



**An assessment of thermal-image acquisition with an Unmanned Aerial Vehicle (UAV) for direct counts of coastal marine mammals ashore.**

Journal:	<i>Journal of Unmanned Vehicle Systems</i>
Manuscript ID	juvs-2016-0029.R2
Manuscript Type:	Note
Date Submitted by the Author:	02-Jan-2018
Complete List of Authors:	Gooday, Oliver; University of Canterbury College of Science, School of Biological Sciences Key, Nicholas ; University of Canterbury College of Science, Geography Goldstien, Sharyn; University of Canterbury College of Science, School of Biological Sciences Zavar-Reza, Peyman ; University of Canterbury College of Science, Geography
Keyword:	aerial, thermal imagery, <i>Arctocephalus forsteri</i> , Survey, Pinniped
Is the invited manuscript for consideration in a Special Issue? :	N/A

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**Title of project:** An assessment of thermal-image acquisition with an Unmanned Aerial Vehicle (UAV) for direct counts of coastal marine mammals ashore.

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**Abstract**

We investigated the efficacy of infrared thermal imaging devices for detecting coastal marine mammals in forested coastal environments. Our objective was to determine whether pinnipeds could be detected through the forest canopy using thermal imagery. We used a UAV mounted and a ground mounted infrared camera to survey New Zealand fur seals (*Arctocephalus forsteri*) located in Ohau Stream and Point Kean coastal shrub forest, on the East Coast of New Zealand. These methods were compared to paired photographs and walk through counts. Ground mounted thermal images detected more seals than paired photographs during the cooler times of the day (morning and evening). In contrast, aerial thermal videos were successful in detecting fur seals in open areas, but were less successful in areas of high canopy cover (>80 %). We discuss the advantages and limitations of thermal imaging for population sampling and provide some recommendations for future research.

Keywords: aerial, thermal, imagery, *Arctocephalus forsteri*, survey, pinniped.

## Introduction

The effective conservation and management of wildlife is reliant on accurate population surveys that estimate the number of individuals, as well as the age structure of the populations (Morris and Doak 2002). Population surveys can be time consuming and logistically difficult in remote or dangerous locations, or where vegetation is dense. The most common and accepted method of counting individuals, mark-recapture, requires large teams of researchers walking amongst the target animal population, manually counting individuals over multiple days. These ground surveys are labour intensive and costly, and can create disturbances within the population being sampled, as well as among populations of non-target species (Ditmer et al. 2015). For large migratory animals, researchers may substitute walking for an aircraft; further increasing the survey cost. Recent technological advances in Unmanned Aerial Vehicle (UAV) technology provides an opportunity to safely access difficult to sample habitats with a smaller team, thereby reducing project costs and disturbance to the wildlife. In combination with thermal imaging or, thermography, which has been assessed as a method to replace manual visual counts since 1972 (Cilulko et al. 2013), these two technologies may provide a novel and cost-effective method for surveying animal populations from a broad range of species and habitats.

Image acquisition in the infrared band (thermal imaging) has been shown to be effective at detecting large terrestrial animals, such as white-tailed deer, *Odocoileus virginianus*, in complex habitats (Croon et al. 1968; Graves et al. 1972), and panthers (*Puma concolor coryi*) from low-flying aircraft (Havens and Sharp 1998). Similarly, previous studies have found surveys using thermal images to be comparable to spot-light surveys (Focardi et al. 2001) and other methodologies used for nocturnal behaviour assessments (Allison and Destefano 2006). Coastal marine species present different challenges for thermal imaging as they are often wet, or spend much of their time away from the more accessible coastal habitat; however, harbour seal (*Phoca vitulina*) and walrus (*Odobenus rosmarus divergens*) (Burn et al. 2006; Duck et al. 2003) populations have been successfully surveyed with

thermal imaging in open, un-structured habitat. UAVs have also been used to survey the little blue and yellow eyed penguin colonies in New Zealand with lower disturbance than traditional ground counts, and with similar accuracy (Ratcliffe et al. 2015).

New Zealand is home to a diverse range of seabirds and marine mammals, some of which are considered 'vulnerable' or 'endangered' and require cost effective, accurate population survey methods. Some of these animals spend the majority of their time in open habitats, such as the ocean and coastal beaches. However, others reside in densely vegetated coastal forests or rocky platforms during periods of rest and for reproduction, where the habitat is more structured and difficult to access without disturbing the target animals and exposing researchers to dangerous situations. The combination of UAV and infrared technology could offer a potentially less invasive method for population surveys of these vulnerable marine species, both on land and at sea.

The aim of this research was to assess the detectability of marine mammals in forested habitat through canopy cover and through ground counts at different times of the day in order to guide future directions and applications of infrared use in terrestrial population sampling of coastal marine mammals. We conducted an exploratory infrared survey of the NZ fur seal pups (*Arctocephalus forsteri*) of up to 6 months old within a forested habitat and evaluated the effectiveness of thermal imagery on the ground and from the air.

## **Materials and Methods**

### **Study Sites and Target Species**

Kaikoura (East Coast of New Zealand) hosts New Zealand's largest breeding colony of the New Zealand fur seal (*Arctocephalus forsteri*). During the mothers feeding periods at sea, NZ fur seal pups undertake migration up a connected freshwater stream (Ohau Stream) under the cover of trees, more akin to sea lion mother and pup migration into the forest on offshore islands (Campbell et al. 2006).

The seal pups become increasingly hard to monitor as they move further into the forest and into denser tree cover, which makes it an ideal study organism for testing infrared image acquisition in open habitat and dense vegetation.

Infrared surveys were conducted at two New Zealand fur seal colonies; Ohau Point (OP) and Point Kean (PK), on the East coast of the South Island of New Zealand (Figure 1) between the 19 and 27th February 2015. Ohau Point is one of the largest breeding colonies of NZ fur seals in New Zealand and is located 30 km north of the Kaikoura township ( $42^{\circ}14'52.2''\text{S}$   $173^{\circ}49'50.2''\text{E}$ ). This site is characterized by a freshwater stream with dense canopy cover that leads to a waterfall, (from here referred to as stream). Point Kean is located on the Kaikoura Peninsula and is host to a small, but rapidly increasing breeding population. This site is characterized by a flat rocky shore platform and low canopy cover, separated by a tourist car park (from here referred to as coast).

### **Thermal imagery surveys**

#### *DraganFlyer X4-P Helicopter™ (Quadcopter)*

Flights were conducted using the DraganFlyer X4-P Helicopter™ (<http://www.draganfly.com/uav-helicopter/draganflyer-x4p/specifications>). Its payload (the camera or thermal sensors attached) consisted of a T320 19 mm infrared camera for thermal imaging flights (Table 1) and a SONY-NEX5N for photographic video flights. The UAV is equipped with a pressure gauge, allowing for flight height to be accurately measured and for the UAV to be flown within the legal guidelines.

The DraganFlyer X4-P takes off and lands vertically, allowing landing on a confined and/or thin landing site. The UAV can be flown for 8–10 minutes per battery using the SONY NEX5N and 15–17 minutes with the T320 thermal attachment and legally must be flown in line-of-sight. The T320 19 mm Infrared camera was connected to a wireless monitor and radio link, so data could be recorded and viewed in real-time. Prior to take off, the standard operating safety procedures for the

DraganFlyer X4-P Helicopter™ were conducted. Three quadcopter transects were flown at 7 am, 12 pm and 4 pm for the photographic and thermal cameras separately (Table 2). The Quadcopter was manually flown by a qualified UAV pilot due to the steepness of terrain and insufficient GPS signal for automated flight. Each transect took approximately 10-20 minutes to conduct, depending on prevailing wind conditions and tourist activity in the area. In addition to UAV transects above the vegetated stream and coast habitats, a walk-through count was conducted to provide a comparison with the acquired images. A walk-through consisted of one person walking a 10 m wide belt-transect through the forest and recording the number of pups detected. Due to time and staff limitations, one walkthrough count was conducted for each site and each time of day.

*Ground mounted Forward Looking Infrared Camera (FLIR) data collection.*

The Optris PL450 Infrared camera was used for the fixed thermal camera comparisons. The Optris PL450 Infrared camera is a high speed, high resolution thermographic camera. It is able to provide real-time thermographic images at high speed, which enables the focusing and altering of the thermal sensitivity (temperature range) to focus and display the required detection temperatures (Hoffmann et al. 2015). To determine the effectiveness of the Optris PL450 Infrared camera at detecting New Zealand fur seals through different foliage, fixed ground trials were conducted using a tripod. The emissivity was set to 0.98 for general observation of relative temperature differences. The Optris PL450 requires direct connection to a laptop or tablet running windows XP or higher. The camera is focused manually using the lens and data is displayed and recorded using PI Connect™ (<http://www.optris.com/optris-pi-connect>). The field of view obtained under the canopy for this lens (33° x 25°) ranged from 2.97 m (W) x 2.21 m (H) x 3.71 (diagonal), with pixel size of 4.55 mm (IFOV) and 13.66 mm (MFOV) where the target was at 5 m; to 8.91 m (W) x 6.63 m (H) x 11.1 m (diagonal), with pixel size of 13.65 mm (IFOV) and 40.94 mm (MFOV) where the target was at 15 m. A Thermal image was taken at three vantage points, at both colonies (KP and OP) and paired with a photographic image (SONY NEX-5) to determine the detection rate of both systems through different foliage types. The Optris PL450 is designed specifically for use on UAV platforms; however, it is not

currently configured for attachment to the DraganFlyer X4-P. Future research would require modification for the Optris PL450 to be integrated into the DraganFlyer gimbal and video system.

## **Data Processing**

All thermal and photographic imagery was displayed and counted on a Viewsonic™ (VX2439WN) 24 inch Full HD (1080p) monitor (<http://www.viewsonic.com/us/monitors/entertainment-vx-series/vx2475smhl-4k.html>). Thermal imagery from the T320 19mm infrared camera can only be viewed and processed using Micro-D player (<http://micro-dvd.en.softonic.com>).

Optris PL450 thermal imagery was processed using PI Connect™ (<http://www.optris.com/optris-pi-connect>).

Pinnipeds have unique thermal qualities that were used to distinguish them from other ‘hot spots’ (heat radiation points) as the target animal in all images: a distinct head shape and movement; hot distinct eyes (which provides a thermal contrast with the rest of the body); and naturally hot flippers (used for thermoregulation).

Canopy cover was estimated from an aerial video transect of each study site.

## **Results**

### *Seal Identification*

In the forested environment, seals were detected by their swaying head movement between trees and their hot eyes (Figure 2). On the exposed rocky shore, the same characteristics were effective in identifying the seals, with the exception of warmer days, when seals were more homogenous, and when seals aggregated their thermal profiles merged, which made detection difficult. Therefore, seals were more accurately detected in the mornings, when it was colder



and the seals were less densely aggregated. Seal pups were harder to detect than adults because of their smaller size.

#### *UAV survey*

The UAV mounted T320 19mm Infrared camera was able to detect some fur seals in low density forest (defined as less than <50% canopy cover) (Figure 3). The percentage of seals detected in low density forest using aerial infrared compared to a thorough walk-through search ranged from 16 to 67%, with detection rate being greatest in the morning (Table 3). In contrast, the UAV mounted T320 19 mm infrared camera detected fur seal pups through the forest where canopy cover was less than 95%, shown by a 0% detection rate for every flight where canopy cover was greater than 95% (Table 3).

In comparison, the Optris PL450 had a greater seal detection rate than photographic detection, but only during the morning and afternoon at both sites (Figure 4, Table 4).

#### **Discussion**

The use of unmanned aerial vehicles for surveying marine mammals offers an innovative, non-disruptive method for estimating the abundance of pinnipeds ashore. This research has shown that the effectiveness of aerial thermal imagery depends on the time of day, the type of camera, and the density of foliage.

We conducted sampling at three different times to determine whether there was an optimum time of day for sampling. We found that the morning and afternoon showed the highest rate of detection, which may be due to the lower temperature of surface-cover creating a larger thermal contrast between the vegetation and the fur seals (Davis and Sharma 2004). Whilst this may suggest that mid-

day is the least optimal time for sampling, we must be mindful that there were also fewer seals under the foliage at mid-day during our study.

For the UAV flights we used the T320 19mm Infrared camera. The T320 19mm Infrared camera is a hot-spot camera which is small, versatile and can be attached to a UAV. The drawbacks of this camera are its low resolution and the inability to measure temperature from the thermal image recorded. This camera was able to detect seals in the open and in very low density foliage but was insufficient when the foliage density was too great or seals were too closely clumped together. When conducting population counts using this camera, one must acknowledge the potential to underestimate counts due to missing seals under foliage (Boonstra et al. 1994). Due to the water composition of foliage, the canopy is highly absorptive and opaque which hides the animals underneath. Thermal technology is also limited by the inability to detect the outline of thermally homogenous animals which can lead to underestimating grouped seals and also mistaking hot rocks for seals. The multi-rotor UAV was crucial to the successful detection of seals as they are manoeuvrable and can fly continuously or stop and hover if a seal was spotted. This allowed for detecting movement or defining characteristics, such as the head or eyes. Hovering to detect movement also aided in distinguishing the number of individuals in groups and their size. The manoeuvrability of the Draganflyer™ and its gimbal (the camera support that allows rotation) also allowed fine scale manipulation of the flight pattern and camera angle. The camera angle manipulation is a key feature that may aid success in detection near canopy edges. For instance, the Point Kean habitat was a small, low-density forest fragment where edges presented a way to view the subcanopy more readily, while maintaining the 50 m height; however, all seals detected in this instance were in the inner part of the canopy and therefore we could not test edge effects. Multi-rotor UAVs manoeuvrability and versatility make them perfect for this kind of sampling of marine mammals, although most models are susceptible to wind, shorter flight distances compared to fixed wings and the thermal imagers are not water proof (Jones IV et al. 2006).

Infrared cameras are not without limitations. Water is a potential issue as it can mask a seal's thermal signature by evaporative cooling of the seal's surface. When a seal has just exited the water, the initial thick layer of water on its fur will make it appear cold or invisible as the camera detects the thermal signature of the water and not the seal (McCafferty 2007). This masking could hide a seal and bias results during a population survey. Conducting an infrared survey in the rain can also present similar issues, as the image will appear faded or blurry due to the camera picking up the thermal emission of rain. Another issue we faced was that rocks hold their temperature for a very long time and maintain temperatures that typically coincide with the seals. Conducting population sampling over rocks in the morning before they heat up could counter this issue.

#### *Concluding remarks*

The conservation of marine mammals is in pressing need of new, less invasive, cost and time effective population sampling methods. The vulnerable New Zealand sea lion and rapidly expanding New Zealand fur seal are both excellent species on which to focus research, due to their biological similarities and different risk levels (Boren et al. 2006; Robertson and Chilvers 2011). The pairing of Unmanned Aerial Vehicles and thermal imagery is showing great potential in providing a cost-effective method for surveying various habitats. Further testing of this technology should include; conducting surveys during the night or early morning to increase the thermal gradient between the substrate/vegetation and the mammal; the use of multi-rotor platforms which have better manoeuvrability than fixed wing UAVs and can hover to confirm heat signatures; and to invest in high resolution cameras such as the Optris PL450, which may offer greater accuracy for counts.

## Acknowledgments

The work was funded by the New Zealand Ministry for Primary Industries (DOC, permit no. 39700-MAR). Thanks to Nathan Walker, Andrew Baxter and Laura Boren for their consultation on UAV flights around marine mammals.

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### Figure Legends

Figure 1: Map of New Zealand with research area inset. Research sites (blue circles) are indicated, Ohau stream and Point Kean on the South Island, Kaikoura, New Zealand (Created by Lon Van Elk).

Figure 2: A close-up thermal image of a New Zealand fur seal pup taken using the Optris PL450 in Ohau Stream, Kaikoura. The number indicates the temperature in degrees Celsius of the pixel beneath the user's cursor (PI Connect™).

Figure 3: Photograph taken from Draganflyer X4-P Helicopter at 50 m height using a SONY NEX-5 camera (A) paired with an aerial thermal image taken using the T320 19mm infrared camera at Point Kean, Kaikoura (B).

Figure 4: Photograph taken from a tripod at ground level using a SONY NEX-5 camera (A) paired with a thermal image of the same frame using the Optris PL450 at Ohau Stream, Kaikoura (B).

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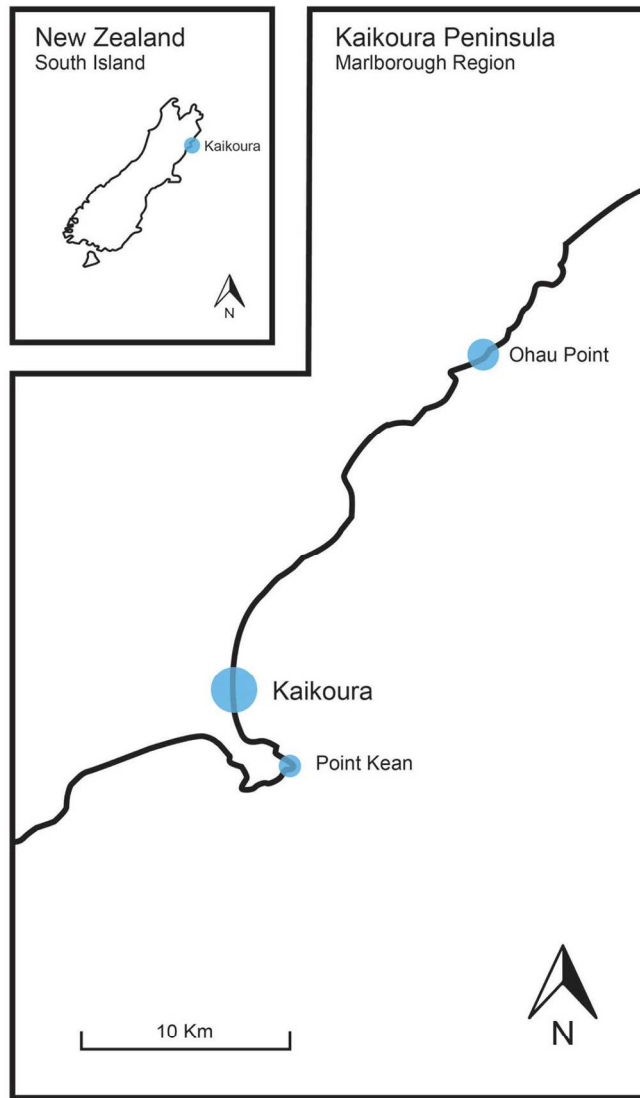


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510x722mm (72 x 72 DPI)



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Figure 3: Photograph taken from Draganflyer X4-P Helicopter at 50 m height using a SONY NEX-5 camera (A) paired with an aerial thermal image taken using the T320 19mm infrared camera at Point Kean, Kaikoura (B).



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Figure 4: Photograph taken from a tripod at ground level using a SONY NEX-5 camera (A) paired with a thermal image of the same frame using the Optris PL450 at Ohau Stream, Kaikoura (B).

64x48mm (220 x 220 DPI)

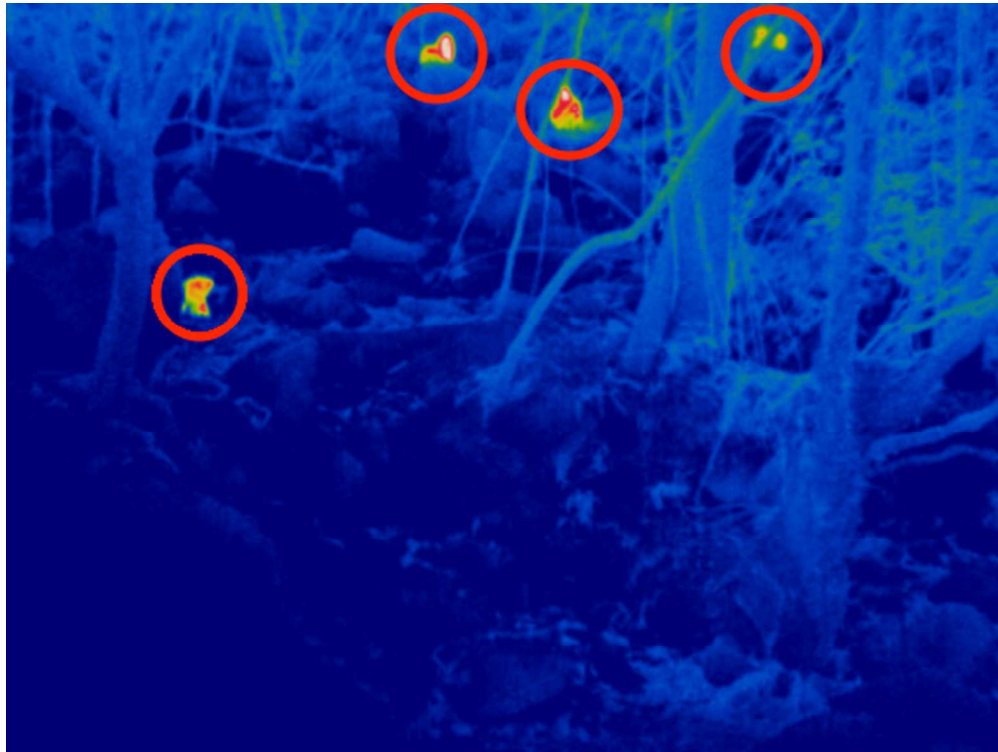


Figure 4: Photograph taken from a tripod at ground level using a SONY NEX-5 camera (A) paired with a thermal image of the same frame using the Optris PL450 at Ohau Stream, Kaikoura (B).

Table 1: T320 19 mm Infrared Camera Technical Specifications.

T320 19mm Infrared Camera	
Temperature range	-40 - 80°C
Analog Video Display Formats	640 x 480 (NTSC) 640 x 512 (PAL)
Detector	Uncooled VOx Microbolometer
Spectral band	7.5 – 13.5 $\mu\text{m}$
Sensitivity (NE $\Delta$ T)	<50 mKat f/1.0
Software	MicroD Player

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Table 2: Details of sample sizes for aerial and ground surveys of New Zealand fur seal conducted at 7 am, 12 pm and 4 pm on the east coast of the South Island, Kaikoura, New Zealand.

Camera	Location	Number of Transects or photographs per time
T320 19 mm Infrared Camera (UAV mounted)	Ohau Stream	3
	Point Kean	3
Optris PL450 (Fixed tripod)	Ohau Stream (2 sites)	3
	Point Kean (4 sites)	3
Walk through for UAV comparison	Ohau Stream	1
	Point Kean	1
Sony photograph for tripod comparison	Ohau Stream	3
	Point Kean	3

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Table 3: Mean number of seals detected using aerial thermal imagery (T320 19mm Infrared camera) and by visual ground counts (walk-through) at Ohau Point and Point Kean, Kaikoura, New Zealand. Detection percentage is calculated as the percentage of seals detected with ground counts that were also detected using infrared camera

Detection method	Morning	Mid-day	Afternoon
<b>Ohau Point (95% canopy cover)</b>			
T320 Infrared (n= 3).	0	0	0
Walk-through count (n= 1)	12	9	5
Detection Percentage (%)	0%	0%	0%
<b>Point Kean (50% canopy cover)</b>			
T320 Infrared (n= 3)	23 (5.48)	2 (0.88)	22 (1.53)
Walk- through count (n=1)	34	12	49
Detection Percentage (%)	67.6	16.7	44.9

Table 4: Total counts of New Zealand fur seals detected using Optris PL450 Infrared camera vs photographic image (SONY NEX-5) through different foliage types (% canopy cover) on the Kaikoura Coast.

Location	Foliage Type	Morning		Mid-day		Afternoon	
		Photo	Thermal	Photo	Thermal	Photo	Thermal
coast	Dense Forest (80%)	11	17	4	4	8	18
coast	Uncovered flat ground and Forest (40 %)	9	15	6	10	6	12
coast	Tall Grass (60 %)	6	10	5	5	5	5
coast	Moderate Forest (70 %)	-	3	1	0	1	5
stream	Dense contorted branches.	7	6	-	7	3	5
stream	Moderate Forest	3	5	2	3	1	5