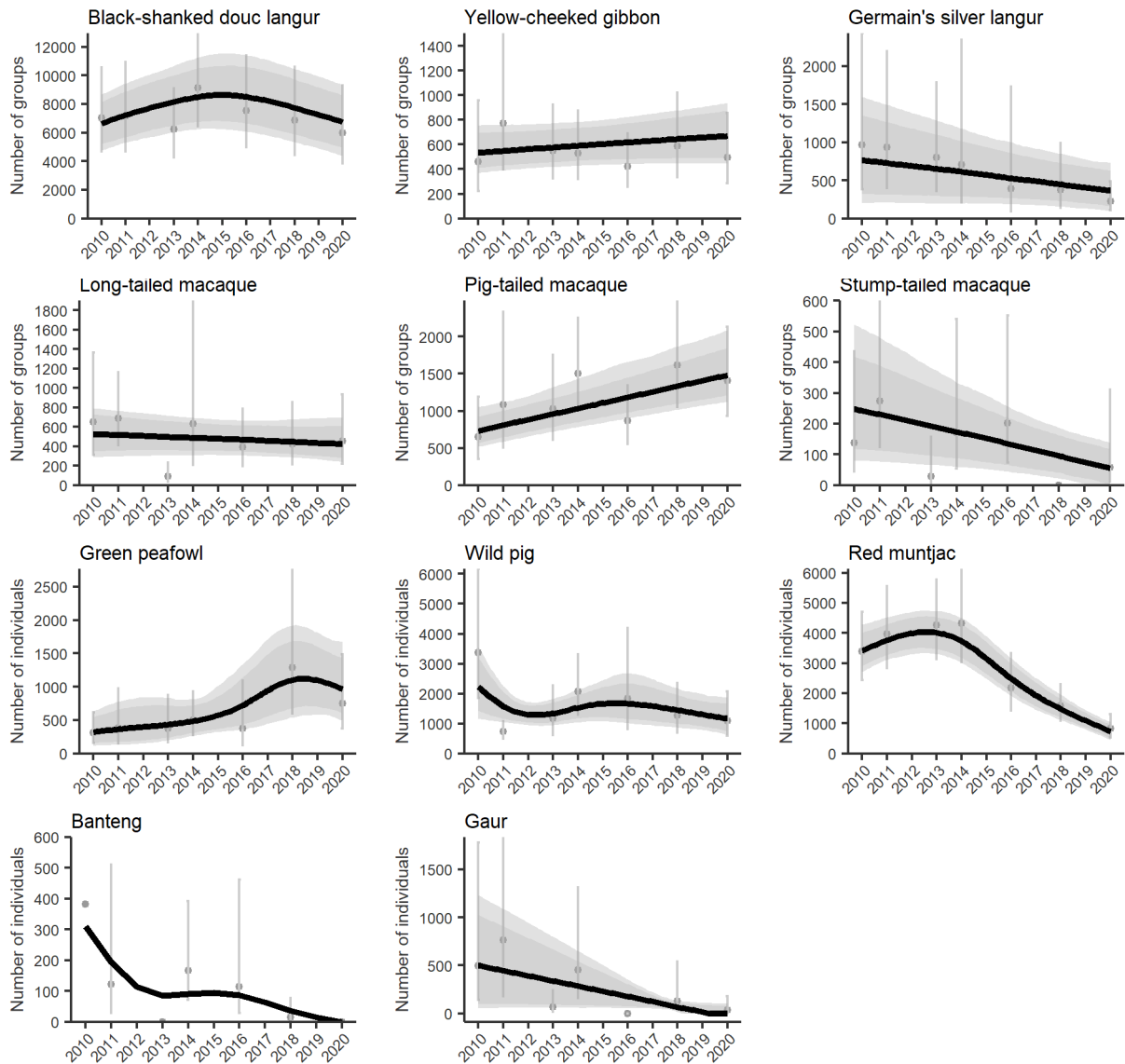
Figure 1. Population estimates and trends for key species in the core area of Keo Seima Wildlife Sanctuary from 2010 to 2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

*Table 1. Global population trend, Keo Seima Wildlife Sanctuary population trend, and Keo Seima Wildlife Sanctuary 2020 population estimates for key species. * denotes trends based on expert assessment. Population estimates for 2020 are not available for four key species due to low encounter rates.*

English name	Global population trend	KSWS population trend	KSWS population
Black-shanked douc langur	Declining	Stable	6756 groups
Yellow-cheeked gibbon	Declining	Stable	669 groups
Germain's silver langur	Declining	Declining	364 groups
Long-tailed macaque	Declining	Stable	424 groups
Pig-tailed macaque	Declining	Increasing	1483 groups
Stump-tailed macaque	Declining	Declining	56 groups
Green peafowl	Declining	Increasing	966 individuals
Wild pig	Stable	Stable	1162 individuals
Northern red muntjac	Declining	Declining	732 individuals
Banteng	Declining	Declining	-
Gaur	Declining	Declining	-
Eld's deer	Declining	Declining*	-
Sambar	Declining	Declining*	-

សេចក្ដីសង្ខេប

- ដែនជម្រកសត្វព្រៃការសីមាបានបង្កើតឡើងក្នុងគោលបំណងសំខាន់ៗចំនួនប្រាំបី ដែលក្នុងនោះគោលបំណងទី១ គឺ ដើម្បី «ការពារ និងថែរក្សាទីជម្រកសត្វព្រៃ និងប្រព័ន្ធអេកូឡូស៊ី ក៏ដូចជាបំពេញលក្ខខណ្ឌចាំបាច់នានាសម្រាប់ ប្រភេទសត្វព្រៃ រុក្ខជាតិ និងជីវៈចម្រុះគ្រប់ប្រភេទ»។

- ប្រសិទ្ធភាពនៃវិធានការណ៍អភិរក្ស និងវឌ្ឍនភាពឆ្ពោះទៅរកគោលដៅនេះអាចត្រូវបានវាស់វែងតែតាមតាមរ យៈគោលបំណងរបស់គម្រោង និងតាមរយៈការអង្កេតតាមដានហ្មត់ចត់លើជីវៈចម្រុះប៉ុណ្ណោះ។ ពេលនេះ យើងសូមរាយការណ៍អំពីទិដ្ឋភាពមួយផ្នែកនៃកម្មវិធីអភិរក្សតាមដានសត្វព្រៃដែលផ្តោតទៅលើចំនួន និងរបាយ សត្វព្រៃចំនួន១៣ប្រភេទសំខាន់ៗដែលមានវត្តមាននៅក្នុងដែនជម្រកសត្វព្រៃការសីមា។

- បច្ចុប្បន្ន ក្ដីបារម្ភរបស់ក្រុមអភិរក្សអំពីការវិនាសផុតពូជនៃប្រភេទសត្វពានបានថយចុះ ដោយសារចំនួនពពួកពានរ ៣ ប្រភេទ (មានស្មានទុយស ទោចប្ដាល់លឿង និងស្វាក្ដាម) នៅថែ និងចំនួនពានរមួយប្រភេទទៀត គឺស្វាត្រោស កំពុងមានការកើនឡើង។ ពពួកពានរទាំងនេះស្ថិតក្នុងចំណាត់ថ្នាក់ផ្សេងៗគ្នារួមមាន ប្រភេទជិតផុតពូជបំផុត ប្រភេទជិតផុតពូជ និងជាប្រភេទកំពុងទទួលរងការគម្រាមកំហែង។ ការរក្សាចំនួនពពួកពានរទាំងនេះឲ្យនៅថែគឺ ជាជោគជ័យដ៏ធំមួយក្នុងការងារអភិរក្សសត្វព្រៃនៅក្នុងដែនជម្រកសត្វព្រៃការសីមា។ ប៉ុន្លែចំនួនពពួកពានរពីរ ប្រភេទគឺ (ស្វាអង្កត់ និងស្វាព្រាម) នៅក្នុងដែនជម្រកសត្វព្រៃការសីមាកំពុងធ្លាក់ចុះ។

- យោងតាមលទ្ធផលនៃការសិក្សាស្រាវជ្រាវបានបង្ហាញថាចំនួនសត្វក្ងោកនៅក្នុងដែនជម្រកសត្វព្រៃការសីមា មាន ការកើនឡើង ដែលប្រការនេះបញ្ជាក់ពីភាពជោគជ័យដ៏ធំមួយសម្រាប់ការអភិរក្សសត្វប្រភេទនេះ នៅក្នុងដែន ជម្រកសត្វព្រៃការសីមា ទោះបីជាចំនួនប្រភេទសត្វនេះ មានការថយចុះយ៉ាងច្រើននៅទូទាំងពិភពលោកក្ដី។

- យោងតាមការសិក្សាស្រាវជ្រាវបានបង្ហាញឲ្យដឹងថា ចំនួននៃពពួកថនិកសត្វដែលមានក្រចកជើងជាំមស្ថិតក្នុង ស្ថានភាព គួរឲ្យព្រួយបារម្ភ។ ចំនួនសត្វប្រភេទនេះ ៥ ប្រភេទក្នុងចំណោម ៦ ប្រភេទបានថយចុះ ឬចាប់ផ្ដើមថយ ចុះនៅក្នុងដែនជម្រកសត្វព្រៃការសីមា ឬឡើបើចំនួនប្រភេទជ្រូកព្រៃនៅថែ។ ប្រភេទសត្វឈ្លូស ត្រូវបានចាត់ទុកជា ប្រភេទដែលប្រឈមនឹងការបរបាញ់របស់ព្រានព្រៃ ហើយចំនួនរបស់វាមានការថយចុះ៥០ភាគរយ ក្នុងចន្លោះពីឆ្នាំ ២០១៤ ដល់ឆ្នាំ ២០២០។ ដោយឡែកចាប់ពីឆ្នាំ ២០១០មក ដង់ស៊ីតែនៃប្រភេទសត្វរមាំង និងសត្វប្រើសគឺមាន ចំនួនទាបបំផុតនៅលើបន្ទាត់ស្រាវជ្រាវត្រង់សិក។ ក៏ដូចគ្នាដែរដង់ស៊ីតែនៃប្រភេទសត្វទន្សោង និងសត្វខ្ទីង គឺមាន ចំនួនទាបបំផុតដែលទៅអនាគតអាចនឹងមិនអាចគណនាចំនួនរបស់វាបានឡើយ។ សរុបសេចក្ដីមកពពួក ថនិកសត្វក្រចកជើងជាំមមាន�៨ធំចំនួន៥ប្រភេទនេះគឺមានការថយចុះក្នុងដែនជម្រកសត្វព្រៃការសីមា។

- ចំនួនសត្វព្រៃសំខាន់ៗ ១០ប្រភេទ ក្នុងចំណោម ១៣ ប្រភេទបានឆ្លើយតប ឬមានភាពកាន់តែប្រសើរបើធៀបនឹង សេណារីយ៉ូ គ្រោងទុកនៃការអនុវត្តគម្រោងរេដបូក (REDD+) ហើយប្រភេទសត្វសំខាន់ៗទាំង១៣ប្រភេទមាន ភាពប្រសើរ បើធៀបនឹងសេណារីយ៉ូ ដែលគ្មានគម្រោងរេដបូក(REDD+) លទ្ធផលបានបង្ហាញពីផលប៉ះពាល់ជា វិជ្ជមាននៃគម្រោងរេដបូកក្នុងដែនជម្រកសត្វព្រៃការសីមាដែលជាតំបន់ជីវៈចម្រុះមានតម្លៃខ្ពស់។

- លទ្ធផលទាំងនេះបង្ហាញពីជោគជ័យទាំងពីរបែបទាំងក្នុងការអភិរក្ស និងការការពារ នៅក្នុងដែនជម្រកសត្វព្រៃការ សីមា ព្រមទាំងតំបន់សំខាន់ៗផ្សេងទៀតដែលត្រូវការកែលម្អជាបន្ថានដើម្បីឆ្លើយតបទៅនឹងគោលដៅនៃការថែ រក្សាចំនួនសត្វព្រៃ។ អត្រានៃការធ្លាក់ចុះចំនួនសត្វព្រៃនៅក្នុងដែនជម្រកសត្វព្រៃការសីមាគឺមានភាពជាយឺត ជាងក្រៅតំបន់ការពារធម្មជាតិ។ តែទោះជាយ៉ាងណាយើងត្រូវបង្កើនកិច្ចខិតខំប្រឹងប្រែងការពារនិងអភិរក្សដើម្បី ការពារប្រភេទសត្វក្រចកជើងជាំមៗដែលបានបាត់បង់ និងដើម្បីទប់ស្កាត់ការថយចុះនៃពពួកសត្វឈ្លូសផងដែរ។
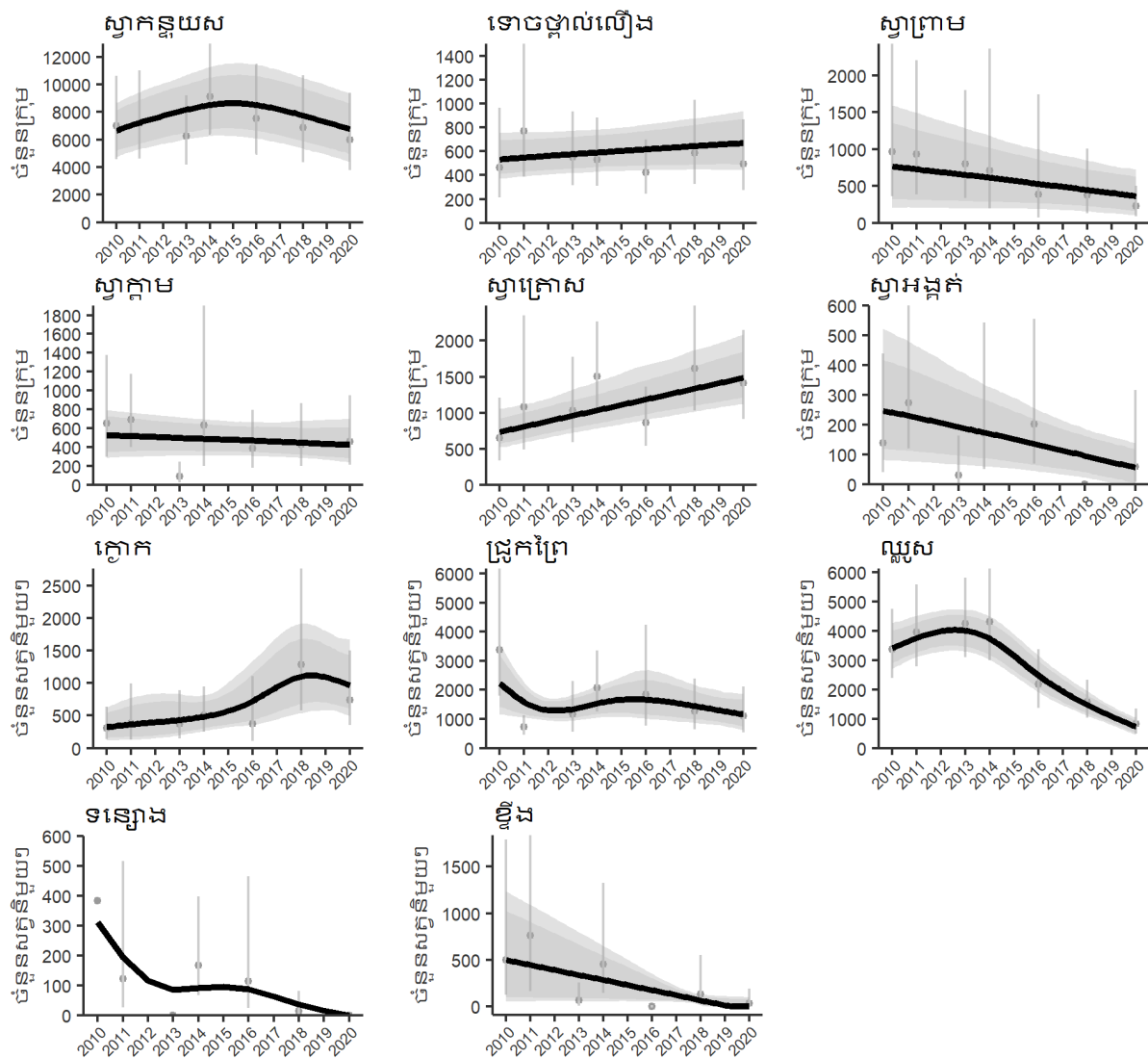
Figure 2. បន្ទាត់ខ្មៅគឺបង្ហាញអំពីការប៉ាន់ប្រមាណចំនួនប្រភេទសត្វព្រៃសំខាន់ៗនៅក្នុងតំបន់ស្នូលនៃដែនជម្រកសត្វព្រៃកែវសីមា

Table 2. ចំនួនសត្វព្រៃជាសកល ចំនួនសត្វព្រៃនៅក្នុងដែនជម្រកសត្វព្រៃកែវសីមា និងការប៉ាន់ប្រមាណចំនួនសត្វព្រៃសំខាន់ៗនៅឆ្នាំ ២០២០ ក្នុងដែនជម្រកសត្វព្រៃកែវសីមា ។ *ការប៉ាន់ប្រមាណចំនួនសត្វព្រៃទាំងនេះគឺធ្វើឡើងតាមរយៈការវាយតម្លៃរបស់អ្នកជំនាញ ។ នៅឆ្នាំ២០២០ យើងមិនអាចធ្វើការប៉ាន់ប្រមាណចំនួនសត្វព្រៃសំខាន់ៗ៤ប្រភេទដោយកំរិតនៃចំនួនរាប់យើញមានតិចពេក ។

No.	ឈ្មោះ៖	និន្នាការរបាយជាសកល	និន្នាការរបាយក្នុងដែនជម្រកសត្វព្រៃកែវសីមា៖	ចំនួនសត្វព្រៃក្នុងដែនជម្រកសត្វព្រៃកែវសីមា
1	ស្វាកន្ទុយស	ថយចុះ៖	ស្ថេរភាព	6756 ក្រុម
2	ទោចផ្គាល់លឿង	ថយចុះ៖	ស្ថេរភាព	669 ក្រុម
3	ស្វាព្រាម	ថយចុះ៖	ថយចុះ៖	364 ក្រុម
4	ស្វាក្ដាម	ថយចុះ៖	ស្ថេរភាព	424 ក្រុម
5	ស្វាគ្រោស	ថយចុះ៖	កើនឡើង	1483 ក្រុម
6	ស្វាអង្គត់	ថយចុះ៖	ថយចុះ៖	56 ក្រុម
7	គ្រោក	ថយចុះ៖	កើនឡើង	966 ក្បាល
8	ជ្រុកព្រៃ	ស្ថេរភាព	ស្ថេរភាព	1162 ក្បាល
9	ឈ្លូស	ថយចុះ៖	ថយចុះ៖	732 ក្បាល
10	ទន្សោង	ថយចុះ៖	ថយចុះ៖	-
11	ខ្ទីង	ថយចុះ៖	ថយចុះ៖	-
12	ម៉ាង	ថយចុះ៖	ថយចុះ៖	-
13	ប្រើស	ថយចុះ៖	ថយចុះ៖	-

Legend:
- KSWS Boundary
- KSWS REDD+ Project area
- Dense forest
- Open forest
- Non-forest
- Water
- Deforestation
- Economic Land Concessions
- Wildlife transects
- Villages
- Main roads

0   5   10   15   20 km

Figure 3. Habitat types and location of transects in Keo Seima Wildlife Sanctuary, with inset showing the location of the protected area within Cambodia. Survey area (within the dotted black line) covers 1880 km2.

KEO SEIMA WILDLIFE SANCTUARY

Keo Seima Wildlife Sanctuary (KSWS), located in eastern Cambodia in Mondulkiri and Kratie provinces, is a site of national, regional, and global importance for a range of biodiversity, as well as the ancestral and contemporary home of the Bunong ethnic group.

The area is composed of a mosaic of habitat types, and is unusual in the region as it contains large areas of both evergreen/semi-evergreen forest and deciduous forest, together with a rich transition zone between them. Semi-natural grasslands are found in the northeast. From the east the Annamite Mountains, recognized as one of Asia's great centers of endemism (Stattersfield, Crosby, Long, & Wege, 1998), extend in from Vietnam: the only representation of this ecoregion in Cambodia. The northwest of the protected area forms part of the Eastern Plains Landscape. These diverse habitats and the comparative intactness of the site mean the site is identified as important in most national, regional, or global biodiversity prioritization exercises (Evans et al., 2013)

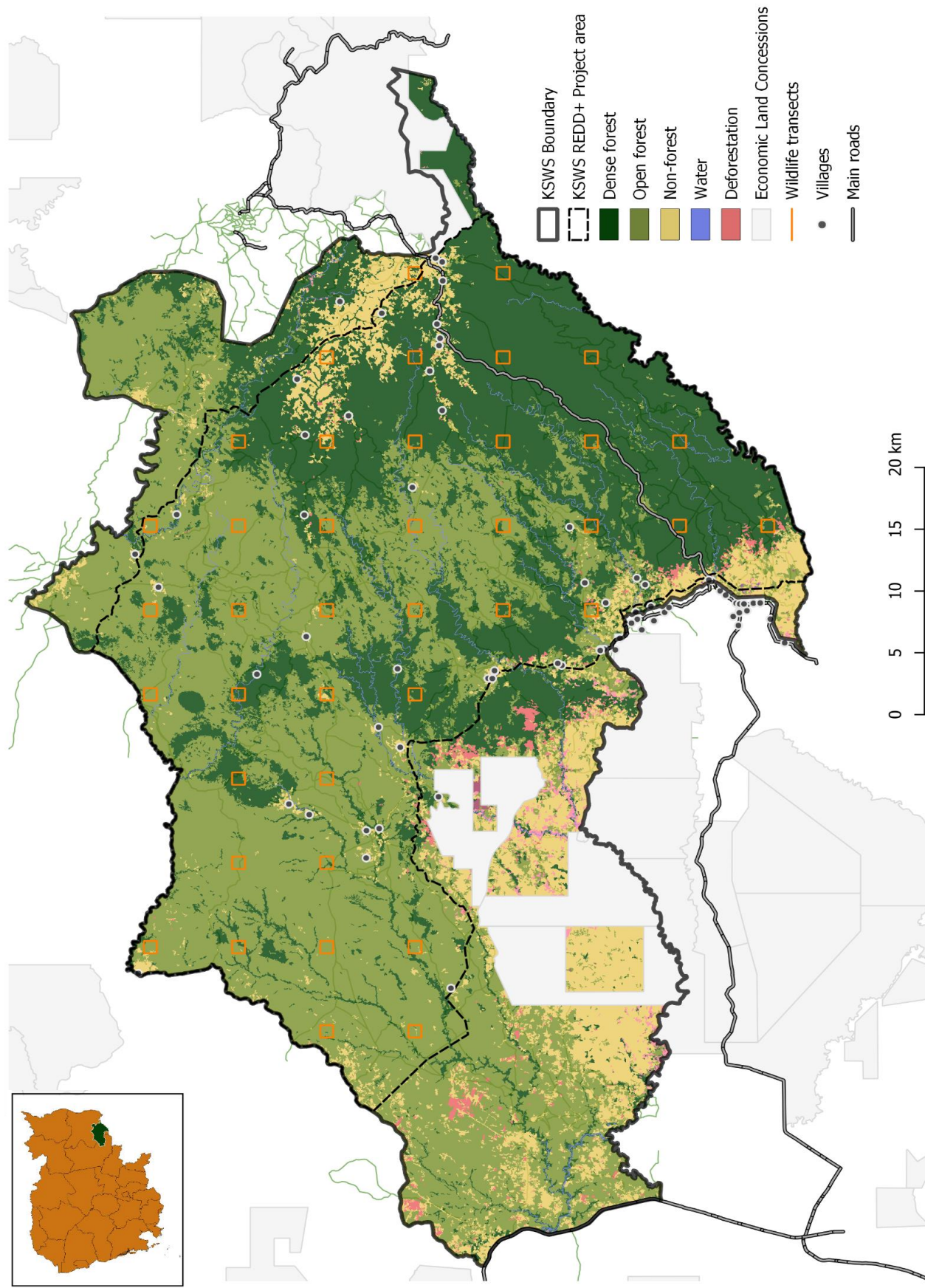The climate is tropical monsoonal, with around 2200–2800 mm of rain per annum at the headquarters in Keo Seima district, mostly from May to October. Elevation of the protected area ranges from 60–750 meters above sea level (Evans et al., 2013)

Legal protection was first provided to the area in 2002, with the establishment of Seima Biodiversity Conservation Area, later becoming Seima Protection Forest, and in 2016 becoming KSWS, covering 292 690 ha, under the management of the Ministry of Environment (MoE) (Royal Government of Cambodia, 2016). The vision for the area is *"a well-managed forest landscape that supports increasing wildlife populations and improving livelihoods for the people who currently live there."* This is to be achieved through a combination of effective protected area management, engaging local stakeholders, and programs to stabilize land use.

Management decisions must be based on an accurate understanding of the context, and biological monitoring is a vital component of any conservation project if the effects of management are to be meaningfully assessed.

To this end, a biodiversity monitoring program supported by WCS was established in 2002, and is now one of the largest and most intensive of its kind in Southeast Asia. This program covers a range of species and data types, all intended to direct, adapt, and refine conservation activities of the KSWS project. Here, we report on the population and distribution of 13 key species.

More than **1000** species recorded within KSWS

356 bird species

75 globally Threatened species

20 newly discovered species have been described from KSWS

106 CITES-listed species

46 Endangered or Rare species under Cambodian law

28 EDGE species

Highest number of species recorded for any protected area in Cambodia

12/08/2002 first designated as a protected area

09/05/2016 established as a wildlife sanctuary by Sub-decree No. 83

292 690 ha total area

2200–2800 mm of rain per annum

60 to 750 m elevation

16 to 36 °C temperature range

ANTICIPATED POPULATION TRENDS WITH AND WITHOUT REDD+ PROJECT

Under the Keo Seima REDD+ project, a range of baseline estimates were produced for forest cover change, socio-economic changes, and biodiversity changes in the absence of a conservation project ("*without*-project scenario") and with a functioning, funded conservation project ("*with*-project scenario") (WCS Cambodia & Ministry of Environment, 2015). Where data were available, these estimates are quantitative (forest cover change), and where data were not available, these estimates are qualitative (socio-economic changes and biodiversity changes). The broad without-project scenario predicted:

> "…a mostly deforested landscape with the remaining forest fragmented, degraded, significantly disturbed by humans due to easier access and heavily over-hunted, leading to a depauperate fauna and flora lacking most of the species of conservation significance present today, with many of the other species surviving in severely reduced numbers."

Global population trends can also provide assessments of conservation success. For example, project stability of a globally declining population is a greater success than project stability of a stable or globally increasing population. Nearly all key species in KSWS have globally declining populations (Table 3).

13 key species anticipated to decline in a *without*-project scenario

6 key species anticipated to be stable under a *with*-project scenario

4 key species anticipated to have a slowed rate of decline under a *with*-project scenario

12 key species with globally declining populations

1 key species with a stable global population

Table 3. Anticipated population trends in KSWS under a with-project scenario, and global population trends for key species. Adapted from Table 7.1.1 of the KSWS REDD+ Project Document.

English name	Khmer name	Scientific Name	Anticipated *with*-project population trend	Global trend
Black-shanked douc langur	ស្វាកន្ទុយស	*Pygathrix nigripes*	Stable	Declining
Yellow-cheeked gibbon	ទោចថ្កាល់លឿង	*Nomascus gabriellae*	Stable	Declining
Germain's silver langur	ស្វាព្រាម	*Trachypithecus germaini*	Stable	Declining
Long-tailed macaque	ស្វាក្ដាម	*Macaca fascicularis*	-	Declining
Northern pig-tailed macaque	ស្វាគ្រោស	*Macaca leonina*	Stable	Declining
Stump-tailed macaque	ស្វាអង្គត់	*Macaca arctoides*	Stable	Declining
Green peafowl	ក្ងោក	*Pavo muticus*	Stable	Declining
Wild pig	ជ្រូកព្រៃ	*Sus scrofa*	-	Stable
Northern red muntjac	ឈ្លូស	*Muntiacus vaginalis*	-	Declining
Banteng	ទន្សោង	*Bos javanicus*	Decline slowed	Declining
Gaur	ខ្ទិង	*Bos gaurus*	Decline slowed	Declining
Eld's deer	ម៉ាង	*Rucervus eldii*	Decline slowed	Declining
Sambar	ប្រើស	*Rusa unicolor*	Decline slowed	Declining

POPULATION AND DISTRIBUTION ESTIMATES

Population estimates allow identification of trends and changes in populations of wildlife species, and distribution estimates allow spatial prioritization. Both are required to inform management decisions and assess project successes.

In KSWS, two methods are used for population estimates. Firstly, Asian elephant populations are assessed with genetic sampling. Secondly, and reported on here, line transects are used to monitor the distribution and population of 13 key species:

- Black-shanked douc (ស្វាកន្ទុយស, *Pygathrix nigripes*, CR)
- Germain's silver langur (ស្វាប្រាម, *Trachypithecus germaini*, EN)
- Long-tailed macaque (ស្វាក្ដាម, *Macaca fascicula*ris, VU)
- Northern pig-tailed macaque (ស្វាប្រៃាស, *Macaca leonina*, VU)
- Stump-tailed macaque (ស្វាអង្កត់, *Macaca arctoides*, VU)
- Yellow-cheeked crested gibbon (ទោចប្ដាល់លៀង, *Nomascus gabriellae*, EN)
- Green peafowl (ក្ដាក, *Pavo muticus*, EN)
- Banteng (ទន្សោង, *Bos javanicus*, EN)
- Eld's deer (រមាំង, *Rucervus eldii*, EN)
- Gaur (ខ្ទីង, *Bos gaurus*, VU)
- Northern red muntjac (ឈ្លូស, *Muntiacus vaginalis*, LC)
- Sambar (ប្រើស, *Rusa unicolor*, VU)
- Wild pig (ជ្រូកព្រៃ, *Sus scrofa*, LC).

Standardized, comparable methods covering the same spatial extent have been used since 2010. Prior to this, a smaller area was sampled, making direct comparison of population estimates more complex. In contrast, densities within the same area are comparable and can show trends.

Of these 13 species, population estimates are produced for 11, with the remaining two (Eld's deer and sambar) observed at such low encounter rates that reliable estimates cannot be produced. Population estimates for an additional two species (banteng and gaur) have a low sample size and comparatively low precision compared to other species.

Distribution estimates are produced for these 13 species using kernel density estimates (KDE). These distribution estimates have been used in the zonation process for KSWS, representing the first time a robust, data driven process incorporating spatial biological monitoring data has been used for zonation in Cambodia.

13 key species:

    6 *ungulate species*

    1 *bird species*

    6 *primate species*

15 years of systematic monitoring

10 years of estimates covering the same spatial extent

9460 km surveyed by teams since 2010, equivalent to walking from Battambang to Moscow, Russia

11 population estimates

13 spatial distribution estimates

METHODS

The distance sampling methodology used at KSWS follows Buckland et al. (2001) and Buckland, Rexstad, Marques, & Oedekoven (2015), with KSWS-specific protocols described in detail in O'Kelly & Nut (2010), Nuttall, Menghor, & O'Kelly (2013), and Nuttall, Nut, Ung, & O'Kelly (2017).

Distance sampling in KSWS uses 40 square transects placed systematically throughout the core area. Each of these transects are surveyed multiple times during a survey season, with teams recording all observations of the 13 target species. These observations are used to estimate the detectability of each species (i.e., what proportion of groups or individuals are successfully seen at increasing distances from the transect). This detection function is then used in conjunction with the observations to calculate the density of each species within the surveyed areas. As the surveyed areas were randomly selected with respect to the distribution of the target species and are representative of habitats across the whole area, density (i.e., number of groups or individuals per unit area) can be estimated. This value is multiplied by the survey area to provide a density estimate of groups or individuals across the core area. For species seen in groups, this value is then multiplied by the group size to give an individual-level population estimate. Resampling with replacement, bootstrapping, and generalized additive models (GAMs) are then used to estimate populations trends and provide variance estimation. These models provide annual estimates even in years without sampling, and better account for encounter rate variation and thus produce estimates that are more reliable. A full technical description of the 2020 analysis will be published in a forthcoming peer-reviewed journal article.

The distribution estimates use raw observation data, adjusted for survey effort, to provide encounter rates for each species. Given the random and representative placement of transects and the known survey effort for each transect and year, kernel density estimation (KDE) provides a non-parametric method of interpolating encounter rates across the core area and between transects. Typically used for home range estimation (Laver & Kelly, 2008), but also used for range and distribution (e.g., Ochieng, 2015) this method does not include modelling covariates (such as habitat type or distance to nearest village). Nonetheless, it provides distribution estimates at a resolution high enough to inform protected area management and to prioritize key areas for conservation efforts. For this analysis, KDE distribution maps were produced using the heatmap (kernel density estimation) algorithm for Quantum GIS 3.4.2 (QGIS.org,

1280 km surveyed by teams during 2020 surveys

1880 km^2 survey area

40 line transects

4 km length of each transect

8 repeats of each transect

2016 individual animals sighted during 2020 surveys

6 months average duration of transect season

6 days for each mission

6 teams during surveys

18 local guides employed from surrounding villages for each mission

2020). Encounter rates (i.e., catch per unit effort) for each species were assigned to each transect centroid, and used to weight the KDE. Optimal bandwidth (7435), used for the kernel radius, was calculated using the number of sampling points and the standard distance between them, following equation 6.16 of Fotheringham, Brunsdon, & Charlton (2000):

$$h_{opt} = \left[\frac{2}{3n} \right]^{1/4} \sigma$$

A quartic (biweight) kernel function was used for kernel shape.

For the all-species hotspot estimate, probabilities were scaled to fall between 0 and 1, so that each species is given equal weight and the all-species distribution estimate is not dominated by a single common or widely occurring species. This has the advantage that more importance is given to an area if that area is the only place a species occurs, and less importance is given to areas where a species occurs if that species also occurs in many other areas.

Clockwise from top left: black-shanked douc langur (KSWS, Eleanor Briggs), southern yellow-cheeked gibbon (KSWS, SVC), Germain's silver langur (Cambodia, Allan Michaud), stump-tailed macaque (Jerry Oldnettel), northern pig-tailed macaque (KSWS, WCS Cambodia), long-tailed macaque (Cambodia, Eleanor Briggs).

RESULTS

Primates

Keo Seima Wildlife Sanctuary is home to a rich diversity of primates, including species for which KSWS holds the majority of the global population. All primates found in KSWS are Threatened on the IUCN Red List.

Of the seven confirmed primate species in KSWS, population estimates are produced for six. The seventh species, pygmy loris (ញ្រីភ្លើង, *Nycticebus pygmaeus*, EN), is too cryptic and nocturnal to survey using line transects.

Since 2002, efforts have been made to monitor the diurnal species through a combination of line transects and listening posts, and robust, comparable estimates are available from 2010 onwards.

Primates are key species that attract tourists to KSWS, including to Jahoo Gibbon Camp, the only site in the world where yellow-cheeked crested gibbon (ទោចថ្កាល់លឿង, *Nomascus gabriellae*, EN) have been habituated and are easily seen by tourists.

Whilst many other sites in the region are under-surveyed, KSWS is undoubtedly of global importance for a number of primate species (see Table 4), especially black-shanked douc langur (ស្វាកន្ទុយស, *Pygathrix nigripes*, CR); KSWS supports the majority of the world's individuals of this species. The black-shanked douc langur can be seen on the logo of KSWS and of the supporting REDD+ project.

7 primate species in KSWS

100 % of these species globally Threatened:

1 Critically Endangered

3 Endangered

3 Vulnerable

6 primate species with population estimates:

1 increasing population

4 stable populations

1 declining population

Table 4. Summary of key primate species in Keo Seima Wildlife Sanctuary

Species	IUCN status	Cambodian law	KSWS trend	Importance of population
Black-shanked douc langur / ស្វាកន្ទុយស *Pygathrix nigripes*	Critically Endangered	Rare	Stable	Global
Yellow-cheeked crested gibbon / ទោចថ្កាល់លឿង, *Nomascus gabriellae*	Endangered	Rare	Stable	Global
Germain's silver langur / ស្វាព្រាម *Trachypithecus germaini*	Endangered	Common	Declining	Global
Long-tailed macaque / ស្វាក្ដាម *Macaca fascicularis*	Vulnerable	Common	Stable	
Northern pig-tailed macaque / ស្វាត្រាស, *Macaca leonina*	Vulnerable	Common	Increasing	National
Stump-tailed macaque / ស្វាអង្កត់ *Macaca arctoides*	Vulnerable	Rare	Declining	Regional

BLACK-SHANKED DOUC LANGUR

Khmer: ស្វាកន្ទុយស
Bunong: Gork
Scientific: *Pygathrix nigripes*

DESCRIPTION

Black-shanked douc langur are one of three douc species. Their black legs distinguish them from the red-shanked and gray-shanked douc species found elsewhere. With a blue face and orange eye patches, this species has a striking appearance. They live in groups of up to 30 individuals. They mostly eat seeds and young leaves, and do not eat ripe fruit. Individuals can live for up to 30 years in the wild.

POPULATION

No global population estimate is available but, aside from the KSWS population, only small fragmented populations are known. The global population is thought to have decreased by more than 50 % over the last 36 years.

The population in KSWS has remained stable since 2010, with a 2020 estimate of 6756 groups (95 % CI 4385–9359). This represents the majority of the global population, making KSWS extremely important for conservation of this Critically Endangered primate.

Figure 4. Group population estimates for black-shanked douc langur in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Year	Number of groups	95 % confidence intervals	
		Lower	*Upper*
2010	6626	4756	8666
2011	7232	5299	9435
2012	7729	5682	10070
2013	8165	6027	10680
2014	8509	6256	11268
2015	8637	6238	11532
2016	8511	6081	11431
2017	8195	5774	11047
2018	7761	5340	10468
2019	7260	4906	9941
2020	6756	4385	9356

DISTRIBUTION

Black-shanked douc langur have a limited range, being found only in eastern Cambodia and central Vietnam. In Vietnam, the population is typically found in small, fragmented patches.

In KSWS, they are found mostly in evergreen and semi-evergreen forest, with a high concentration to the south of Andoung Kraloeng village.

6756 groups in KSWS

Decreasing population globally

Stable population in KSWS

Critically Endangered on IUCN Red List

Rare under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Restricted distribution globally

Wide distribution within KSWS
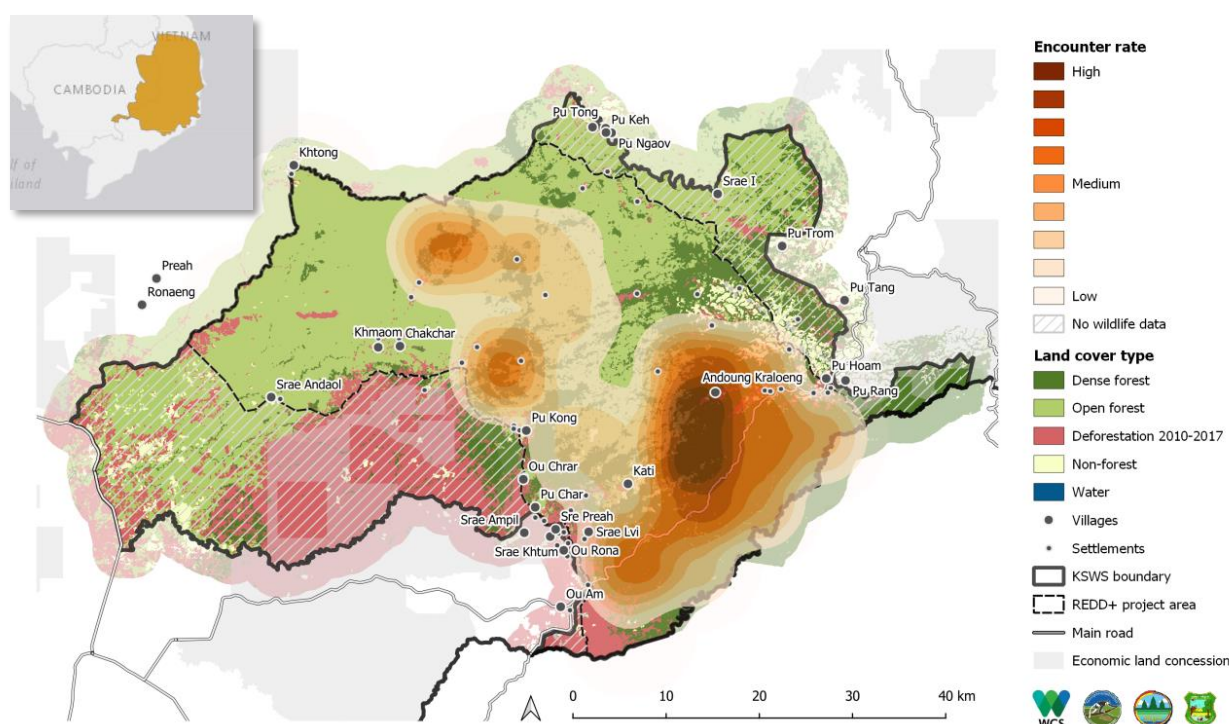
Figure 5. Distribution of black-shanked douc langur in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment. Inset map top left: global distribution of black-shanked douc langur (IUCN 2020, version 2020-2).

YELLOW-CHEEKED GIBBON

Khmer: ទោចថ្កាល់លឿៀង
Bunong: Gvanh Termpom Earl
Scientific: *Nomascus gabriellae*

DESCRIPTION

Southern yellow-cheeked crested gibbons have no tail, and use their long arms to move through the treetops, rarely coming down to the ground. Males are black with yellow cheeks, whilst females are yellow with a black patch on the top of their head. Infants are born yellow then change to black in their first year. Females become yellow again as they reach sexual maturity. They live in small family groups, with an adult male and one or two females, along with their recent offspring. The lifespan of wild individuals is unknown, but in captivity individuals have been known to live for 50 years.

POPULATION

No global population estimate is available, but the trend is thought to be decreasing.

The population in KSWS has remained stable since 2010, with a 2020 estimate of 669 groups (95 % CI 445–937).
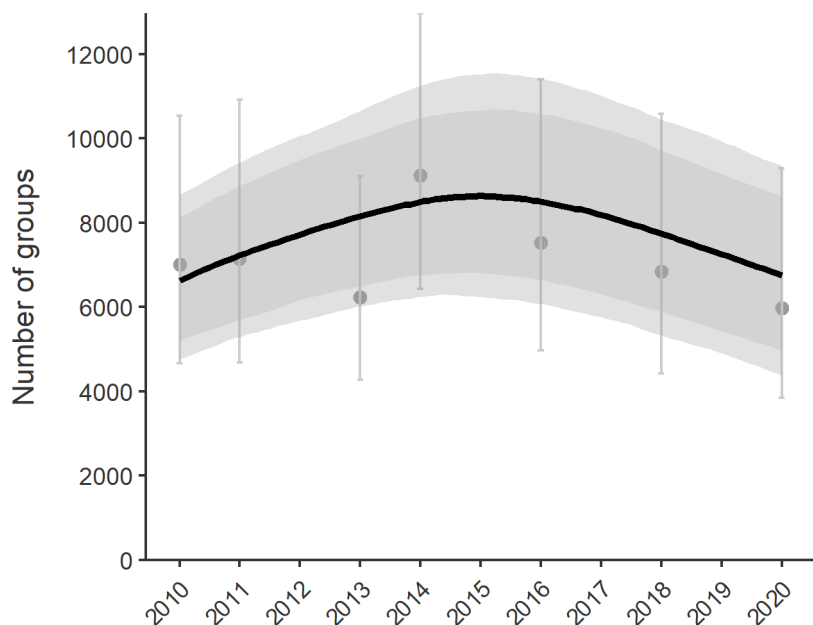

Figure 6. Group population estimates for southern yellow-cheeked gibbon in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Female southern yellow-cheeked gibbon ទោចថ្កាល់លឿៀង, *Nomascus gabriellae*, EN. Jahoo (KSWS), SVC.

669 groups in KSWS

Decreasing population globally

Stable population in KSWS

Endangered on IUCN Red List

Rare under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Restricted distribution globally

Wide distribution within KSWS

Table 6. Group population estimates of southern yellow-cheeked gibbon in the KSWS core area between 2010 and 2020.

Year	Number of groups	95 % confidence intervals	
		Lower	*Upper*
2010	532	369	755
2011	547	389	761
2012	563	406	762
2013	576	417	773
2014	590	429	783
2015	604	435	800
2016	616	440	823
2017	630	444	850
2018	644	447	875
2019	656	445	905
2020	669	445	937

DISTRIBUTION

Southern yellow-cheeked gibbon are found in eastern Cambodia and central Vietnam. This species is divided from a similar species, the northern yellow-cheeked gibbon, *Nomascus annamensis*, by the Srepok River in Cambodia. In KSWS, southern yellow-cheeked gibbon are mostly found in evergreen and semi-evergreen forest. High concentrations are found close to Andoung Kraloeng, home of the Jahoo community gibbon ecotourism project (www.gibbon.life).
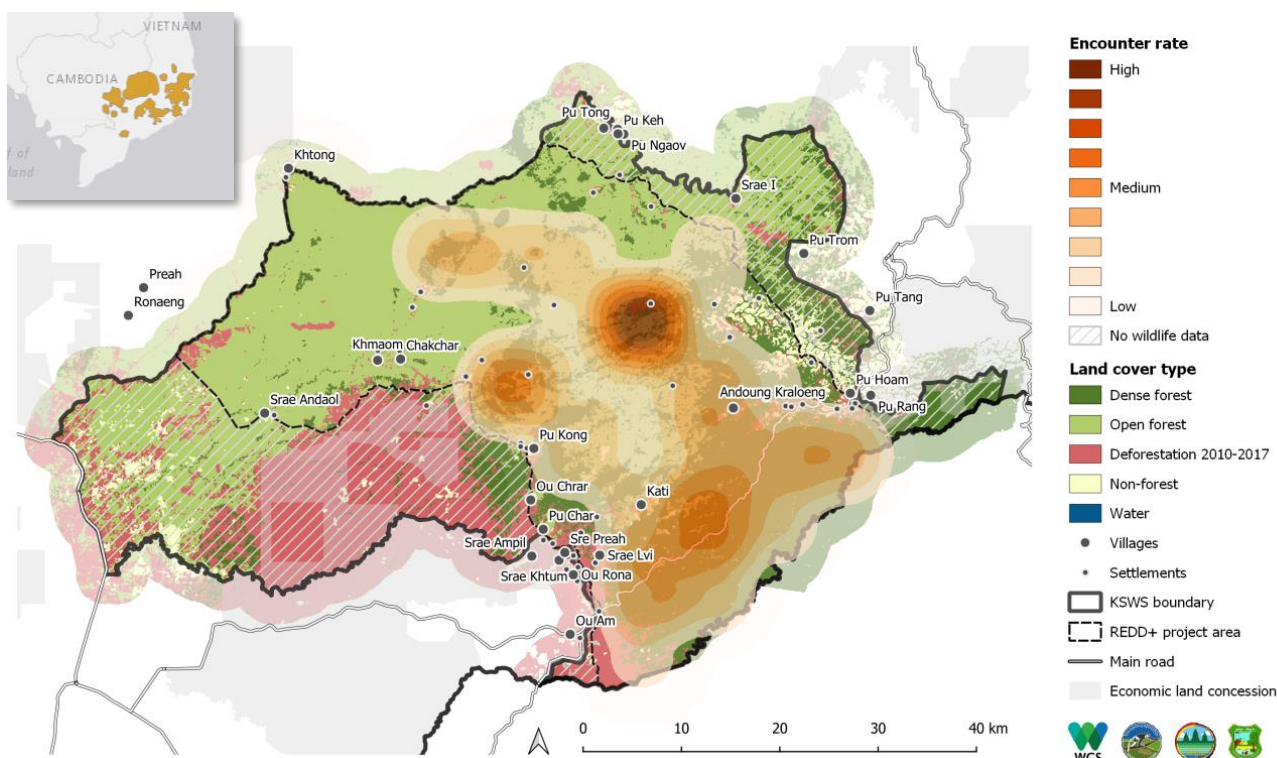
Figure 7. Distribution of southern yellow-cheeked gibbon in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of southern yellow-cheeked gibbon (IUCN 2020, version 2020-2).

23

GERMAIN'S SILVER LANGUR

Khmer: ស្វាព្រាម
Bunong: Tourk Rakong
Scientific: *Trachypithecus germaini*

DESCRIPTION

Adult Germain's silver langur have black and gray hair, whilst babies are born with bright orange hair. They mostly eat leaves, shoots, and fruits. They can be found in groups; the largest group recorded in KSWS is approximately 20 individuals, with a mix of males and females, but in some areas groups of up to 50 have been seen. They are eaten by leopards, tigers, dholes, and large snakes, and threatened by illegal forest clearance and logging within protected areas, as well as poaching.

POPULATION

No global population estimate is available, but the population is thought to have decreased by 50 % or more over the last 36 years. The population in KSWS has been declining since 2010, with a 2020 estimate of 364 groups (95 % CI 100–727). These estimates have wide confidence intervals, meaning statistical significance at 95 % is not reached (93 % of bootstraps show a negative trend). However, based on the clear decline in mean annual estimates, and in bootstrapped trend, as well as the restricted distribution of silver langur in KSWS, it is valid to interpret this result as a clear decline in the context of protected area management.
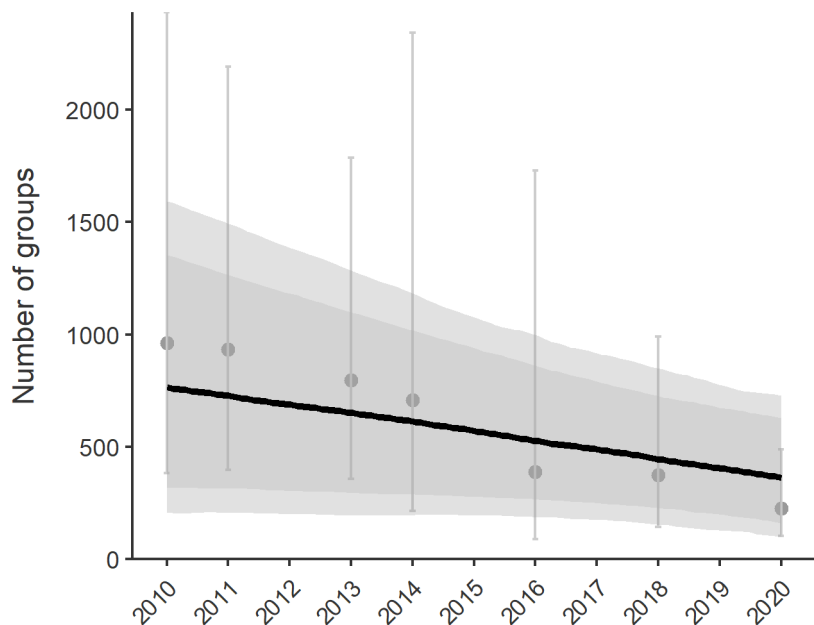
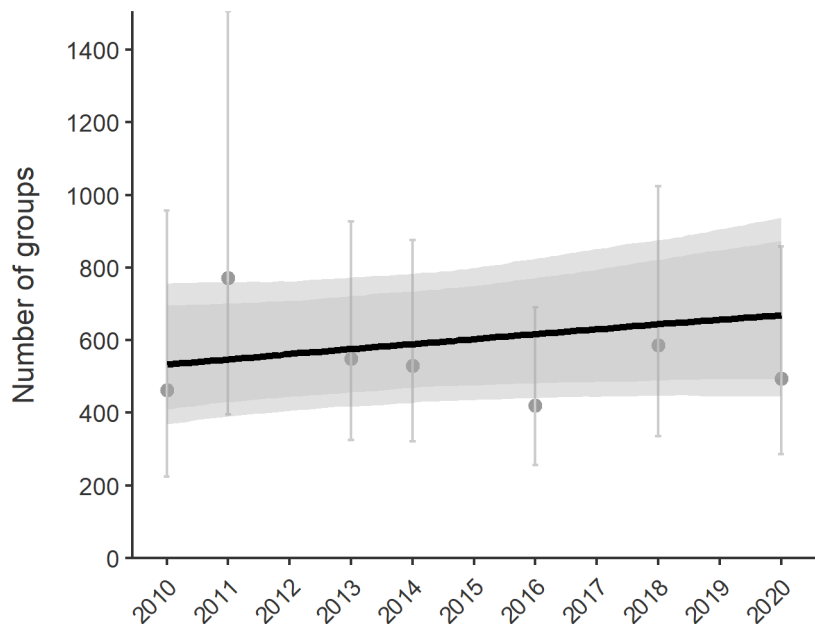*Figure 8. Group population estimates for Germain's silver langur in the core area of KSWS in 2010-2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.*

Table 7. Group population estimates of Germain's silver langur in the KSWS core area between 2010 and 2020.

Year	Number of groups	95 % confidence intervals	
		Lower	*Upper*
2010	765	205	1594
2011	727	206	1494
2012	687	200	1386
2013	650	195	1283
2014	612	196	1178
2015	569	194	1072
2016	527	188	1002
2017	490	174	919
2018	446	153	851
2019	405	127	777
2020	364	100	727

DISTRIBUTION

Currently, it is not clear where the boundaries between closely related *Trachypithecus* species lie. Global distribution estimates are likely to change in coming years as more research, especially genetic, clarifies which populations belong to which species. The population in KSWS appears to be intermediate between two species, *T. germaini* and *T. margarita*. The KSWS population is very restricted, and mostly found near O Khtong.

364 groups in KSWS

Decreasing population globally

Decreasing population in KSWS

Endangered on IUCN Red List

Common under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Unclear distribution globally

Restricted distribution within KSWS

Figure 9. Distribution of Germain's silver langur in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of Germain's silver langur (IUCN 2020, version 2020-2).

LONG-TAILED MACAQUE

Khmer: ស្វាក្តាម
Bunong: Tourk Bar
Scientific: *Macaca fascicularis*

DESCRIPTION

These medium-sized primates have a long tail, typically 40 to 65 cm, which is used for balance. Their hair varies in color from light brown to dark gray. Their skin is black on their feet and ears, and on their faces is a light grayish pink. These macaques have a cheek pouch that they use to store food while foraging, and they feed on a wide variety of food sources depending on habitat. Unusually for primates, they typically spit out seeds, rather than swallowing them. They live for 15–30 years in the wild, and can live longer in captivity. In the wild they can be found in large groups of up to 100 individuals.

POPULATION

No global population estimate is available. This species is common across much of its large range, but it is thought that the population is slowly decreasing.

The population in KSWS has remained stable since 2010, with a 2020 estimate of 424 groups (95 % CI 238–696).

Figure 10. Group population estimates for long-tailed macaques in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Table 8. Group population estimates of long-tailed macaque in the KSWS core area between 2010 and 2020.

Year	Number of groups	95 % confidence intervals	
		Lower	*Upper*
2010	524	284	792
2011	515	296	761
2012	506	302	740
2013	494	308	714
2014	486	308	692
2015	476	308	672
2016	468	306	664
2017	456	295	660
2018	446	285	676
2019	433	265	687
2020	424	238	696

424 groups in KSWS

Decreasing population globally

Stable population in KSWS

Vulnerable on IUCN Red List

Common under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Wide distribution globally

Wide distribution within KSWS

DISTRIBUTION

Long-tailed macaques are a tolerant and adaptable species found across Southeast Asia in a range of habitats, from mangroves and swamp forest, to human dominated urban landscapes, and intact forest such as KSWS.

In KSWS, they are found in most areas, including along the main road, where they are sometimes fed by people in cars. The highest densities are found in the north of KSWS.
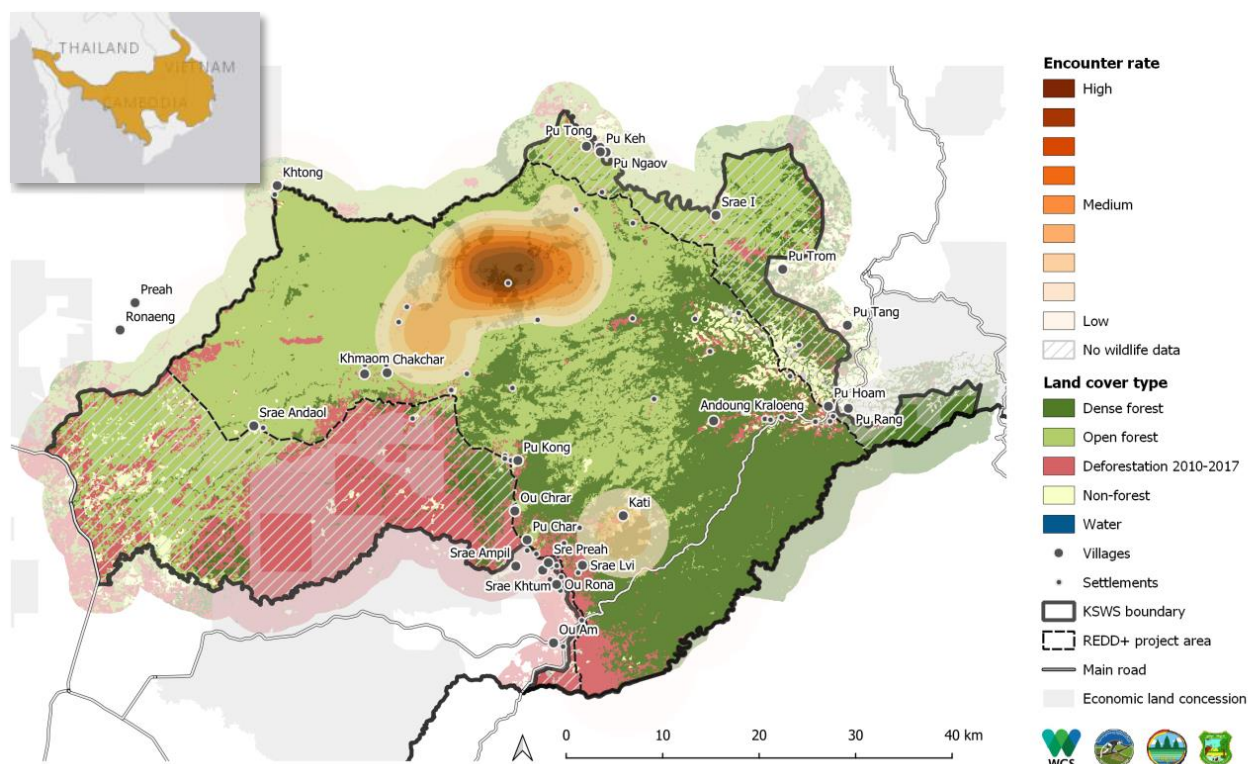

Figure 11. Distribution of long-tailed macaque in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of long-tailed macaques (IUCN 2020, version 2020-2).

PIG-TAILED MACAQUE

Khmer: ស្វាក្រោស
Bunong: Tourk Lut
Scientific: *Macaca leonina*

DESCRIPTION

Northern pig-tailed macaque have a short tail of less than 23 cm, distinguishing them from long-tailed and stump-tailed macaques. They live in large groups of between 15 and 40 individuals, and mostly eat fallen fruit and other food found on the forest floor, including seeds, young leaves, buds, shoots, fungus, and insects. In the wild, individuals live to approximately 26 years. As the groups move through the forest, they drop feces; in this way seeds from their diet of fruits, leafy trees, and vegetation are spread throughout the forest.

POPULATION

No global population estimate is available for this species, and no estimates are available for much of its range. Populations in China and India are less than 1700 and 1500 individuals respectively, with perhaps a larger population in Thailand.

The population in KSWS has been increasing since 2010, with a 2020 estimate of 1483 groups (95 % CI 1122–2088).
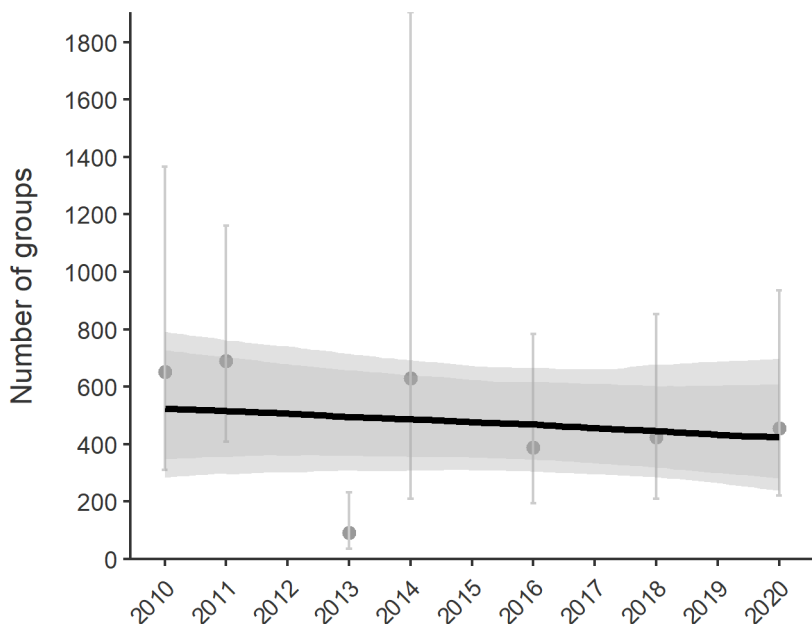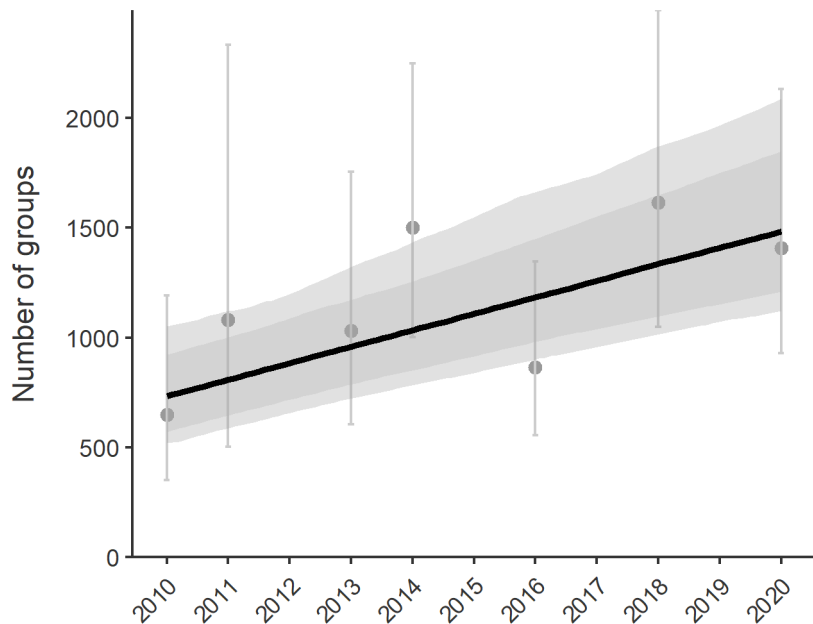

Figure 12. Group population estimates for northern pig-tailed macaque in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Table 9. Group population estimates of northern pig-tailed macaque in the KSWS core area between 2010 and 2020.

Year	Number of groups	95 % confidence intervals	
		Lower	*Upper*
2010	733	520	1052
2011	809	588	1120
2012	885	657	1199
2013	961	723	1325
2014	1037	786	1439
2015	1112	842	1555
2016	1181	897	1660
2017	1257	954	1741
2018	1335	1014	1870
2019	1408	1071	1966
2020	1483	1122	2088

DISTRIBUTION

Northern pig-tailed macaque are mostly found in Thailand and Cambodia, with smaller populations in Vietnam and patchy populations in Myanmar.

In KSWS, they are found across the protected area, mostly in evergreen and semi-evergreen forest.

1483 groups in KSWS

Decreasing population globally

Increasing population in KSWS

Vulnerable on IUCN Red List

Common under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

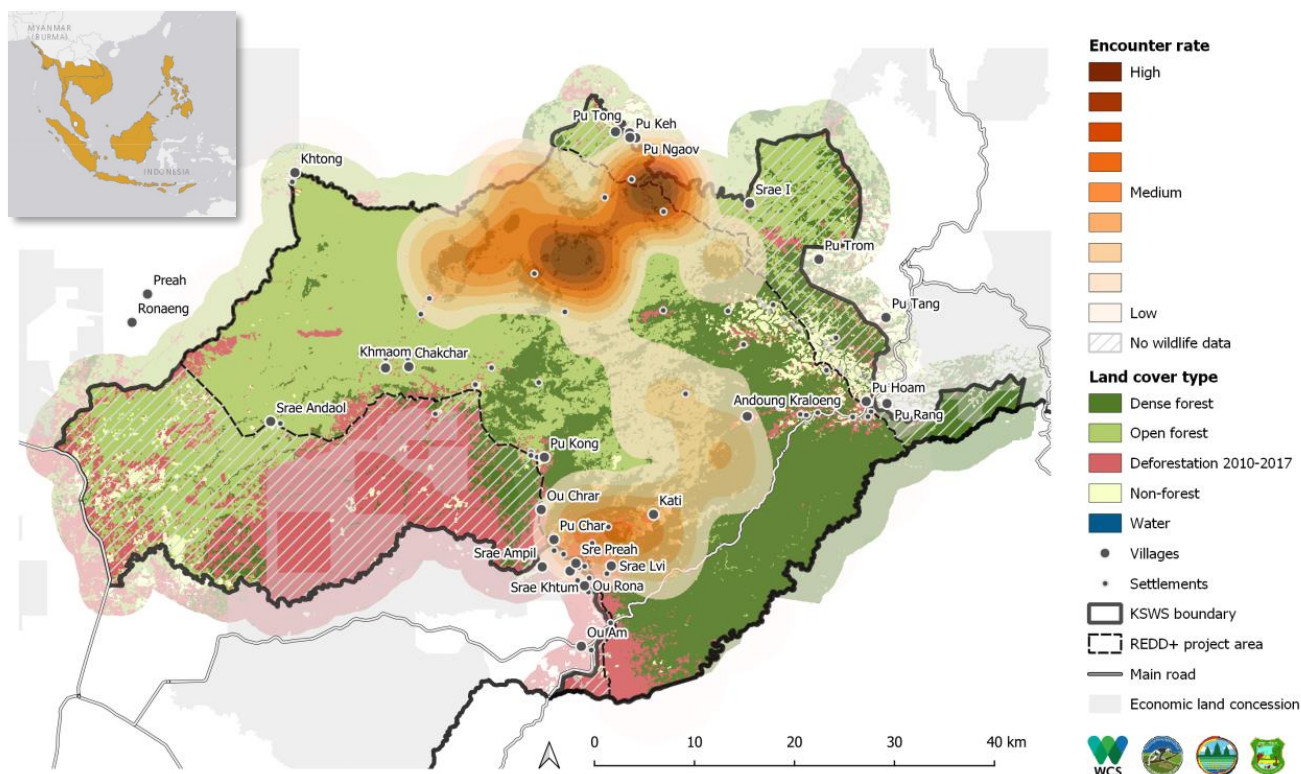Wide distribution globally

Wide distribution within KSWS

Figure 13. Distribution of northern pig-tailed macaque in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of northern pig-tailed macaque (IUCN 2020, version 2020-2).

STUMP-TAILED MACAQUE

Khmer: ស្វាអង្គត់
Bunong: Tourk His / Tourk Hars
Scientific: *Macaca arctoides*

DESCRIPTION

Stump-tailed macaque have a very short tail of between 3 and 7 cm. Adults have long brown hair, whilst babies are born white and darken as they age. Adults' faces are hairless with bright pink or red skin, sometimes darkening to black in old individuals. Males are larger than females. They mostly eat fruit, but also seeds, flowers, frogs, birds, bird eggs, and freshwater crabs, when available. They live in groups of up to 60 individuals, and spend most of their time on the ground, foraging for food in the mornings and evenings. Like other primate species, they play an important role in forests, spreading seeds as they travel. They prefer intact, undisturbed forest, which is increasingly rare in Cambodia.

POPULATION

No global population estimate is available, but it is thought that there has been a population reduction of over 30 % the past 36 years.

The population in KSWS has been significantly decreasing since 2010, with a 2020 estimate of 56 groups (95 % CI 0–138).

Figure 14. Group population estimates for stump-tailed macaque in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Table 10. Group population estimates of stump-tailed macaque in the KSWS core area between 2010 and 2020.

Year	Number of groups	95 % confidence intervals Lower	95 % confidence intervals Upper
2010	247	80	523
2011	230	76	481
2012	211	71	433
2013	192	66	380
2014	173	59	333
2015	154	53	296
2016	136	45	258
2017	116	34	220
2018	96	22	188
2019	76	6	162
2020	56	0	138

DISTRIBUTION

Stump-tailed macaque are found in Cambodia, southwestern China, northeastern India, Lao PDR, northwestern Peninsular Malaysia, northern Myanmar, Thailand, and Vietnam, and have been introduced to Hong Kong.

In KSWS, they are found in most areas, including along the main road, where they are sometimes fed by people in cars. The highest densities are found in the north of KSWS.

56 groups in KSWS

Decreasing population globally

Decreasing population in KSWS

Vulnerable on IUCN Red List

Rare under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

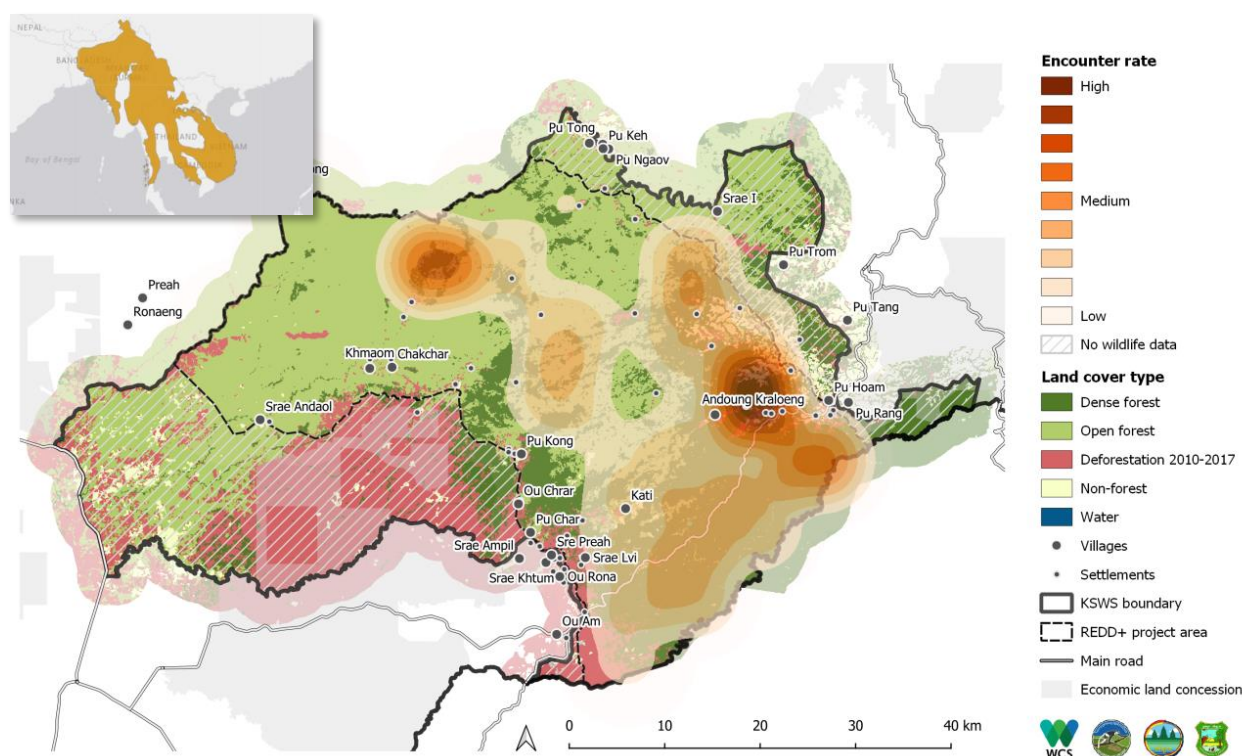**Wide** distribution globally

Restricted distribution within KSWS

Figure 15. Distribution of stump-tailed macaque in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of stump-tailed macaque. Orange shows current range, red shows areas in which this species is possibly extinct (IUCN 2020, version 2020-2).

Birds

GREEN PEAFOWL

Khmer: ក្ងោក
Bunong: Brak
Scientific: *Pavo muticus*

DESCRIPTION

Male and female green peafowl are similar in appearance, but males have longer tail covert feathers during the breeding season. Outside this season, males and females can be more difficult to tell apart. Females lay between three and six eggs. Peafowl spend most of their time on or near the ground. Families roost in trees at a height of approximately 10 m. They mostly eat fruits, flower petals, buds, leaves, berries, insects like ticks and termites, reptiles, frogs and rodents, and can even hunt venomous snakes.

POPULATION

The global population is thought to be 10 000–20 000 mature individuals, with a decreasing trend.

The population in KSWS has increased significantly since 2010, with a 2020 estimate of 966 individuals (95 % CI 495–1674).
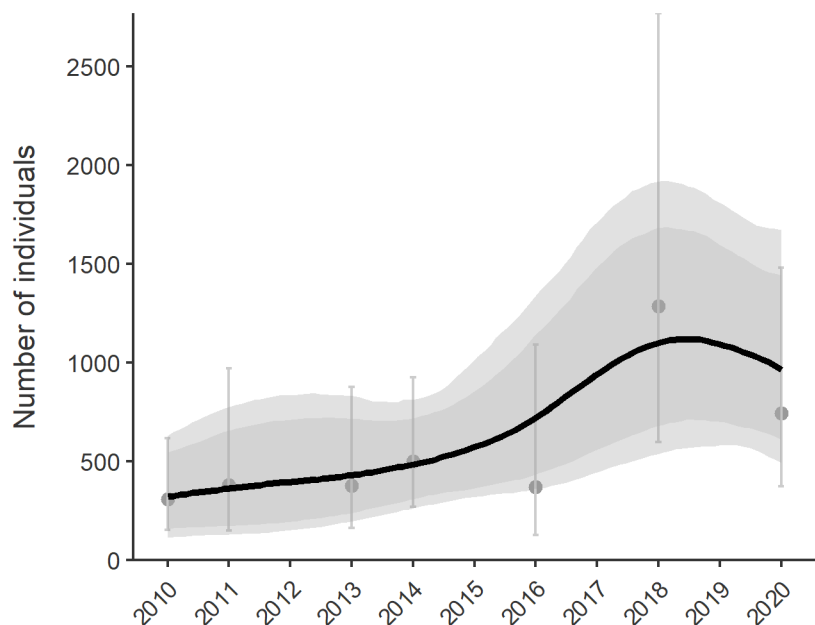
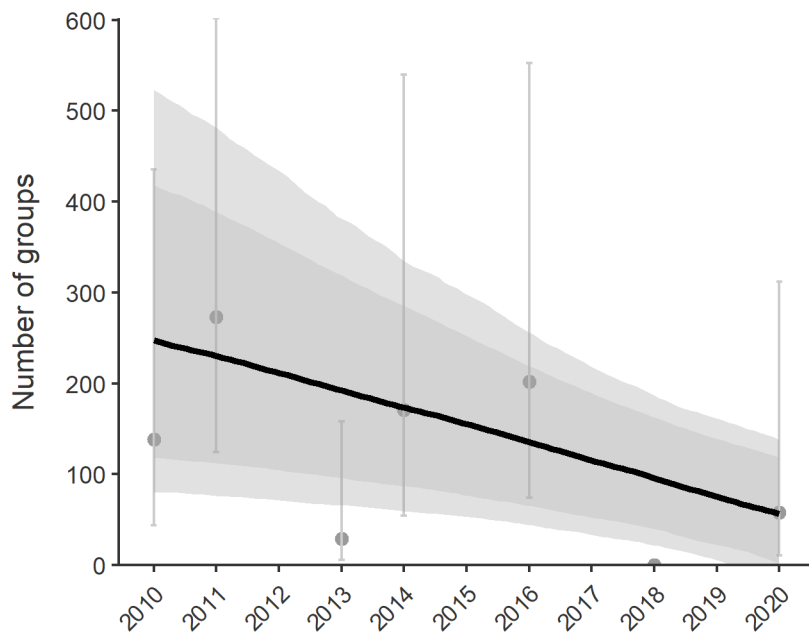*Figure 16. Individual population estimates for green peafowl in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.*

Table 11. Individual population estimates of green peafowl in the KSWS core area between 2010 and 2020.

Year	Number of individuals	95 % confidence intervals	
		Lower	*Upper*
2010	323	114	631
2011	363	130	776
2012	397	153	835
2013	432	199	831
2014	489	265	815
2015	579	322	1029
2016	712	359	1323
2017	936	441	1703
2018	1098	538	1917
2019	1095	580	1812
2020	966	495	1674

966 individuals in KSWS

Decreasing population globally

Increasing population in KSWS

Endangered on IUCN Red List

Rare under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Restricted distribution globally

Wide distribution within KSWS

DISTRIBUTION

In the past, green peafowl had a large range, across which it was once common and widespread. It is now extinct in large areas.

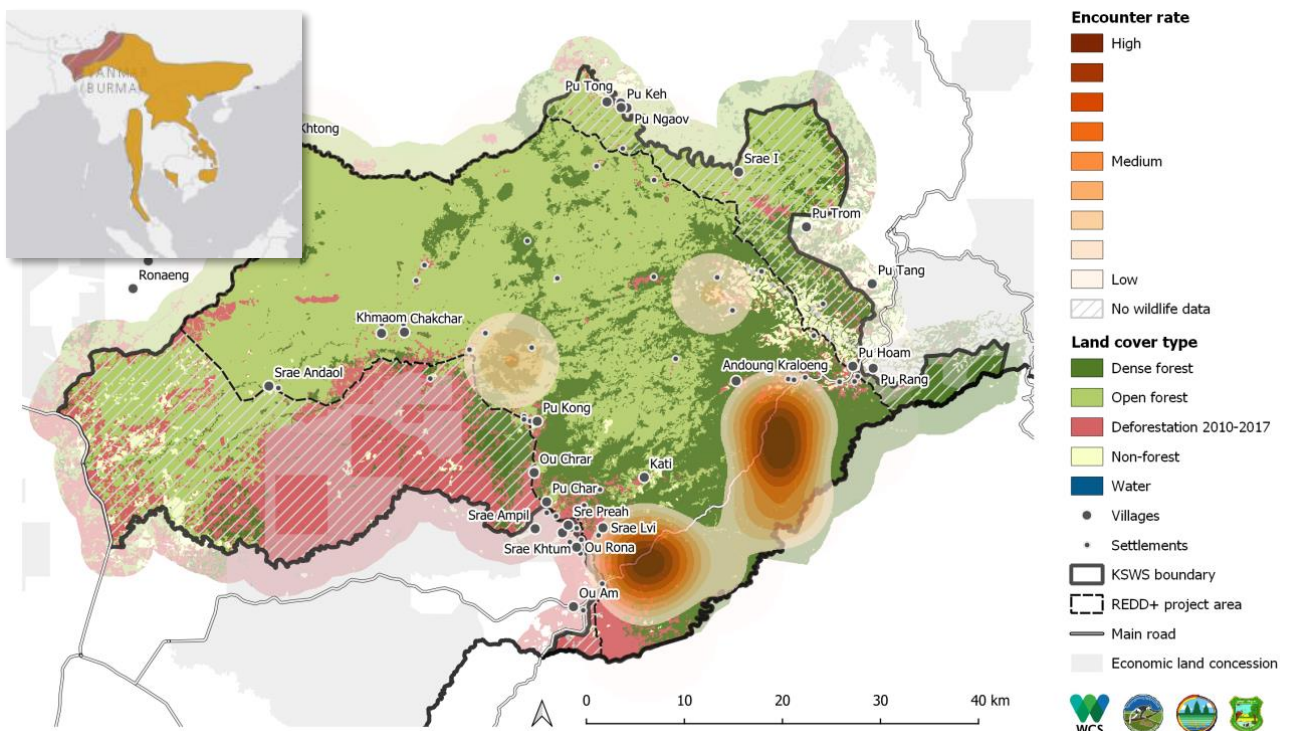In KSWS, they are found mostly in open dry deciduous forest in the west.
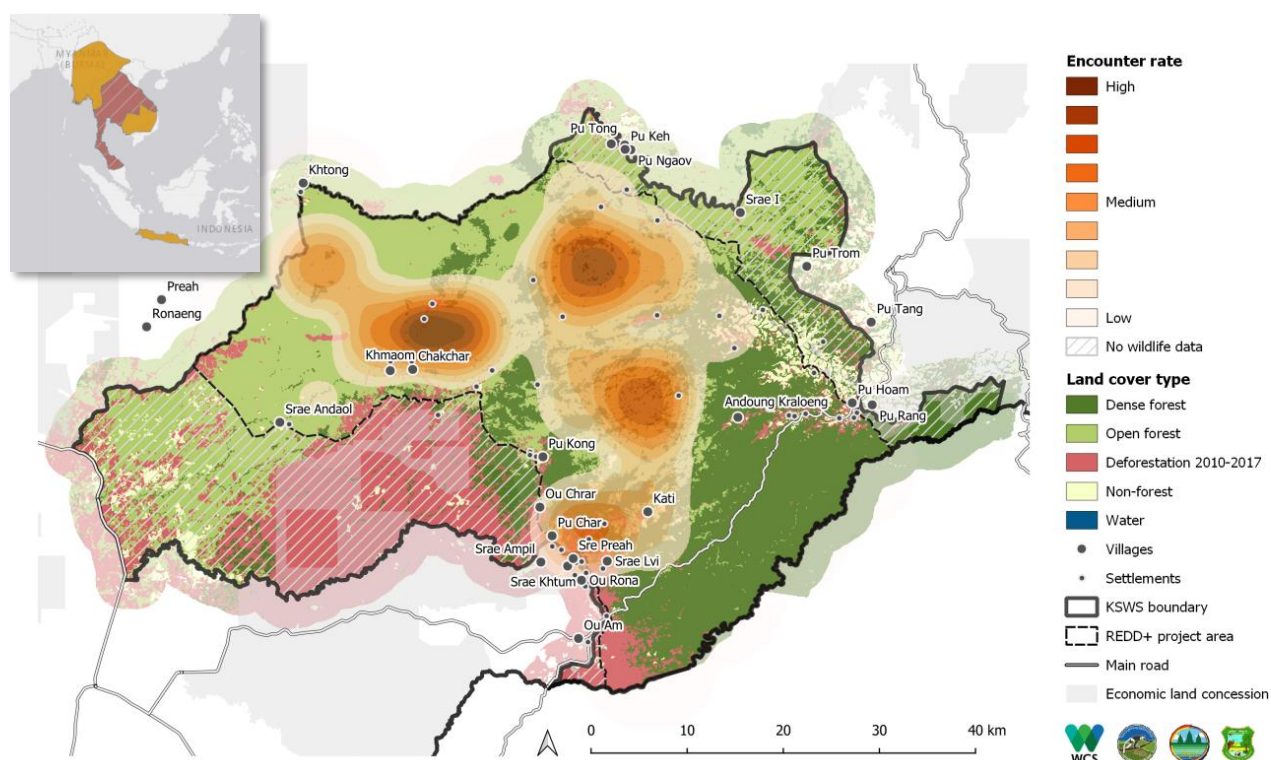
Figure 17. Distribution of green peafowl in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of green peafowl. Orange shows current range, red shows areas in which this species is possibly extinct (IUCN 2020, version 2020-2).

Clockwise from top left: wild pig (KSWS, WCS Cambodia), northern red muntjac (KSWS, WCS Cambodia), banteng (Preah Vihear, WCS Cambodia), sambar (KSWS, WCS Cambodia), Eld's deer (Cambodia, SVC), gaur (Preah Vihear, WCS Cambodia).

UNGULATES

KSWS is home to eight even-toed ungulates (Artiodactyla). Historically, it was likely also home to odd-toed ungulates, including the Javan rhino *Rhinoceros sondaicus*, although the last record of this species in Cambodia is from 1930, and the last known individual of this sub-species in the region was shot and killed in 2010 in Vietnam.

Six of the eight ungulates present are monitored during line transect surveys: wild pig (*Sus scrofa*), northern red muntjac (*Muntiacus vaginalis*), banteng (*Bos javanicus*), gaur (*Bos gaurus*), Eld's deer (*Rucervus eldii*), and sambar (*Rusa unicolor*).

However, sambar and Eld's deer occur at such low densities that it is not possible to produce population estimates, although spatial distribution can still be estimated. These populations are instead assessed by expert opinion.

Ungulates across KSWS and the Eastern Plains Landscape are in decline; even species typically considered robust to hunting such as northern red muntjac are now declining. Removal of the ecological role of these ungulates will gradually change aspects of habitat structure in KSWS; some ungulates, such as red muntjac, play an important seed dispersal role, while others have an important grassland-grazing role.

8 ungulate species in KSWS

63 % of these species are globally Threatened

6 ungulate species monitored during line transects

4 ungulate species with robust population estimates available

0 increasing populations

1 stable population

5 declining populations (including species using expert assessment)

*Table 12. Summary of key ungulate species in Keo Seima Wildlife Sanctuary. * denotes trends based on expert assessment of four species for which robust estimates are not available.*

Species	IUCN status	Cambodian law	KSWS trend	Importance of population
Wild pig / ជ្រូកព្រៃ *Sus scrofa*	Least Concern	Common	Stable	
Northern red muntjac / ឈ្លូស *Muntiacus vaginalis*	Least Concern	Common	Declining	
Banteng / ទន្សោង *Bos javanicus*	Endangered	Rare	Declining	Global
Gaur / ខ្ទីង *Bos gaurus*	Vulnerable	Rare	Declining	Regional
Eld's deer / រមាំង *Rucervus eldii*	Endangered	Endangered	Declining*	Regional
Sambar / ប្រើស *Rusa unicolor*	Vulnerable	Common	Declining*	Possibly regional

WILD PIG

Khmer: ជ្រូកព្រៃ
Bunong: Knach
Scientific: *Sus scrofa*

DESCRIPTION

Wild pigs normally live in groups of 6–20 individuals, but groups of up to 100 have been recorded. Fruits, seeds, roots, and tubers make up 90 % of their diet, and they have also been recorded consuming soil, earthworms, and, in mangrove areas, mollusks, crabs, and other arthropods. In rare cases, they eat small mammals such as baby deer.

Wild pigs are normally most active in the early morning and late afternoon, though they become nocturnal in disturbed areas.

POPULATION

The global population is large but unknown, and is likely to be stable. The population in KSWS has remained stable since 2010, with a 2020 estimate of 1162 individuals (95 % CI 619–1870). Wild pig populations often fluctuate in response to food availability, particularly from mast years, where trees produce a huge crop of nuts and seeds. As such, assessments of stability are difficult. It is possible that there has been a small, slow decline in the average population that is beyond our ability to detect.

Figure 18. Individual population estimates for wild pig in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

A young wild pig / ជ្រូកព្រៃ
Sus scrofa
KSWS, WCS Cambodia

Table 13. Individual population estimates of wild pig in the KSWS core area between 2010 and 2020.

Year	Number of individuals	95 % confidence intervals	
		Lower	*Upper*
2010	2228	1169	3554
2011	1575	1042	2249
2012	1296	945	1708
2013	1338	945	1837
2014	1540	1040	2140
2015	1660	1073	2474
2016	1664	1014	2669
2017	1588	943	2485
2018	1449	868	2187
2019	1303	788	1985
2020	1162	619	1870

DISTRIBUTION

This species has one of the widest geographic distributions of all terrestrial mammals and is found from Europe to eastern China. However, multiple subspecies are found within this range.

In KSWS, they are found mostly in open dry deciduous forest in the west.

1162 individuals in KSWS

Stable population globally

Stable population in KSWS

Least Concern on IUCN Red List

Common under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Very wide distribution globally

Wide distribution within KSWS

Figure 19. Distribution of wild pig in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of wild pig. Orange shows current range, green shows areas in which this species has been reintroduced (IUCN 2020, version 2020-2).

NORTHERN RED MUNTJAC

Khmer: ឈ្លូស
Bunong: Youl
Scientific: *Muntiacus vaginalis*

DESCRIPTION

Red muntjac are small and brown, with a darker face, and males have short antlers. They eat grass, fruit, shoots, seeds, bird eggs, and small animals, and occasionally scavenge on animal carcasses. When startled, they make a sound like a dog barking.

Red muntjac breed with multiple partners. A gestation of between six and seven months typically produces a single calf but occasionally twins. Females give birth in dense undergrowth to avoid predators. After six months, the offspring will leave the mother to establish its own territory. Muntjac can breed all year round, with no specific breeding season.

POPULATION

The global population is large but unknown, and is likely to be declining across its range. The muntjac population in KSWS has dramatically and significantly decreased since 2014, with a 2020 estimate of 732 individuals (95 % CI 450–1052).
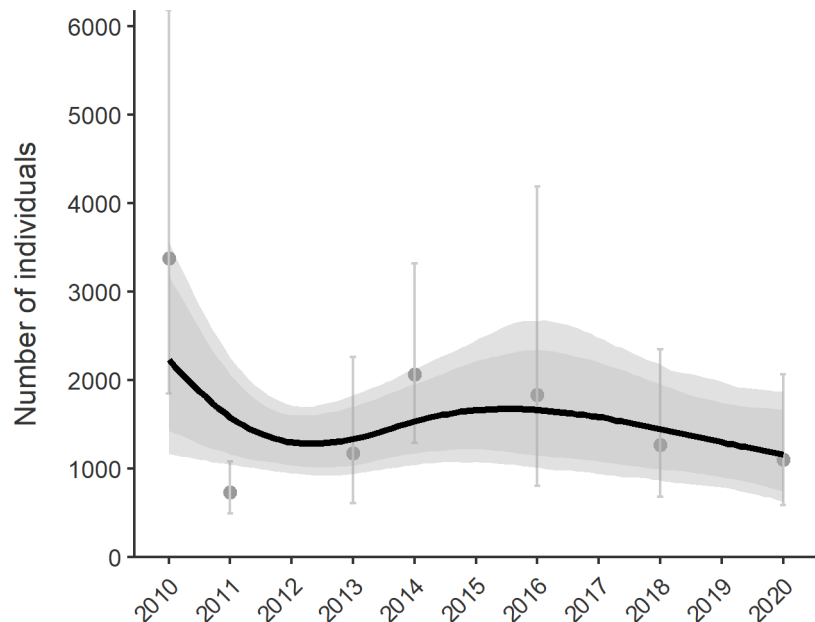

Figure 20. Individual population estimates for northern red muntjac in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Table 14. Individual population estimates of northern red muntjac in the KSWS core area between 2010 and 2020.

Year	Number of individuals	95 % confidence intervals	
		Lower	*Upper*
2010	3421	2710	4281
2011	3766	3117	4518
2012	3992	3291	4704
2013	4007	3297	4719
2014	3713	3000	4482
2015	3118	2456	3860
2016	2516	1938	3198
2017	1945	1469	2524
2018	1489	1119	1966
2019	1097	804	1449
2020	732	450	1052

DISTRIBUTION

Red muntjac are widely distributed. The taxonomy of red muntjac across its range is unclear, although populations within Indochina are thought to be of a single species.

In KSWS, they are found mostly in open dry deciduous forest in the west.

732 individuals in KSWS

Decreasing population globally

Decreasing population in KSWS

Threatened in KSWS by **illegal hunting** (snares, gun hunting, hunting with dogs)

Least Concern on IUCN Red List

Common under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Wide distribution globally

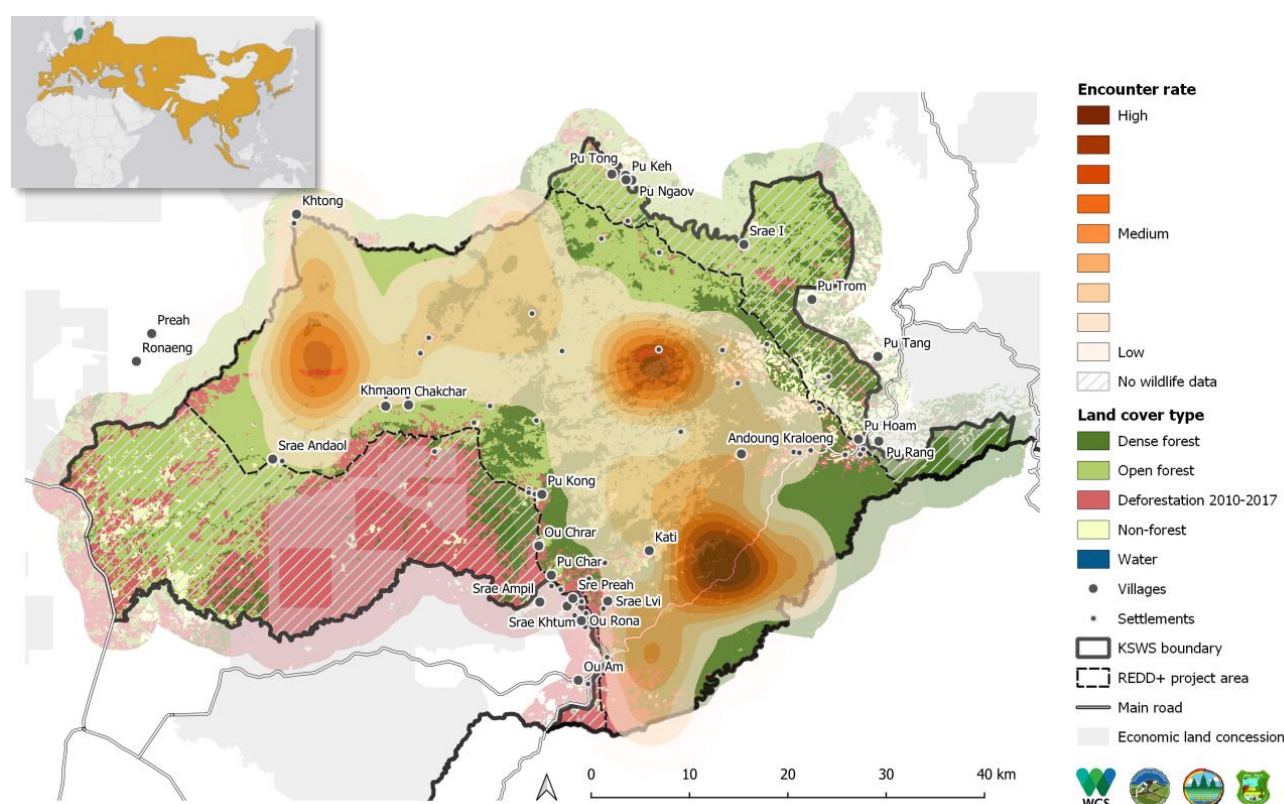**Wide** distribution within KSWS
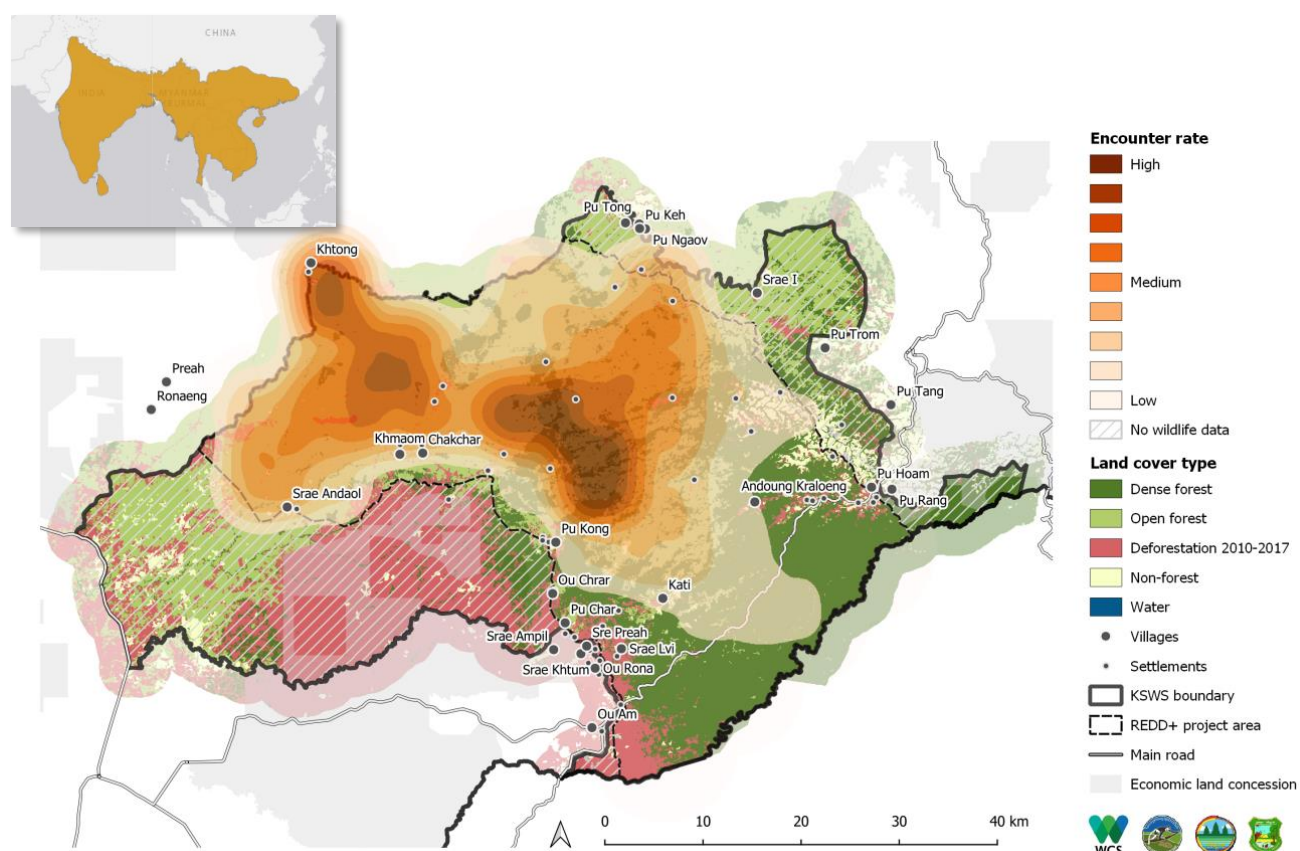
Figure 21. Distribution of northern red muntjac in Keo Seima Wildlife Sanctuary. Data from 2010–2020 line transect surveys conducted by WCS Cambodia, Forestry Administration, and Ministry of Environment.
Inset map top left: global distribution of northern red muntjac (IUCN 2020, version 2020-2).

BANTENG

Khmer: ទន្សោង
Bunong: Karup
Scientific: *Bos javanicus*

DESCRIPTION

Smaller than gaur, banteng are brown with white legs. They are social animals, and live in herds, normally led by an older female, that typically include one mature male. Males are darker in color than females. They feed on grasses, bamboo, fruit, leaves, and young branches. They are active during both day and night, but in places where they are hunted tend to be more active at night.

POPULATION

In 2016, the global population of mature individuals was estimated at between 4000 and 8000, but is likely to have significantly decreased since then. Cambodia is home to the largest native population, which is also declining. Outside eastern Cambodia, fewer than eight sub-populations of more than 50 animals are known.

The population in KSWS is declining. A few individuals remain and have recently been caught on camera trap, but the population is now so small that line transect surveys failed to detect any, despite teams walking 1260 km, giving an encounter rate of less than 0.0008 individuals per km.

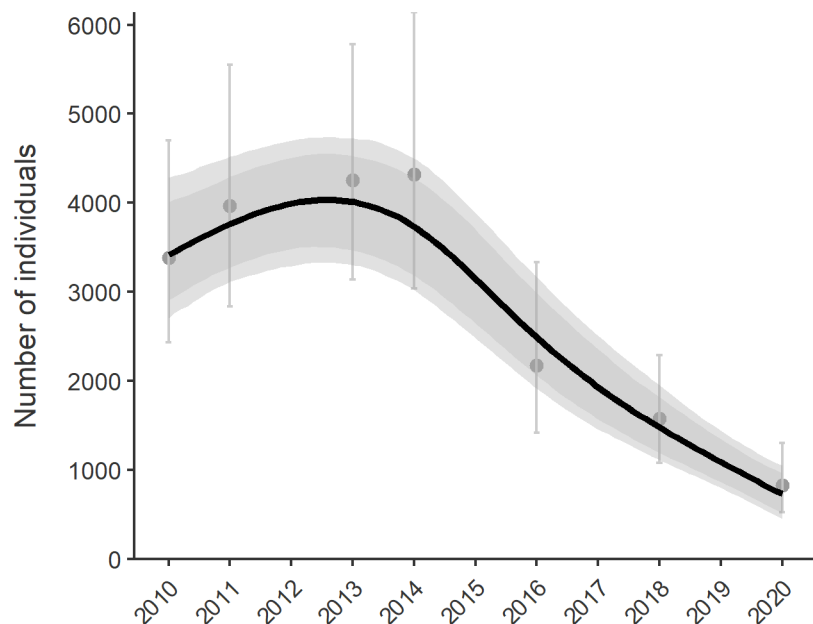*Figure 22. Individual population estimates for banteng in the core area of KSWS in 2010–2020. Black line shows population trend. Trend confidence intervals for banteng are not available, due to low sample size. Gray dots show annual estimates, and vertical gray lines show confidence intervals of annual estimates. The 2010 upper confidence was 1956, truncated here to improve plot readability.*

Table 15. Individual population estimates of banteng in the KSWS core area between 2010 and 2020. Confidence intervals are not available due to low sample size. No banteng were observed during the 2020 survey.

Year	Number of individuals
2010	310
2011	193
2012	115
2013	84
2014	90
2015	95
2016	86
2017	63
2018	36
2019	15
2020	-

DISTRIBUTION

This species has a fragmented distribution across Southeast Asia, with no connectivity between populations. In Cambodia, they are mostly found in the Eastern Plains Landscape.

In KSWS, they are only found in one or two locations in open forest at very low densities. A distribution map for this species in KSWS is not given in this report due to their restricted distribution and the threat they face from poaching, but is available on request.

Figure 23. Global banteng distribution (IUCN 2020, version 2020-2). A distribution map for this species in KSWS is available on request.

Very small number of individuals in KSWS

Decreasing population globally

Decreasing population in KSWS

Threatened in KSWS by illegal hunting (snares, gun hunting)

Endangered on IUCN Red List

Rare under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Restricted distribution globally

Restricted distribution within KSWS

GAUR

Khmer: ខ្ទីង
Bunong: Bai
Scientific: *Bos gaurus*

DESCRIPTION

Gaur are the largest cattle species in the world and one of the largest living land mammals: only elephants, hippopotamus, and giraffes are consistently heavier. Large male gaur can weigh up to 100 kg and reach up to 2.2 m at the shoulder. Due to their large size, gaur have few natural predators aside from humans; only tigers have been known to kill healthy adult animals. Gaur live in herds led by an older female, and eat grasses, bamboo, shrubs, and tree leaves. In areas where they are not hunted, they are active in the daytime, but in areas where they are hunted, they become largely nocturnal.

POPULATION

The global population is between 6000 and 21 000 mature individuals and is declining, with less than 10 of the fragmented populations estimated to have more than 1000 individuals each.

The population in KSWS is rapidly declining. Less than 102 individuals are estimated to be present in 2020, with an encounter rate of 0.0008 individuals per kilometer.
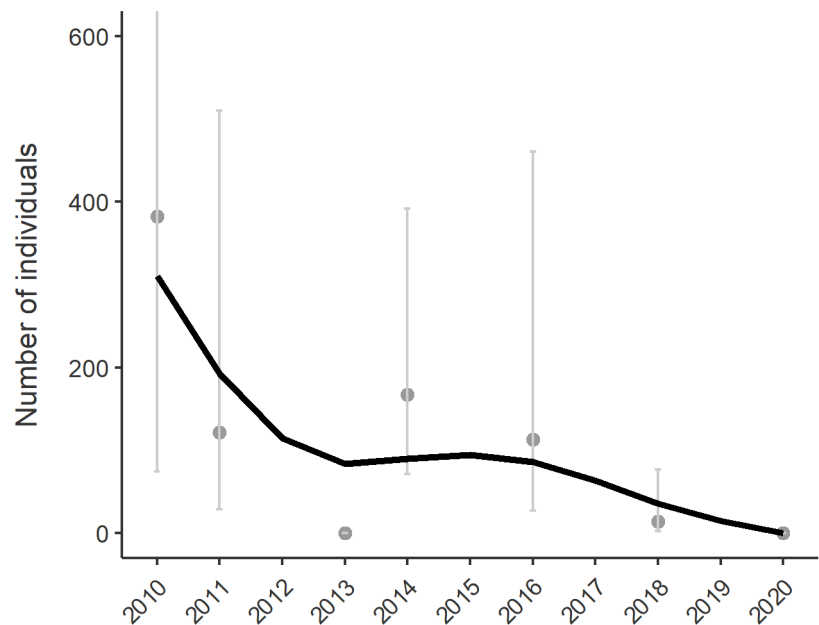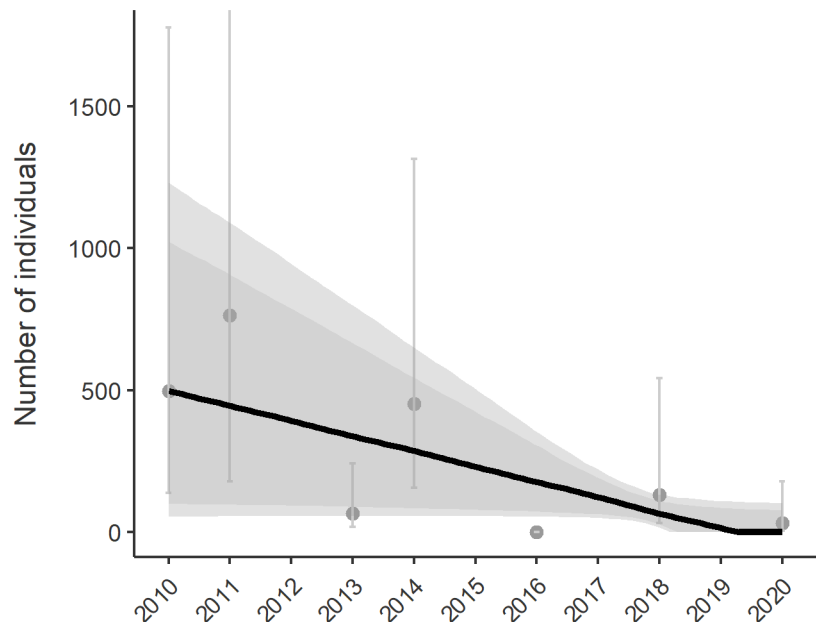

Figure 24. Individual population estimates for gaur in the core area of KSWS in 2010–2020. Black line shows population trend, gray fill shows 95 % (light gray) and 85 % (dark gray) confidence interval of trends. Gray dots show conventional distance sampling annual estimates, and vertical gray lines show confidence intervals of annual estimates.

Year	Number of individuals	95 % confidence intervals	
		Lower	*Upper*
2010	498	54	1231
2011	445	56	1089
2012	391	57	942
2013	336	57	795
2014	285	56	644
2015	228	57	496
2016	179	55	359
2017	125	50	225
2018	66	18	135
2019	16	0	110
2020	-	0	102

DISTRIBUTION

This species is widely distributed across Southeast Asia, but in fragmented populations.

In KSWS, they are found in a limited number of areas, mostly within evergreen and semi-evergreen forest. A distribution map for this species in KSWS is not given in this report due to their restricted distribution and the threat they face from poaching, but is available on request.

Figure 25. Global distribution of gaur (IUCN 2020, version 2020-2). A distribution map for this species in KSWS is available on request.

Fewer than 102 individuals in KSWS

Decreasing population globally

Decreasing population in KSWS

Threatened in KSWS by **illegal hunting** (snares, gun hunting)

Vulnerable on IUCN Red List

Rare under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Restricted distribution globally

Restricted distribution within KSWS

ELD'S DEER

Khmer: រមាំង
Bunong: Yerng
Scientific: *Rucervus eldii*

DESCRIPTION

Male Eld's deer are known for their impressive antlers, which they shed and regrow each year. They eat grasses, fruits, and plants, and typically graze new grass shoots after grassland has burnt. Females normally live alone or in pairs with their young, forming larger groups of up to 50 individuals during the breeding season.

POPULATION

The global population is unknown, and is likely to be declining.

The population in KSWS is too small to estimate using line transect distance sampling. During the 2020 survey, no Eld's deer were observed, giving an encounter rate of less than 0.0008 individuals per kilometer.

DISTRIBUTION

Most Eld's deer are found in Myanmar and Cambodia. In Cambodia, there are sub-populations found across the Northern and Eastern Plains Landscapes.

In KSWS, they are only found in one area of the open dry deciduous forest.

Very small number of individuals in KSWS

Decreasing population globally

Decreasing population in KSWS

Threatened in KSWS by illegal hunting (snares, gun hunting)

Endangered on IUCN Red List

Endangered under Preah Reach Kram No. S/RKM/0802/016 and Prakas No. 020 PR.MAFF

Restricted distribution globally

Restricted distribution within KSWS

Figure 26. Global distribution of Eld's deer. Orange shows current range (IUCN 2020, version 2020-2).

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Eld's deer / រមាំង
Rucervus eldii
Cambodia, SVC

SAMBAR

Khmer: ប្រើស
Bunong: Joun
Scientific: *Rusa unicolor*

DESCRIPTION

Sambar are mostly active at night, and are usually solitary. During the mating season, females can be found in small groups, and males will defend an area by scent marking and exhibiting aggression towards other males. Sambar normally breed once per year, giving birth to a single offspring. The young will stay with the mother for one to two years. Sambar eat leaves, berries, grasses, bark from young trees, fallen fruit, herbs, and buds. They browse mainly in clearings and at forest edges.

POPULATION

The global population is unknown, and is declining everywhere except for Taiwan and in well-managed Indian protected areas.

The population in KSWS is too small to estimate using line transect distance sampling. During the 2020 survey, no sambar were observed, giving an encounter rate of less than 0.0008 individuals per kilometer.

DISTRIBUTION

The natural range of this species is across Southeast Asia. In KSWS, they are found in only a few areas in evergreen and semi-evergreen forest close to National Route 76.

Very small number of individuals in KSWS

Decreasing population globally

Decreasing population in KSWS

Threatened in KSWS by **illegal hunting** (snares, gun hunting), and **vehicle collisions** along National Route 76

Vulnerable on IUCN Red List

Common under Preah Reach Kram No. NS/RKM/0802/016 and Prakas No. 020 PR.MAFF

Wide distribution globally

Restricted distribution within KSWS

Figure 27. Global distribution of sambar. Orange shows current natural range (IUCN 2020, version 2020-2).

Sambar / ប្រើស
Rusa unicolor
KSWS, WCS Cambodia

ANTICIPATED AND ACTUAL WITH-PROJECT TRENDS

Comparison of anticipated *with*-project population trends with those estimated using robust monitoring shows 10 of 13 species either matched or improved upon their anticipated trend. Two species, stump-tailed macaque and Germain's silver langur, were anticipated to remain stable but have declined. For the three key species for which no anticipated trend was given in the project document, populations are stable (long-tailed macaque, wild pig) or decreasing (northern red muntjac).

For species anticipated to decline, no robust monitoring data is available for habitat outside protected areas. However, given extensive and rapid deforestation and habitat loss across Cambodia, especially between 2010 and 2014, along with low levels of wildlife law enforcement, it is reasonable to assume a rapid decline in populations of these species.

Anticipated trends were not reported for three species (long-tailed macaque, red muntjac, and wild pig). As typically robust and common species, it is reasonable to assume anticipated trends of stability for the sake of this assessment.

8 species matching anticipated trend

2 species improving upon anticipated trend

3 species performing worse than anticipated

*Table 17. Anticipated with-project and measured with-project population trends for key species. Adapted from Table 7.1.1 of the KSWS REDD+ Project Document. Green shows improvement between anticipated and actual trends; blue shows matched anticipated and actual trends; and red shows a decrease against anticipated trends. * denotes species for which an anticipated trend is not reported in the KSWS REDD+ Project Document.*

English name	Khmer name	Scientific Name	Anticipated *with*-project population trend (2010)	Actual *with*-project population trend (2020)
Black-shanked douc langur	ស្វាកន្ទុយស	*Pygathrix nigripes*	Stable	Stable
Yellow-cheeked gibbon	ទោចថ្កាល់លៀង	*Nomascus gabriellae*	Stable	Stable
Germain's silver langur	ស្វាព្រាម	*Trachypithecus germaini*	Stable	Declining
Long-tailed macaque	ស្វាក្ដាម	*Macaca fascicularis*	Stable*	Stable
Pig-tailed macaque	ស្វាត្រោស	*Macaca leonina*	Stable	Increasing
Stump-tailed macaque	ស្វាអង្គត់	*Macaca arctoides*	Stable	Declining
Green peafowl	ក្ងោក	*Pavo muticus*	Stable	Increasing
Wild pig	ជ្រូកព្រៃ	*Sus scrofa*	Stable*	Stable
Northern red muntjac	ឈ្លូស	*Muntiacus vaginalis*	Stable*	Declining
Banteng	ទន្សោង	*Bos javanicus*	Decline slowed	Decline slowed
Gaur	ខ្ទីង	*Bos gaurus*	Decline slowed	Decline slowed
Eld's deer	រមាំង	*Rucervus eldii*	Decline slowed	Decline slowed
Sambar	ប្រើស	*Rusa unicolor*	Decline slowed	Decline slowed

DISCUSSION

Contrasting actual and anticipated trends, ten of thirteen species either match or improve upon their anticipated trend, and three species show an unanticipated negative trend: stump-tailed macaque, Germain's silver langur, and northern red muntjac.

Broadly, arboreal species (species that spend most of their time in trees) have stable or growing populations, whilst terrestrial species (species that spend more time on the ground) have declining populations. This suggests a shared threat in some cases, likely to be poaching, particularly hunting with snares and dogs.

Stump-tailed macaque spend considerable time on the ground, and are thus exposed to similar threats as deer and cattle species. Germain's silver langur have a very restricted range within KSWS, and may be exposed to local threats. The remaining primate species show stable or increasing populations. Compared with global trends, this is a significant conservation success. KSWS is home to the vast majority of the global population of the Critically Endangered black-shanked douc langur, and well as the largest known population of the Endangered yellow-cheeked crested gibbon. Globally, these species are in severe decline, thus the large stable populations in KSWS are cause for celebration.

The endangered green peafowl has been extirpated from much of its original range, and globally its population is in decline. Appearing stable from 2010 to 2016, the population is now increasing, which is another significant conservation success.

The declines in muntjac, banteng, gaur, Eld's deer, and sambar, although anticipated for the large ungulates, are serious and alarming. Banteng, gaur, Eld's deer, and sambar are thought to be in severe decline across Cambodia, including within many protected areas. Red muntjac are normally considered robust to hunting, therefore their significant and rapid decline from 2014 to 2020 is of serious concern. Rates of decline within KSWS are likely to be slower than those outside of protected areas. Nevertheless, this slowed rate of loss will not be sufficient to retain healthy populations of these species. Similar declines are seen in other protected areas in the same landscape, and across Cambodia.

Without substantial improvements in management, it is likely that the four large species (banteng, gaur, Eld's deer, and sambar) will disappear from the protected area entirely within a few years, eventually following the path of the kouprey, tiger, and wild water buffalo in Cambodia. The smaller, more robust, and quicker breeding muntjac is likely to remain for longer, with a small population. Loss of these species and the ecological role they play will greatly impact the structure and health of the forest, in turn impacting local indigenous communities who depend on the forest and its resources for survival.

MANAGEMENT RECOMMENDATIONS

The broad strategy outlined in the KSWS REDD+ Project Document and the KSWS annual strategy and work plans are designed to meet the project goal of:

- A well-managed forest landscape that supports increasing wildlife populations and improving livelihoods for the people who currently live there

… as well as the project targets to:

1. Maintain the variety, integrity, and extent of all forest types
2. Increase populations of wildlife of conservation concern
3. Increase security and productivity of natural resources to support local livelihoods
4. Sufficient farmland to support the livelihoods of current residents.

Here, we highlight key areas to address in order to better meet Target 2, above. Some of these are addressed within the current project strategy, although some will require development in response to the new information relating to the near-complete collapse of ungulate populations presented here.

Law enforcement

- **Increasing the number of wildlife rangers** in KSWS is required to manage the site effectively. Current ranger densities in KSWS (1.9 rangers/100 km^2) are lower than optimal ranger densities proposed by Henson, Malpas, & D'Udine (2016; 2–10 rangers/100 km^2), and lower than those in effectively managed protected areas at other sites that support ungulate populations (Nepal: 12.5–107.3 rangers/100 km^2; India 12.5–127 rangers/100 km^2) (Walston et al., 2010; Harihar et al., 2018). This will require additional financial and operational resources.
- **Improving law enforcement strategy** and implementation is required to improve effectiveness. Simple patrol-based law enforcement alone is ineffective in preventing illegal activity within protected areas. Improving the targeting of patrols using data can increase patrol efficiency without requiring additional resources (Critchlow et al., 2017). Effective patrols can both detect and deter more illegal activity (Milner-Gulland & Leader-Williams, 1992). This is being addressed through the current testing and rollout of SMART Connect which utilizes cloud-based data management to streamline the data flow from patrol teams to analysts and managers.
- **Integrating modern crime science approaches** into tackling wildlife and conservation crime will be key to improving current practices (Moreto, 2015), which are often based on ad-hoc, well-intentioned practices, reinvented site by site by non-expert

practitioners with limited policing background (Kurland, Pires, McFann, & Moreto, 2017).

- **Commercial trade must be addressed** nationally and internationally. Wildlife trade networks (including those outside protected areas and crossing national boundaries) must be targeted and national demand reduced.

Direct management

Given the near-total collapse of large ungulate populations, both in KSWS and nationally, drastic direct management interventions may be needed.

- **Captive breeding programs** may be required for some species to recover. Populations of Eld's deer are so small across Cambodia that their natural recovery, even with effective law enforcement, is very unlikely. The remaining population should be captured for a well-managed breeding program to preserve remaining genetic diversity. As law enforcement and protected area management improves, captive-bred individuals can be released to repopulate suitable areas.
- **Fenced areas** that are well maintained, protected, and patrolled may be necessary to exclude poachers and protect remaining source populations of large ungulates.

Threat reduction

- **Proposed mining exploration** within KSWS in the Preak Khlung and O Khtong concessions will negatively affect populations of key species. The most severe impact will be on the Endangered Germain's silver langur, the majority of whose population in KSWS is within the boundaries of these mining concessions. **Impact mitigation is essential where biodiversity will be negatively impacted by mining** exploration, operations, or associated development. Biodiversity offsets should be used when impacts cannot be fully mitigated.
- **Tourism concessions** have been granted within KSWS. An open and transparent environmental impact assessment should be made, with **impact mitigation** introduced where biodiversity will be negatively impacted by tourism or associated development. Biodiversity offsets should be used when impacts cannot be fully mitigated.
- **Illegal forest clearance**, although not a direct threat to key species populations, will begin to have a negative impact as the total area of habitat shrinks. Representing a significant threat to the REDD+ project goal and to forest protection, this significant threat must be addressed to ensure long-term viability of the project.
- **Reducing the use of snares, home-made and conventional guns** will play a role in reducing poaching. Anti-snare teams should target areas of high biodiversity, as snare detection and removal efficacy is low. Snares and guns are likely major drivers in ungulate loss.
- **Reducing the threat to wildlife from dogs** should be a focus of future work; despite the ban on dogs for hunting purposes in protected areas under the 2008 Protected Area law, this is rarely enforced. Most dogs in and around KSWS are free-roaming, and have significant impact of wildlife both from hunting and from disease transfer.

CONCLUSION

Keo Seima Wildlife Sanctuary remains a site of very high biodiversity value. It holds the highest recorded number of species of any protected area in Cambodia, and is home to globally significant populations of several species, including the world's largest known populations of some Endangered and Critically Endangered primate species.

Habitat remains broadly intact, including some that is unique within Cambodia, such as the southern end of the Annamite Mountain range. A significant number of species found in KSWS are found nowhere else in Cambodia, including orange-necked partidge, and more than 20 species new to science have been discovered and described from the site.

Population trends of all species monitored perform better than would be expected if there was no project (*without*-project scenario), and more than three quarters of species trends are equal to or better than anticipated *with*-project scenarios. These facts demonstrate the positive impact of the project on the rich wildlife and broader ecosystem of the landscape.

The scale of threats to Cambodia's natural resources and biodiversity is very high, and despite signficant protection efforts these threats continue to cause biodiversity and forest loss.

Significant actions must be taken both nationally and in KSWS to stop further decline of species showing negative trends, and new measures must be adopted to support the recovery of large ungulates, without which ecosystems will degrade, in turn degrading the natural resources on which many Cambodians rely on for their livelihood, recreation, culture, and religion.

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Table 18. Distance sampling model summaries, used for annual estimates and for bootstrapping.

Species	Year	Key	Adjustment	Covariates	Level
	2010	Hn			Group
	2011	Hn			Group
	2013	Hn			Group
	2014	Hn		Observer + habitat	Group
	2016	Hr		AM/PM	Group
	2018	Hn		Observer + habitat	Group
	2020	Hr		Observer	Group
Black-shanked douc langur	2010	Hn			Individual
	2011	Hn			Individual
	2013	Hn			Individual
	2014	Hn		Observer + habitat	Individual
	2016	Hr		AM/PM	Individual
	2018	Hn		Observer + habitat	Individual
	2020	Hr		Observer	Individual
	2010	Hn		Year	Group
	2011	Hn		Cluster size	Group
	2013	Hn		Year	Group
	2014	Hn		Cluster size	Group
	2016	Hn		Cluster size	Group
	2018	Hn		Year	Group
	2020	Hn		Year	Group
Yellow-cheeked crested gibbon	2010	Hn		Year	Individual
	2011	Hn		Cluster size	Individual
	2013	Hn		Year	Individual
	2014	Hn		Cluster size	Individual
	2016	Hn		Cluster size	Individual
	2018	Hn		Year	Individual
	2020	Hn		Year	Individual
	2010	Hn		Size + year	Group
	2011	Hn		Size + year	Group
	2013	Hn		Size + year	Group
	2014	Hn		Size + year	Group
	2016	Hn		Size + year	Group
	2018	Hn		Size + year	Group
	2020	Hn		Size + year	Group
Germain's silver langur	2010	Hn		Size + year	Individual
	2011	Hn		Size + year	Individual
	2013	Hn		Size + year	Individual
	2014	Hn		Size + year	Individual
	2016	Hn		Size + year	Individual
	2018	Hn		Size + year	Individual
	2020	Hn		Size + year	Individual
	2010	Hn		Size + year	Group
	2011	Hn		Size + year	Group
	2013	Hn		Size + year	Group
	2014	Hn		Size + year	Group
Long-tailed macaque	2016	Hn		Size + year	Group
	2018	Hn		Size + year	Group
	2020	Hn		Size + year	Group
	2010	Hn		Size + year	Individual
	2011	Hn		Size + year	Individual

	2013	Hn	Size + year	Individual
	2014	Hn	Size + year	Individual
	2016	Hn	Size + year	Individual
	2018	Hn	Size + year	Individual
	2020	Hn	Size + year	Individual
Pig-tailed macaque	2010	Hn	Cluster size + year	Group
	2011	Hr	Cluster size	Group
	2013	Hn	Cluster size + year	Group
	2014	Hr	Cluster size	Group
	2016	Hr	Cluster size	Group
	2018	Hn	Cluster size + year	Group
	2020	Hn	Cluster size + year	Group
	2010	Hn	Cluster size + year	Individual
	2011	Hr	Cluster size	Individual
	2013	Hn	Cluster size + year	Individual
	2014	Hr	Cluster size	Individual
	2016	Hr	Cluster size	Individual
	2018	Hn	Cluster size + year	Individual
	2020	Hn	Cluster size + year	Individual
Stump-tailed macaque	2010	Hr		Group
	2011	Hr		Group
	2013	Hr		Group
	2014	Hr		Group
	2016	Hr		Group
	2018	Hr		Group
	2020	Hr		Group
	2010	Hr		Individual
	2011	Hr		Individual
	2013	Hr		Individual
	2014	Hr		Individual
	2016	Hr		Individual
	2018	Hr		Individual
	2020	Hr		Individual
Banteng	2010	Uni	SimPoly	Group
	2011	Uni	SimPoly	Group
	2013	Uni	SimPoly	Group
	2014	Uni	SimPoly	Group
	2016	Uni	SimPoly	Group
	2018	Uni	SimPoly	Group
	2020	Uni	SimPoly	Group
	2010	Uni	SimPoly	Individual
	2011	Uni	SimPoly	Individual
	2013	Uni	SimPoly	Individual
	2014	Uni	SimPoly	Individual
	2016	Uni	SimPoly	Individual
	2018	Uni	SimPoly	Individual
	2020	Uni	SimPoly	Individual
Gaur	2010	Hn		Group
	2011	Hn		Group
	2013	Hn		Group
	2014	Hn		Group
	2016	Hn		Group
	2018	Hn		Group
	2020	Hn		Group
	2010	Hn		Individual
	2011	Hn		Individual

Species	Year				
	2013	Hn			Individual
	2014	Hn			Individual
	2016	Hn			Individual
	2018	Hn			Individual
	2020	Hn			Individual
Wild pig	2010	Hr		Year	Group
	2011	Hr		Year	Group
	2013	Hr		Year	Group
	2014	Hr		Year	Group
	2016	Hr		Year	Group
	2018	Hr		Year	Group
	2020	Hr		Year	Group
	2010	Hr		Year	Individual
	2011	Hr		Year	Individual
	2013	Hr		Year	Individual
	2014	Hr		Year	Individual
	2016	Hr		Year	Individual
	2018	Hr		Year	Individual
	2020	Hr		Year	Individual
Red muntjac	2010	Hn	Cos		Group
	2011	Hn	Cos		Group
	2013	Hn	Cos		Group
	2014	Hn	Cos		Group
	2016	Hn	Cos		Group
	2018	Hn	Cos		Group
	2020	Hn	Cos		Group
	2010	Hn	Cos		Individual
	2011	Hn	Cos		Individual
	2013	Hn	Cos		Individual
	2014	Hn	Cos		Individual
	2016	Hn	Cos		Individual
	2018	Hn	Cos		Individual
	2020	Hn	Cos		Individual
Green peafowl	2010	Hn		Stratum + size	Group
	2011	Hn		Stratum + size	Group
	2013	Hn		Stratum + size	Group
	2014	Hn		Stratum + size	Group
	2016	Hn		Stratum + size	Group
	2018	Hn		Stratum + size	Group
	2020	Hn		Stratum + size	Group
	2010	Hn		Stratum + size	Individual
	2011	Hn		Stratum + size	Individual
	2013	Hn		Stratum + size	Individual
	2014	Hn		Stratum + size	Individual
	2016	Hn		Stratum + size	Individual
	2018	Hn		Stratum + size	Individual
	2020	Hn		Stratum + size	Individual

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