ACADEMIA JOURNAL OF BIOLOGY 2018, 40(4): 37–44
DOI: 10.15625/2615-9023/v40n4.12839

ESTIMATING DETECTION PROBABILITY AND SITE OCCUPANCY OF *Leiolepis guentherpetersi* IN THE COASTAL SANDY AREAS OF PHU LOC DISTRICT, THUA THIEN HUE PROVINCE

Cao Thi Thanh Nguyen, Ngo Van Binh*, Ngo Dac Chung

Department of Biology, Hue University of Education, Hue City, Vietnam

ABTRACT

The Peter's butterfly lizard (*Leiolepis guentherpetersi*) is endemic to Vietnam. However, there is no available information related to detection probability and site occupancy of this species so far. Nine surveys were conducted at 50 plots in the coastal areas of Phu Loc district from September to December 2017 in order to detect the presence of *Leiolepis guentherpetersi*. Our results showed that the detection probability of *L. guentherpetersi*, when combined with environmental factors, was 0.383, which was higher than the naive detection probability of 0.34. The total AIC weight of the near sea ecosystem was 85.9% while the total AIC weight of the ecosystem far from the sea was only 13.5%. The AIC weight of weather conditions was 99.4% while the total AIC weight of temperature was 62.3% and the total AIC weight of humidity was 27.2%. These results indicated that the probability of detecting *L. guentherpetersi* influenced by both site covariates (near the sea or far from the sea) and sample covariates (temperature, humidity, and rainfall). In there, the near sea ecosystem is the best habitat for *L. guentherpetersi* and rainfall is sample covariates that had the greatest influence on detection probability and site occupancy of this species.

Keywords: Butterfly lizard, detection probability, site occupancy, Phu Loc.

Citation: Cao Thi Thanh Nguyen, Ngo Van Binh, Ngo Dac Chung, 2018. Estimating detection probability and site occupancy of *Leiolepis guentherpetersi* in the coastal sandy areas of Phu Loc district, Thua Thien Hue province. *Academia Journal of Biology*, 40(4): 37–44. https://doi.org/10.15625/2615-9023/v40n4.12839.

**Corresponding author email*: nvb6868@gmail.com

Received 19 July 2018, accepted 5 December 2018

INTRODUCTION

The Peter's Butterfly Lizard, *Leiolepis guentherpetersi* Darevsky & Kupriyanova, 1993, is currently found in some coastal sandy areas of central Vietnam only (Nguyen et al., 2009; Grismer et al., 2014). *L. guentherpetersi* is a parthenogenetic species, all individuals in the population are females (Darevsky & Kupriyanova, 1993; Grismer & Grismer, 2010). Currently, the populations of *L. guentherpetersi* are declining at an alarming speed due to overexploitation, habitat loss, and climate change (Grismer, 2010).

Previous studies on *L. guentherpetersi* mainly focus on the distributed regions, morphological characters, ecology in captivity conditions, and karyotype (Darevsky & Kupriyanova, 1993; Le & Ngo, 2009; Nguyen et al., 2009; Tran et al., 2009; Grismer & Grismer, 2010; Tran & Ngo, 2012; Grismer et al., 2014). Other ecological data of *L. guentherpetersi* is not available. In this study, we used the dada of detection and non-detection for each plot over multiple visits to estimate the site occupancy of *L. guentherpetersi* in the coastal sandy areas

of Phu Loc district, central Vietnam. We also compared detection and occupancy probabilities for two specific habitat types (site covariates) and tested the influence of sample covariates (temperature, humidity, and rainfall) on the occupancy and detection of *L. guentherpetersi* lizards.

MATERIALS AND METHODS

This study was carried out at the coastal sandy areas of Phu Loc district (approximately 721 km^2 in size), Thua Thien Hue province, central Vietnam (Fig. 1). The study area is characterized by a monsoon tropical climate: the dry season begins from February to July and the rainy season begins from August to January next year (Nguyen et al., 2004).

We designed 50 standard plots belonging to two habitat types (site covariates) in the coastal sandy areas of Phu Loc district to monitor *L. guentherpetersi* during the rainy season of 2017. Twenty-five plots were set up close to the sea (NS) with microhabitat types represented by sandy soil, casuarinas, mangrove plants, wild pineapple, and cactus. These plots are strongly affected by the developmental projects of sea travel. Twenty-five other plots were located in the inner part of seashore from 400–1500 m (FS) with microhabitat types of mixed sandy land, acacia forests, shrubs, lawns, and bare land. Area of each standard plot is 1000 m^2 (20 × 50 m). The standard plots were randomly selected, approximately 500 m apart from each other. We designed thirty standard plots in the Loc Vinh locality (16°17'28"N–108°02'22"E) with fifteen plots near the sea (< 400 m) and fifteen plots far from the sea (from 400–1500 m) and twenty standard plots in the Vinh Hien locality (16°21'57"N–107°54'07"E) (ten plots near the sea and ten other plots far from the sea) (Fig. 1).

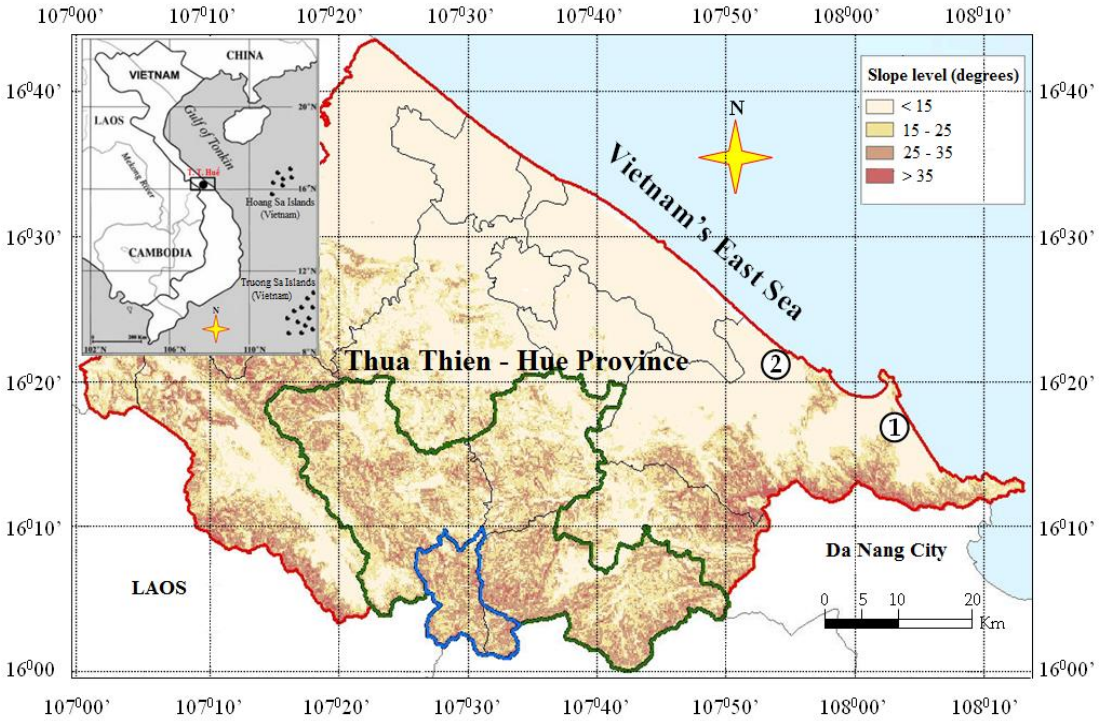

Figure 1. Map showing the study localities in the coastal sandy areas of Phu Loc district, Thua Thien Hue province: (1) Loc Vinh and (2) Vinh Hien locality

Nine field surveys (two days for each survey) were conducted during the rainy season from September to December of 2017. All 50 plots were visited in each survey. Monitoring time lasted from 8:30 to 16:30 h. The presence of *L. guentherpetersi* was recorded in each standard plot (codes: 1 = present, 0 = absent). In each survey at two habitat types, we noted environmental parameters: air temperature, relative humidity, precipitation, and these factors are considered as sampling variables (sample covariates) to infer and select the best model. All statistical analyses were performed with the PRESENCE software version 12.10 (https://www.mbr-pwrc.usgs.gov/software/presence.html).

The following parameters were tested in this study: ψ is the probability of a plot where occupied by *L. guentherpetersi*; p_j is the probability of detecting *L. guentherpetersi* in the j^{th} survey.

Each plot has its own detection history that can be represented by a mathematical equation. Supposing 50 plots were each sampled four times within a season and *L. guentherpetersi* was detected at plot 1 during the first and last survey occasion (1001). The plot was occupied (ψ), the probability of detecting *L. guentherpetersi* during the j^{th} survey was p_j, and *L. guentherpetersi* was detected on the first and last surveys (p_1 and p_4) but not on the second and third surveys. We can write the probability of this detection history as following: $\Pr(H_1 = 1001) = \psi p_1(1 - p_2)(1 - p_3)p_4$.

Plot 2 represents the case where *L. guentherpetersi* was never detected (detection history = 0000). This plot could either be unoccupied, which mathematically is $(1 - \psi)$, or they could be occupied but not detected. In this case, we can write the probability of this detection history as follows: $\psi(1 - p_1)(1 - p_2)(1 - p_3)(1 - p_4)$ or $\psi(1 - p_j)^4$. Thus, we can write the probability of detection history (0000) as follows:

$$\Pr(H_2 = 0000) = \psi \prod_{j=1}^{4}(1 - p_j) + (1 - \psi)$$

Finally, the mathematical equation of all detection histories are combined into model likelihood as follows:

$$L(\psi, p/H_{1,} \ldots, H_{50}) = \prod_{i=1}^{50} \Pr(H_i)$$

Maximum likelihood method was incorporated in the program PRESENCE version 12.10 and this software was used to obtain estimates of occupancy and detectability for *L. guentherpetersi* in the sandy coastal areas of Phu Loc district, Thua Thien Hue Province, central Vietnam. We used two essential models for the present study. The first model assumes that occupancy and detection probabilities with respect to *L. guentherpetersi* are constant across plots and surveys [denoted as $\psi(.)p(.)$]. The second model assumes constant occupancy among plots, but detection probabilities are allowed to vary among nine surveys [denoted as $\psi(.)p$(survey)].

We used the Akaike Information Criteria for small sample size (AIC_c), usually the ratio of $n/K < 40$, where n is the sample size and K is model parameters deduced. The difference in the Akaike Information Criteria for a particular model when compared to the top-ranked model (ΔAIC_c), the AIC model weight (w), the number of parameters for each model (K), and twice the negative log-likelihood value ($-2l$), to establish the process of model selection (Burnham & Anderson, 2002). All models with AIC differences of < 2.0 have a substantial level of empirical support and should be considered when making statistical inferences or reporting parameter estimates of the best models (Burnham & Anderson, 2002).

RESULTS AND DISCUSSION

During nine surveys, *L. guentherpetersi* was detected at least once at 17 of the 50 plots, yielding an overall naive occupancy estimate of 0.34 (detection probability < 1). However, testing the global model (the model with the most parameters) from the candidate set, the model [ψ(NS), p(temp,humid,W1,W2,W3)], when combined with environmental factors, the probability of occupying is 0.383. The naive occupancy estimate of *L. guentherpetersi* in the Loc Vinh locality (0.4) was higher than the Vinh Hien locality (0.3).

We used two basic models to test the level of statistical significance. The first model [ψ(.),p(.)] assumes that the occupancy and detection probabilities are constant across plots and surveys. The second model [ψ(.),p(survey)] assumes constant occupancy among plots, but detection probabilities are various among nine surveys (Table 1). The results of testing were as following: $\chi^2 = 26.04$, degree of freedom (df = 8), significant level ($p < 0.001$). This result indicated that the probability of detecting *L. guentherpetersi* being affected by different surveys and environmental factors. Thus, through the level of statistical significance between two basic models, we have sufficient evidence to select and infer the further models.

Table 1. Summary of two basic models to test the statistical significance of the detection probability of *L. guentherpetersi* in the coastal sandy areas of Phu Loc district. AIC_c = Akaike's Information Criteria for small sample size; ΔAIC_c = the difference in AIC value for a particular model when compared with the top-ranked model; *w* = the AIC model weight; ML = model likelihood; *K* is the number of inference parameters; *–2l* is twice the negative log-likelihood value.

Model	AIC_c	ΔAIC_c	*w*	ML	*K*	*–2l*
ψ(.),p(survey)	187.78	0.00	0.993	1.00	10	167.78
ψ(.),p(.)	197.82	10.04	0.007	0.01	2	193.82

The results of two basic models showed that the detection probability of *L. guentherpetersi* in the coastal sandy areas of Phu Loc district was influenced by surveys and environmental factors. The detection probability of *L. guentherpetersi*, when combined with environmental factors (temperature, humidity, and rainfall) was 0.383, which was higher than the naive probability (not combined with environmental factors) of 0.34 (a 12.65% increase over the plot proportion at which *L. guentherpetersi* was actually observed). The probability of detecting *L. guentherpetersi* over nine different surveys was shown in Fig. 2.

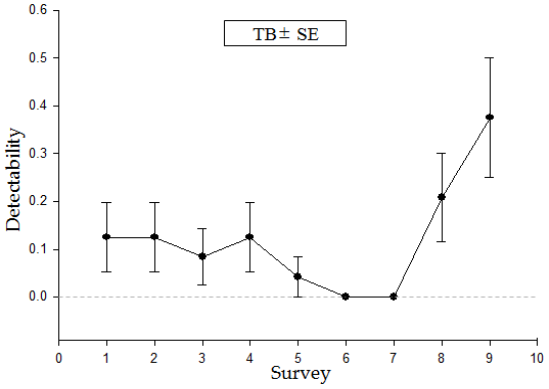

Figure 2. The probability of detecting *L. guentherpetersi* from the model [ψ(.), p(survey)] in this study.

Testing the model with the most parameters (seven parameters) from the candidate set (Table 2), the model [ψ(NS),p(temp,humid,W1,W2,W3)], does not show any evidence of overdispersion (χ^2 = 135.54, p = 0.1287, weighted $\hat{c}$ = 1.13), indicating insufficient evidence of the poor model fit using 10,000 bootstrap iterations. From this model with habitat types close to the sea, when combined with temperature, humidity and other weather factors (sunny, rain, and unidentified sunny-rain), the occupancy probability of *L. guentherpetersi* was 0.383; which was higher than the probability of occupying plots from the model [ψ(.), p(survey)] of 0.378.

Table 2. Summary of candidate models to infer the possible effects of environmental factors on the detection of *L. guentherpetersi* in the coastal sandy areas of Phu Loc district. NS = plots near the sea; FS = plots far from the sea; temp = temperature; humid = humidity; W = weather (including W1 = sunny; W2 = rain; W3 = unidentified sunny-rain)

Model	AIC_c	ΔAIC_c	*w*	ML	*K*	*–2l*
ψ(NS),p(temp,W1,W2,W3)	153.87	0.00	0.363	1.00	6	141.87
ψ(NS),p(W1,W2,W3)	153.87	0.00	0.359	1.00	5	141.87
ψ(NS),p(temp, humid,W1,W2,W3)	155.81	1.94	0.137	0.38	7	141.82
ψ(FS),p(temp, humid,W1,W2,W3)	155.82	1.95	0.135	0.38	7	141.82
ψ(NS),p(temp, humid)	164.27	10.40	0.002	0.01	4	156.27
ψ(FS),p(temp, humid)	164.27	10.40	0.002	0.01	4	156.27
ψ(FS),p(humid,W1,W2,W3)	165.33	11.46	0.001	0.00	6	153.33
ψ(NS),p(humid,W1,W2,W3)	165.33	11.46	0.001	0.00	6	153.33
ψ(FS),p(temp,W1,W2,W3)	171.49	17.62	0.000	0.00	6	161.49
ψ(FS),p(W1,W2,W3)	171.49	17.62	0.000	0.00	5	161.49
ψ(FS),p(humid)	180.51	26.64	0.000	0.00	3	174.51
ψ(NS),p(humid)	180.51	26.64	0.000	0.00	3	174.51
ψ(NS),p(temp)	218.61	64.74	0.000	0.00	3	212.61
ψ(FS),p(temp)	218.61	64.74	0.000	0.00	3	212.61

To evaluate the site covariates that affect the probability of detecting *L. guentherpetersi* in the coastal sandy areas of Phu Loc district, based on the influence of AIC weight on $\Delta AIC \leq 2.0$; the total AIC weight NS = 0.859, accounting for 85.9%; the total AIC weight FS = 0.135, accounting for 13.5% (evidence ratio [Akaike weight of the ψ(NS) model/Aikaike weight of the ψ(FS) model = 6.36 times). This indicated that habitat types near the sea were strong determinants of *L. guentherpetersi* occupancy and the near sea ecosystem was the best habitat for this species.

In addition, the detection probability of *L. guentherpetersi* also being influenced by the sample covariates such as temperature, humidity, rainfall, and even surveys. Our results showed that the total AIC weight temp = 0.623; the total AIC weight humid = 0.272; the total AIC weight W = 0.994. From these results indicated that environmental factors affected the detection probability of *L. guentherpetersi*. However, weather conditions were the most important factor for the detection probability of *L. guentherpetersi* compared to temperature and humidity factors. To determine the influence of each weather factor (sunny, rain, and unidentified weather) for the detection probability of *L. guentherpetersi*, we used the candidate models as presented in table 3.

Weather conditions had a great effect on the detection probability of *L. guentherpetersi*. In there, the total AIC weight W1 = 0.418; the total AIC weight W2 = 0.582; the total AIC weight W3 = 1.0. As a result, the detection probability of *L. guentherpetersi* being influenced by site covariates (near the sea or far from the sea) and sample covariates (temperature, humidity, and rainfall). In there, weather conditions had a direct and significant impact on the detection probability of *L. guentherpetersi* and the unidentified weather factor (W3) still had the greatest influence.

Table 3. Summary of candidate models to infer the effect of sunny, rain, and unidentified sunny-rain factors on the detection probability of *L. guentherpetersi* in the coastal sandy areas of Phu Loc district

Model	AIC_c	ΔAIC_c	*w*	ML	*K*	*–2l*
ψ(NS),p(W2,W3)	195.76	0.00	0.395	1.00	4	187.76
ψ(NS),p(W1,W3)	195.76	0.00	0.229	1.00	4	187.76
ψ(FS),p(W1,W3)	196.77	1.01	0.189	0.62	4	188.77
ψ(FS),p(W2,W3)	196.77	1.01	0.187	0.61	4	188.77
ψ(NS),p(W3)	216.35	20.59	0.000	0.00	3	210.35
ψ(FS),p(W3)	216.35	20.59	0.000	0.00	3	210.35
ψ(NS),p(W1,W2)	237.55	41.79	0.000	0.00	4	229.55
ψ(FS),p(W1,W2)	237.55	41.79	0.000	0.00	4	229.55
ψ(NS),p(W2)	255.41	59.64	0.000	0.00	3	249.41
ψ(FS),p(W2)	255.41	59.64	0.000	0.00	3	249.41
ψ(FS),p(W1)	258.49	62.73	0.000	0.00	3	252.49
ψ(NS),p(W1)	258.49	62.73	0.000	0.00	3	252.49

Note: symbols and abbreviated words in this table like table 2

CONCLUSION

The detection probability of *L. guentherpetersi*, when combined with environmental factors, was 0.383, which was higher than the probability of naive detection (only 0.34). The extinct probability of this species in the study area was very high (about 62.2%).

The detection probability of *L. guentherpetersi* being affected by the site covariates (evidence ratio of Akaike weight = 6.36 times). In there, the near sea ecosystem was the best habitat for this species.

The detection probability of *L. guentherpetersi* also being influenced by sample covariates (temperature, humidity, and rainfall). In there, the unidentified weather factor had the greatest influence.

Acknowledgements: This research was supported by the Department of Biology, Hue University of Education. We thank Huynh Thi Tuong Vy, Nguyen Tan Long, Dong Thi Suong, Ho Thi My Quy and Tran Thi Kim Anh for our assistance during the study period.

REFERENCES

Burnham K. P., Anderson D. R., 2002. Model Selection and Inference: a Practical Information-theoretic Approach. Springer-Verlag, New York, USA, 488 pp.

Darevsky I. S., Kupriyanova L. A., 1993. Two new all-female lizard species of the genus *Leiolepis* Cuvier, 1829 from Thailand and Vietnam (Squamata: Sauria: Uromastycinae). *Herpetozoa*, 6(1/2): 3–20.

Grismer J. L., 2010. Phylogeny, Taxonomy, Biogeography and Evolution of Asexuality within the Southeast Asian Lizard Genus *Leiolepis* Cuvier (1829). A Thesis Presented to the Department of Biology, Villanova University, USA.

Grismer J. L., Bauer A. M., Grismer L. L., Thirakhupt K., Aowphol A., Oaks J. R., Wood P. L., Onn C. K., Thy N., Cota M., Jackman T., 2014. Multiple origins of parthenogenesis, and a revised species phylogeny for the Southeast Asian butterfly lizards, *Leiolepis. Biol. J. Linn. Soc*., 113: 1080–1093.

Grismer J. L., Grismer L. L., 2010. Who's your mommy? Identifying maternal ancestors of asexual species of *Leiolepis* Cuvier, 1829 and the description of a new endemic species of asexual *Leiolepis* Cuvier, 1829 from Southern Vietnam. *Zootaxa*, 2433: 47–61.

Le N. T., Ngo C. D., 2009. Some population characteristics of the Butterfly Lizard *Leiolepis reevesii* (Gray, 1861) and *Leiolepis guentherpetersi* in Da Nang. Proceedings in the 1stNational Scientific Workshop on Amphibians and Reptiles in Vietnam". Hue University Press, Hue, Vietnam, pp. 233–244.

Nguyen V., Truong D. H., Hoang T. L., et al., 2004. Climatic-hydrology characters of Thua Thien Hue province. Thuan Hoa Publishing House, Hue, Vietnam.

Nguyen V. S., Ho T. C., Nguyen Q. T., 2009. Herpetofauna of Vietnam. Edition Chimaira. Frankfurt am Main, Germany, 767 pp.

Tran D. Q., Ngo C. D., Tran T. V., 2009. Comparative analysis of the karyotypes of two Agamidae species of the genus *Leiolepis* in Thua Thien Hue province. Proceedings in the 1st National Scientific Workshop on Amphibians and Reptiles in Vietnam". Hue University Press, Hue, Vietnam, pp. 39–42.

Tran D. Q., Ngo T. Q., 2012. Data on nutrition and growth of the Butterfly Lizards *Leiolepis guentherpetersi* (Darevsky and Kupriyanova, 1993) in raising condition in Hue city. Proceedings in the 2nd National Scientific Workshop on Amphibians and Reptiles in Vietnam. Vinh University Press, Nghe An, pp. 120–136.

Appendix A. The data of detection history for *Leiolepis guentherpetersi* during the the rainy season in the coastal sandy areas of Phu Loc district, Thua Thien Hue province

Plots	NS	FS	Surveys								
			I	II	III	IV	V	VI	VII	VII	IX
1	0	1	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0	0
4	0	1	0	0	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0	0	0	0
6	0	1	0	0	0	0	0	0	0	0	0
7	0	1	0	0	0	0	0	0	0	0	1
8	0	1	0	0	0	0	0	0	0	0	0
9	0	1	0	0	0	0	0	0	0	0	0
10	0	1	0	0	0	0	0	0	0	0	0
11	0	1	0	0	0	0	0	0	0	1	0
12	0	1	0	0	0	0	0	0	0	0	0
13	0	1	0	0	0	0	0	0	0	0	0
14	0	1	0	0	0	0	0	0	0	0	1
15	0	1	0	0	0	0	0	0	0	0	0
16	1	0	0	0	0	0	0	0	0	0	0
17	1	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	1	0	0	0	0	1	1
19	1	0	1	0	0	0	0	0	0	0	1
20	1	0	0	0	0	0	0	0	0	0	1
21	1	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	0	0	0	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0
24	1	0	0	0	0	0	0	0	0	0	0
25	1	0	0	0	0	0	0	0	0	0	0
26	1	0	0	0	0	0	0	0	0	0	1

Plots	NS	FS	Surveys								
			I	II	III	IV	V	VI	VII	VII	IX
27	1	0	1	0	0	1	0	0	0	0	0
28	1	0	0	0	0	1	0	0	0	1	0
29	1	0	0	0	1	1	0	0	0	0	0
30	1	0	1	0	0	0	0	0	0	0	0
31	1	0	0	0	0	0	0	0	0	0	0
32	1	0	0	0	0	0	0	0	0	0	1
33	1	0	0	0	0	0	0	0	0	0	0
34	1	0	0	0	0	0	0	0	0	0	0
35	1	0	0	0	0	0	0	0	0	0	0
36	1	0	0	0	0	0	0	0	0	0	0
37	1	0	0	1	0	0	0	0	0	1	0
38	1	0	0	0	0	0	0	0	0	0	0
39	1	0	0	1	0	0	1	0	0	0	1
40	1	0	0	1	0	0	0	0	0	0	0
41	0	1	0	0	0	0	0	0	0	0	1
42	0	1	0	0	0	0	0	0	0	0	0
43	0	1	0	0	0	0	0	0	0	1	0
44	0	1	0	0	0	0	0	0	0	0	0
45	0	1	0	0	0	0	0	0	0	0	0
46	0	1	0	0	0	0	0	0	0	0	0
47	0	1	0	0	0	0	0	0	0	0	0
48	0	1	0	0	0	0	0	0	0	0	0
49	0	1	0	0	0	0	0	0	0	0	0
50	0	1	0	0	0	0	0	0	0	0	0