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Data paper for Special Issue of *Ecological Research*

Photographic records of plant phenology and spring river flush timing in a river lowland ecosystem at the taiga–tundra boundary, north-eastern Siberia

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Abstract

Arctic terrestrial ecosystems near the treeline in river lowlands are vulnerable to the changing
climate and seasonal extreme events, including flooding. We set up a simple camera
monitoring system to record the timings and durations of the leafy period and the spring flush
of river water at three observation sites (Boydom [B]: 70.64°N, 148.15°E; Kodac
[K]:70.56°N, 148.26°E; Verkhny-Khatistakh [VK]:70.25°N,147.47°E) in the Indigirka

lowland, in north-eastern Siberia. Time-lapse digital cameras were located at seven points across the three sites. The time intervals were 1–4 or 24 hours. The minimum and maximum monitoring periods were 2-years (July-2016 to August-2018) at B and 5-years (August-2013 to July-2018) at K. One camera documented the timings of river ice melt and open water periods from the riverbank of the Kryvaya River, one of the small tributaries of the Indigirka River. The other six cameras recorded several types of ground cover typical of the area, including larch trees (*Larix cajanderi*), shrubs (including *Salix* spp., and *Betula nana*), forbs, mosses, and graminoids in an ecosystem of sparsely forested shrublands, wetlands, and riversides. The data consists of 45,617 JPEG-format images. This dataset can be used to detect the onset and offset of the growing season and to capture the ice melt timing and water cover periods in wetlands and riversides. It may be useful in validating satellite data such as the vegetation remote sensing index for remote and little-known areas. These data may contribute to the study of the role of high-latitude ecosystems in global climate changes.

Key words: Tundra, Digital camera, Wetland, Ground-truth, Plant phenology

1. INTRODUCTION

Growth patterns of Arctic terrestrial ecosystems are changing because they are affected by the changing climate (Buntgen *et al.*, 2015). These changes may cause large uncertainties in carbon uptake/release in the carbon cycle and climate feedbacks. Increasing land-surface carbon uptake in the warmer arctic summer has been shown through both direct observations and earth system models (Ciais *et al.*, 2013; Forkel *et al.*, 2016). Increased uptake will lead to negative feedback to climate warming, though missing information about carbon release processes leads to uncertainty about these effects (Ciais *et al.*, 2013). Shifting phenological events, such as earlier snow melt and start of the growing season, with rising temperature may enhance annual net carbon uptake, although risk of frost damage, enhanced respiration, and phenological mismatch may inhibit growth, carbon fixation, and reproduction in tundra ecosystems (Cooper *et al.*, 2014). In this way, phenology is key in studying the function of Arctic terrestrial ecosystems and assessing climate change. Spring ice break-up and water flush timing in rivers, expected to change under climate warming, are significant abiotic hydrology factors disturbing vegetation and delivering nutrients to riparian ecosystems at high latitudes (Nilsson *et al.*, 2013; Prowse *et al.*, 2006; Scrimgeour, *et al.*, 1994). Therefore, monitoring the vegetation and the river at seasonal and annual time scales is important in understanding changing ecosystems.

Digital time-lapse cameras are widely used tools in monitoring plant phenology, including leaf opening, leaf senescence, flowering, and leaf falling, to determine the processes and drivers of ecosystem change. These cameras are set at intervals of one to a few hours and mounted on monopods to target a stand (Anderson *et al.*, 2016), on towers to target the

canopy (Nagai *et al.*, 2011), or on mountain lodges to target the landscape (Ide & Oguma 2013). Most camera sensors are sensitive to visible wavelengths (350–700 nm) and the wavelengths captured are recorded as red, green, and blue (RGB) values (Brown *et al.*, 2016). Vegetation indices (e.g., the green-red vegetation index) (Motohka *et al.*, 2010) can be used to extract phenological information from photographic records. Various photograph databases have been established and are being developed via open-access monitoring networks (Brown *et al.*, 2016; Moore *et al.*, 2016; Nagai *et al.*, 2018; Nasahara & Nagai 2015; Richardson *et al.*, 2018a; Wingate *et al.*, 2015). URLs of monitoring networks are as follows: Phenological Eyes Network: <http://www.pheno-eye.org/>; European Phenology Camera Network: <http://european-webcam-network.net/>; PhenoCam: <http://explore.phenocam.us/>; e-phenology: <http://www.recod.ic.unicamp.br/ephenology/>; Australian Phenocam Network: <https://phenocam.org.au/>.

Datasets of digital camera images provide useful on-the-ground information for calibrating, validating, and interpreting satellite time-series analyses (Kobayashi *et al.*, 2016; Nagai *et al.*, 2014; Richardson *et al.*, 2018b), and therefore they should cover widespread areas on a global scale. Existing databases cover much of the world, but only a few datasets have been from the Arctic. Phenology monitoring has been performed in Svalbard (Anderson *et al.*, 2016), Greenland (Westergaard-Nielsen *et al.*, 2017) and Alaska (Andresen *et al.*, 2018; Kobayashi *et al.*, 2016; Sugiura *et al.*, 2013), but has not yet covered the rest of the Arctic.

Here, we describe an archive of seasonal images taken by seven time-lapse digital cameras, starting in 2013, of a river in the Indigirka lowland in north-eastern Siberia. At the Kodac site, or site “K” (70.56°N, 148.26°E), integrative studies have been conducted (Fan *et al.*,

2018; Iwahana *et al.*, 2014; Liang *et al.*, 2014; Morozumi *et al.*, 2019a; Morozumi *et al.*,
2019b; Shingubara *et al.*, 2019; Tei *et al.*, 2017a; Tei *et al.*, 2017b). Information about some
of the environmental factors at the study site are archived at the ADS database
(<https://ads.nipr.ac.jp/>). The time-lapse camera images were previously examined to link the
seasonal patterns of river water, plant physiological condition, and river water chemistry (Fan
et al., 2018; Morozumi *et al.*, 2019a). Our dataset can provide unique information on
quantitative phenological variables such as leaf opening, leaf falling, and flowering, and
environmental variables including snowmelt timing and spring water flush timing of this
river in eastern Siberia. This dataset can be used to complete further studies across ecosystem
types using data from other phenology databases or to fill the gaps in calibration and variation
for satellite data analysis at circumarctic scales.

118 **2 DATA DESCRIPTION**

119 **2.1 Identifier**

120 ERDP-2020-02

121 **2.2 Contributor**

122 **A Dataset owner**

123 Atsuko Sugimoto, Trofim Maximov, Tomoki Morozumi, Shin Nagai, Hideki Kobayashi,
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125 **B Dataset creator**

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132 **2.3 Projects**

133 **A Title**

134 1. GRENE Arctic Climate Change Research Project

135 2. Belmont forum 2014 CRA COPERA project

136 **B Personnel**

137 1. Atsuko Sugimoto

138 2. Atsuko Sugimoto

139 **C Funding**

140 1. Ministry of Education, Culture, Sports, Science, and Technology (MEXT)

2. Japan Science and Technology Agency (JST)

2.4 Geological coverage

Geological coverage is shown in Table 1.

2.5 Temporal coverage

Temporal coverage of the data is shown in Table 2 and the Supporting Information.

2.6 Methods

A Study site

The study site was located in the Indigirka river lowland close to Chokurdakh (70.6°N 147.9°E), Republic of Sakha (Yakutia), Russia. A research collaboration between Hokkaido University and the Institute for Biological Problems of the Cryolithozone Siberian Branch of the Russian Academy of Sciences (IBPC SB RAS) began ecological and biogeochemical observation of the forested tundra in 2011, under the GRENE Arctic Research Project. The only tree species is Siberian larch (*Larix cajanderi*; syn *L. gmelinii*). The dominant shrubs are dwarf birch (*Betula nana*), alder (*Alnus fruticosa*; syn *Descokia fruticosa*), and willows (*Salix boganidensis*, *S. alaxensis*, *S. richardsonii*, *S. glauca*, *S. pulchra*, etc.). In the local area (10 km scale), 60 vascular and 11 moss species grow. Sedge-dominant wetland is also the dominant land-cover type, covering more than 20% of the landscape. Larch tree density is less than 6% in the local area, with 341 trees ha⁻¹ in the 100 × 100 m forested site (K) (Liang *et al.*, 2014). The vegetation and dominant species at the site were described in detail in Morozumi *et al.*, 2019b. Plant species in the view of the cameras are described in the Supporting Information, which was uploaded separately from this file.

B Data recorded by time-lapse cameras

The photographic images were captured by low-cost commercial time-lapse cameras (GardenWatchCam, Brinno, Taipei, Taiwan). We used lithium AA batteries to keep the cameras running for more than a year under low-temperature conditions. The picture format was AVI at 1280×720 pixels. The cameras' dark mode omitted images at night and during the polar-night season, although dark mode was turned off during a few observation periods. Each camera was set on a tree or an iron pole, and the view angles and the recorded image quality (e.g., lens haze) were sometimes unstable because of strong winds and low temperatures. Observation time stamps were automatically recorded in the footer of the image (e.g., GARDENWATCHCAM V.1.0 YYYY/MM/DD HH:MM:SS). Machine time was recorded in fixed time offset (UTC+0900; YAKT from 2014 to 2019) for stable time stamp identifier of descriptive purposes, because local time in Chokurdakh had been changed from UTC+1200 (MAGT) to UTC+1100 (SRET) at 2014 during the observation periods. Therefore, shift of time zone in 2014 is ignorable for temporal analysis of the dataset. We considered that the error of time stamp was less than ± 1 hour when we manually checked the time stamp of logger on GardenWatchCam in every summer in the field.

C Data processing

The recorded data were reprocessed into a single JPEG format from the original AVI file format. The open-image software FFMPEG (FFmpeg Developers, 2016) was used to separate the movie files into a series of JPEG images. Program settings on FFMPEG were -q:v 1 and scale = 1280:1040 for quality image output. Output files were renamed as the recorded date and time for each image using a command prompt in Windows 10 (Microsoft,

Redmond, WA). For the file names, recorded times were simplified to ignore minutes, and, therefore, the timestamp of the file name differed from the original sampling time within ± 1 hour.

The data files in klk2016 and klk2017 were modified to correct the incorrect time stamps on the image footer. The corrected time stamp was inserted as a graphic of upper 110-pixel width of the original image using Interactive Data Language (IDL) (Harris Geospatial Solutions, Boulder, Colorado). The correction time was obtained from the saved date and the start date recorded when the logger USB was connected to the PC in the field.

2.7 Data structure

A Data files

There are 45,617 images in total, accounting for approximately 6.5 GB. The image files are ordered by date and stored in a directory for each Camera ID, with a subfolder for each observed year (Table 3).

The data files are named in the format of “gwc_2016_208_1800_0900_CKH_KLK_h.jpg”. The notation of “gwc” means GardenWatchCam system, 2016 is the recorded calendar year, 208 is the day of year (DOY), 1800 is identifier of machine time (HH:MM), 0900 is offset of Universal Coordinated Time, CKH is an identifier of this dataset and is the name of the central town in the region (Chokurdakh), KLK is the Camera ID, and h is the angle of view (h: horizontal view; d: downward view). In this example, machine time at 18:00 corresponds to universal time (UTC + 0) at 09:00. A simple readme file is in the Supporting Information.

The data files in KLK2016 and KLK2017 were recorded with incorrect time stamps;

corrected time stamps with a small margin of error (± 1 hour) were inserted into those images and file names (see Methods).

B File format

The data files were saved in JPEG format.

2.8 Accessibility

A License

This data set is provided under a Creative Commons Attribution 4.0 International license (CC-BY 4.0: <https://creativecommons.org/licenses/by/4.0/>).

B Location of storage

<https://ads.nipr.ac.jp/dataset/A20200225-001>

SUPPORTING INFORMATION

The Supporting Information file (Supporting Information.docx) is uploaded separately from the main text.

ACKNOWLEDGEMENT

This data set was obtained under grants from the GRENE Arctic Climate Change Research Project by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), and the Belmont forum 2014 CRA COPERA project by Japan Science and Technology Agency (JST).

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REFERENCES

- Anderson HB, Nilsen L, Tommervik H, Karlsen SR, Nagai S, Cooper EJ (2016) Using Ordinary Digital Cameras in Place of Near-Infrared Sensors to Derive Vegetation Indices for Phenology Studies of High Arctic Vegetation. *Remote Sensing* 8: 17. DOI: 10.3390/rs8100847
- Andresen CG, Tweedie CE, Loughheed VL (2018) Climate and nutrient effects on Arctic wetland plant phenology observed from phenocams. *Remote Sensing of Environment* 205: 46-55. DOI: 10.1016/j.rse.2017.11.013
- Brown TB, Hultine KR, Steltzer H, Denny EG, Denslow MW, Granados J, Henderson S, Moore D, Nagai S, SanClements M, Sanchez-Azofeifa A, Sonnentag O, Tazik D, Richardson AD (2016) Using phenocams to monitor our changing Earth: toward a global phenocam network. *Frontiers in Ecology and the Environment* 14: 84-93. DOI: 10.1002/fee.1222
- Buntgen U, Hellmann L, Tegel W, Normand S, Myers-Smith I, Kirdyanov AV, Nievergelt D, Schweingruber FH (2015) Temperature-induced recruitment pulses of Arctic dwarf shrub communities. *Journal of Ecology* 103: 489-501. DOI: 10.1111/1365-2745.12361
- Ciais P, Sabine C, Bala G, Bopp L, Brovkin V, Canadell J, Chhabra A, DeFries R, Galloway J, Heimann M, Jones C, Le Quéré C, Myneni RB, Piao S, Thornton P eds. (2013) Carbon and Other Biogeochemical Cycles *In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
- Cooper EJ (2014) Warmer Shorter Winters Disrupt Arctic Terrestrial Ecosystems. In: DJ Futuyma (ed) *Annual Review of Ecology, Evolution, and Systematics*, Vol 45. Annual Reviews, Palo Alto, pp. 271.
- Fan R, Morozumi T, Maximov TC, Sugimoto A (2018) Effect of floods on the delta C-13 values in plant leaves: a study of willows in Northeastern Siberia. *PeerJ* 6: 20. DOI: 10.7717/peerj.5374
- Forkel M, Carvalhais N, Rodenbeck C, Keeling R, Heimann M, Thonicke K, Zaehle S, Reichstein M (2016) Enhanced seasonal CO₂ exchange caused by amplified plant productivity in northern ecosystems. *Science* 351: 696-699. DOI: 10.1126/science.aac4971
- Ide R, Oguma H (2013) A cost-effective monitoring method using digital time-lapse cameras for detecting temporal and spatial variations of snowmelt and vegetation phenology in alpine ecosystems. *Ecological*

Informatics 16: 25-34. DOI: 10.1016/j.ecoinf.2013.04.003

Iwahana G, Takano S, Petrov RE, Tei S, Shingubara R, Maximov TC, Fedorov AN, Desyatkin AR, Nikolaev AN, Desyatkin RV, Sugimoto A (2014) Geocryological characteristics of the upper permafrost in a tundra-forest transition of the Indigirka River Valley, Russia. *Polar Science* 8: 96-113. DOI: 10.1016/j.polar.2014.01.005

Kobayashi H, Yunus AP, Nagai S, Sugiura K, Kim Y, Van Dam B, Nagano H, Zona D, Harazono Y, Bret-Harte MS, Ichii K, Ikawa H, Iwata H, Oechel WC, Ueyama M, Suzuki R (2016) Latitudinal gradient of spruce forest understory and tundra phenology in Alaska as observed from satellite and ground-based data. *Remote Sensing of Environment* 177: 160-170. DOI: 10.1016/j.rse.2016.02.020

Liang MC, Sugimoto A, Tei S, Bragin IV, Takano S, Morozumi T, Shingubara R, Maximov TC, Kiyashko SI, Velivetskaya TA, Ignatiev AV (2014) Importance of soil moisture and N availability to larch growth and distribution in the Arctic taiga-tundra boundary ecosystem, northeastern Siberia. *Polar Science* 8: 327-341. DOI: 10.1016/j.polar.2014.07.008

Moore CE, Brown T, Keenan TF, Duursma RA, van Dijk A, Beringer J, Culvenor D, Evans B, Huete A, Hutley LB, Maier S, Restrepo-Coupe N, Sonnentag O, Specht A, Taylor JR, van Gorsel E, Liddell MJ (2016) Reviews and syntheses: Australian vegetation phenology: new insights from satellite remote sensing and digital repeat photography. *Biogeosciences* 13: 5085-5102. DOI: 10.5194/bg-13-5085-2016

Morozumi T, Shingubara R, Murase J, Nagai S, Kobayashi H, Takano S, Tei S, Fan R, Maximov TC, Sugimoto A (2019a) Usability of water surface reflectance for the determination of riverine dissolved methane during extreme flooding in northeastern Siberia. *Polar Science*. DOI: 10.1016/j.polar.2019.01.005

Morozumi T, Shingubara R, Suzuki R, Kobayashi H, Tei S, Takano S, Fan R, Liang M, Maximov TC, Sugimoto A (2019b) Estimating methane emissions using vegetation mapping in the taiga-tundra boundary of a north-eastern Siberian lowland. *Tellus Series B-Chemical and Physical Meteorology* 71: 17. DOI: 10.1080/16000889.2019.1581004

Motohka T, Nasahara KN, Oguma H, Tsuchida S (2010) Applicability of Green-Red Vegetation Index for Remote Sensing of Vegetation Phenology. *Remote Sensing* 2: 2369-2387. DOI: 10.3390/rs2102369

Nagai S, Akitsu T, Saitoh TM, Busey RC, Fukuzawa K, Honda Y, Ichie T, Ide R, Ikawa H, Iwasaki A, Iwao K, Kajiwarra K, Kang S, Kim Y, Khoon KL, Kononov AV, Kosugi Y, Maeda T, Mamiya W, Matsuoka M, Maximov TC, Menzel A, Miura T, Mizunuma T, Morozumi T, Motohka T, Muraoka H, Nagano H, Nakai T, Nakaji T, Oguma H, Ohta T, Ono K, Pungga RAS, Petrov RE, Sakai R, Schunk C, Sekikawa S, Shakhmatov R, Son Y, Sugimoto A, Suzuki R, Takagi K, Takanashi S, Tei S, Tsuchida S, Yamamoto H, Yamasaki E, Yamashita M, Yoon TK, Yoshida T, Yoshimura M, Yoshitake S, Wilkinson M, Wingate L, Nasahara KN (2018) 8 million phenological and sky images from 29 ecosystems from the Arctic to the tropics: the Phenological Eyes Network. *Ecological Research* 33: 1091-1092. DOI: 10.1007/s11284-018-1633-x

Nagai S, Inoue T, Ohtsuka T, Kobayashi H, Kurumado K, Muraoka H, Nasahara KN (2014) Relationship between spatio-temporal characteristics of leaf-fall phenology and seasonal variations in near surface- and satellite-observed vegetation indices in a cool-temperate deciduous broad-leaved forest in Japan. *International Journal of Remote Sensing* 35: 3520-3536. DOI: 10.1080/01431161.2014.907937

Nagai S, Maeda T, Gamo M, Muraoka H, Suzuki R, Nasahara KN (2011) Using digital camera images to detect canopy condition of deciduous broad-leaved trees. *Plant Ecology & Diversity* 4: 79-89. DOI: 10.1080/17550874.2011.579188

Nasahara KN, Nagai S (2015) Review: Development of an in situ observation network for terrestrial ecological remote sensing: the Phenological Eyes Network (PEN). *Ecological Research* 30: 211-223. DOI: 10.1007/s11284-014-1239-x

Richardson AD, Hufkens K, Milliman T, Aubrecht DM, Chen M, Gray JM, Johnston MR, Keenan TF, Klosterman ST, Kosmala M, Melaas EK, Friedl MA, Frolking S (2018a) Tracking vegetation phenology across diverse North American biomes using PhenoCam imagery. *Scientific Data* 5: 24. DOI: 10.1038/sdata.2018.28

Richardson AD, Hufkens K, Milliman T, Frolking S (2018b) Intercomparison of phenological transition dates derived from the PhenoCam Dataset V1.0 and MODIS satellite remote sensing. *Scientific Reports* 8: 12. DOI: 10.1038/s41598-018-23804-6

Nilsson C, Jansson R, Kuglerova L, Lind L, Strom L (2013) Boreal Riparian Vegetation Under Climate Change. *Ecosystems* 16: 401-410. DOI: 10.1007/s10021-012-9622-3

Prowse TD, Wrona FJ, Reist JD, Gibson JJ, Hobbie JE, Levesque LMJ, Vincent WF (2006) Climate change effects on hydroecology of Arctic freshwater ecosystems. *Ambio* 35: 347-358. DOI: 10.1579/0044-7447(2006)35[347:cceoho]2.0.co;2

Scrimgeour GJ, Prowse TD, Culp JM, Chambers PA (1994) Ecological effects of river ice break-up - A review and perspective. *Freshwater Biology* 32: 261-275. DOI: 10.1111/j.1365-2427.1994.tb01125.x

Shingubara R, Sugimoto A, Murase J, Iwahana G, Tei S, Liang MC, Takano S, Morozumi T, Maximov TC (2019) Multi-year effect of wetting on CH₄ flux at taiga-tundra boundary in northeastern Siberia deduced from stable isotope ratios of CH₄. *Biogeosciences* 16: 755-768. DOI: 10.5194/bg-16-755-2019

Sugiura K, Nagai S, Nakai T, Suzuki R (2013) Application of time-lapse digital imagery for ground-truth verification of satellite indices in the boreal forests of Alaska. *Polar Science* 7: 149-161. DOI: 10.1016/j.polar.2013.02.003

Tei S, Sugimoto A, Liang MC, Yonenobu H, Matsuura Y, Osawa A, Sato H, Fujinuma J, Maximov T (2017a) Radial Growth and Physiological Response of Coniferous Trees to Arctic Amplification. *Journal of Geophysical Research-Biogeosciences* 122: 2786-2803. DOI: 10.1002/2016jg003745

Tei S, Sugimoto A, Yonenobu H, Matsuura Y, Osawa A, Sato H, Fujinuma J, Maximov T (2017b) Tree-ring

analysis and modeling approaches yield contrary response of circumboreal forest productivity to climate change. Global Change Biology 23: 5179-5188. DOI: 10.1111/gcb.13780

Westergaard-Nielsen A, Lund M, Pedersen SH, Schmidt NM, Klosterman S, Abermann J, Hansen BU (2017) Transitions in high-Arctic vegetation growth patterns and ecosystem productivity tracked with automated cameras from 2000 to 2013. Ambio 46: S39-S52. DOI: 10.1007/s13280-016-0864-8

Wingate L, Ogee J, Cremonese E, Filippa G, Mizunuma T, Migliavacca M, Moisy C, Wilkinson M, Moureaux C, Wohlfahrt G, Hammerle A, Hortnagl L, Gimeno C, Porcar-Castell A, Galvagno M, Nakaji T, Morison J, Kolle O, Knohl A, Kutsch W, Kolari P, Nikinmaa E, Ibrom A, Gielen B, Eugster W, Balzarolo M, Papale D, Klumpp K, Kostner B, Grunwald T, Joffre R, Ourcival JM, Hellstrom M, Lindroth A, George C, Longdoz B, Genty B, Levula J, Heinesch B, Sprintsin M, Yakir D, Manise T, Guyon D, Ahrends H, Plaza-Aguilar A, Guan JH, Grace J (2015) Interpreting canopy development and physiology using a European phenology camera network at flux sites. Biogeosciences 12: 5995-6015. DOI: 10.5194/bg-12-5995-2015

Table 1. Location of cameras and landscape type, latitude, longitude, elevation, and azimuth angle.

Site name	Camera ID	Type	Latitude (N)	Longitude (E)	Elevation (m a.s.l)	Azimuth angle ^{*1}
B	B	Wetland	70.63795	148.1548	5	SW
K	KDF	Shrubland	70.56288	148.265	5	- ^{*2}
K	KLK	Wetland (look down)/Larch tree branch	70.56526	148.2603	5	NW
K	KLF	Wetland (look down)	70.56266	148.267	5	- ^{*2}
K	KR	Shrubland (riverbank)/Larch tree	70.56318	148.26368	5	SW
K	KSN	Wetland	70.56361	148.2685	5	NE
VK	VK	Shrubland/Larch tree	70.24838	147.46754	10	N

^{*1} Direction of horizontal view from camera

^{*2} Downward view

346 **Table 2.** Start and end dates of the recording, no-data period, and interval time of the data.

Camera (site)	ID	Start YYYY/MM/DD (DOY)	End YYYY/MM/DD (DOY)	no-data period YYYY E:early L:late	Interval hours (year used)
B		2016/07/27 (209)	2018/08/02 (214)	-	3
KDF		2013/08/03 (215)	2016/08/12 (226)	2014E	3
KLK		2016/07/26 (208)	2018/08/03 (215)	-	4(2017), 1(2018)
KLF		2013/08/03 (215)	2016/09/24 (268)	2014L-2015E	3
KR		2013/08/03 (215)	2017/07/26 (207)	-	3
KSN		2013/08/03 (215)	2018/07/16 (197)	2016L-2017E	3
VK		2013/08/02 (214)	2018/07/25 (206)	2014L-2017E	3(2013- 2014) 24(2016- 2018)

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348 **Table 3.** Directory of Camera-ID, Subfolder ID, Year, and the number of image files in each
 349 folder.

CameraID	SubfolderID	Year	Number of image files
	total		45617
B	B2016	2016	1256
	B2017	2017	2647
	B2018	2018	1685
KDF	KDF2013	2013	1205
	KDF2014	2014	1589
	KDF2015	2015	1850
	KDF2016	2016	1331
KLK	KLK2016	2016	950
	KLK2017	2017	3270
	KLK2018	2018	3894
KLF	KLF2013	2013	1205
	KLF2014	2014	1663
	KLF2015	2015	734
	KLF2016	2016	1454
KR	KR2013	2013	1205
	KR2014	2014	2316
	KR2015	2015	1929

	KR2016	2016	1934
	KR2017	2017	1236
KSN	KSN2013	2013	1206
	KSN2014	2014	2325
	KSN2015	2015	1914
	KSN2016	2016	1203
	KSN2017	2017	1245
	KSN2018	2018	1555
VK	VK2013	2013	1212
	VK2014	2014	1245
	VK2017	2017	153
	VK2018	2018	206

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