MINISTRY OF EDUCATION AND TRAINING
HUE UNIVERSITY
HUE COLLEGE OF EDUCATION

NGUYEN VAN HOANG

STUDY ON THE POPULATION STATUS OF THE ASIAN WATER DRAGON (*Physignathus cocincinus* Cuvier, 1829) WITH IMPLICATIONS FOR CONSERVATION IN THUA THIEN HUE

Major:**Zoology**
Code:**62 42 01 03**

SUMMARY OF DOCTOR OF BIOLOGY THESIS

Academic Instructors:
PROF. PHD. NGO DAC CHUNG
ASSOC. PROF. PHD. NGUYEN QUANG TRUONG

HUE - 2018

This thesis was completed at: .....

.....

Academic Instructors:
1. Prof. PhD. Ngo Dac Chung
2. Assoc. Prof. PhD. Nguyen Quang Truong

1. Reviewer 1:.....

.....

2. Reviewer 2:.....

.....

3. Reviewer 3:.....

.....

The thesis will be protected at the thesis review Council of Hue University meeting at:.....

At, ...hours, day..... , month ..... , year .....

This thesis can be found at the library: .....

INTRODUCTION

1. Reason for choosing topic

The Asian Water Dragon, *Physignathus cocincinus*, was originally described from southern Vietnam (Cuvier, 1829). The Asian Water Dragon is widely distributed in tropical forests from Southern China through Vietnam, Laos, southwards to Thailand. In Thua Thien Hue, *P. cocincinus* has been recorded in the evergreen forests of A Luoi, Huong Thuy, Huong Tra, Phu Loc and Nam Dong districts (Nguyen et al. , 2009). This species was listed in the Vietnam Red Data Book (2007) as Vulnerable due to the population reduction and a decline in area of extent of occurrence and habitat quality (Dang et al., 2007). However, populations of this species are being hunted excessively to make specialty foods and trade in domestic and foreign markets. Besides, many construction works traffic through forests, deforestation, and burning forest for cultivation are also causes of loss or habitat loss of this species. Research on the Asian Water Dragon the world and in Vietnam focuses on characterization of morphology and distribution records. In 2007, there was a study on the nutritional and reproductive characteristics of the Asian Water Dragon in captivity in Nam Dong district, Thua Thien Hue province. In 2009, there was a research on fertility and growth of this species in captivity in Ben Tre province, the juveniles were collected from Nam Dong district, Thua Thien Hue and Dak Nong province. In 2012, there was a study of the Asian Water Dragon as a scene.

2. Study purposes

Assess the population status, ecological characteristics, distribution and diet of *P. cocincinus* in Thua Thien Hue province with implications for conservation.

3. Study scope

3.1. Assess the population status of Physignathus cocincinus in Phong Dien, A Luoi and Nam Dong districts

- Estimate the population density;
- Estimate the population size;
- Assess the population structure at study sites, age groups and sexes.

3.2. Assess the distribution characteristics and ecological characteristics of Physignathus cocincinus

- Distribution of *P. cocincinus*in altitude and habitat;

- Characteristics of microhabitat and home range;
- Foraging mode of *P. cocincinus*.

3.*3. Dietary composition of Physignathuscocincinus*

- Dietary compositionof *P. cocincinus*ineach study site;
- Dietary composition*P. cocincinus*ineach habitat, age groups and sex.

3.4. Assess the impact factors and propose recommendations for the conservation and sustainable use of Physignathus cocincinus

- Determiningthe threats to habitat and population;
- Proposing the conservation of microhabitat and sustainable use of *P. cocincinus*.

4. The scientific and practical significance of the thesis

The results of this thesis provide updated data on the population status as a scientific basis for the planning ofthe Asian Water Dragon conservation in Thua Thien Hue Province. It also providesthe ecological and dietary compositionof *P. cocincinus*which are useful information for the captivity and development of this endangered reptile in Thua Thien Hue Province as well as replication in other localities.

5. New contributions of the thesis

- Provide the first contribution of information on the status and population structure of *P. cocincinus*in Thua Thien Hue Province.
- Determine the distribution characteristics, foraging mode and use of microhabitats of *P. cocincinus*in natural habitat.
- Identify thedietary composition, important prey items of *P. cocincinus*.
- Determine factors affect the microhabitat and populations of*P. cocincinus*in the study sites and proposethe conservation and sustainable development of the Asian Water Dragon in Thua Thien Hue Province.

CHAPTER 1. LITERATURE REVIEW

Through the references in the world as: Cuvier (1829), Duméril and Bibron (1837), Boulenger (1885), Barbour (1912), Smith (1935), Taylor (1963), Nabhitabhata et al. (2000), Teynie et al. (2004), To (2005), Stuart et al. (2006), Grismer et al. (2007), Grismer et al. (2008a, 2008b), Hartmann et al.(2013) show that the study of *Physignathus cocincinus*focused only on the morphological characteristics and record habitat of this species. Smith (1935),Vosjoli (1992), Kaplan (1997),Foster and Smith (1997) studied on the ecology of *P.*

*cocincinus*in captivity. In Vietnam, Bourret's (1937, 1940, 1943) Amphibians and Reptiles studies in Indochina and Vietnamese scientists only described morphological characteristics and only record the habitat of *P. cocincinus*. Ngo Dac Nguyen et al. (2007), Ngo Dac Thong and Bui Thi Thuy Bac (2009) studied on the reproduction and growth of *P. cocincinus* in captivity. In 2012, there was a study of the Asian Water Dragon as a scene. Therefore, making a study of the population status of the asian water dragon (*P. cocincinus* Cuvier, 1829) in Thua Thien Hue, Viet Nam with implications for conservation is needed to provide scientific data for further studies and this is especially true for the conservation and sustainable use of these endangered reptiles

CHAPTER 2
SITES, TIME, OBJECTIVES AND METHODS OF STUDY

2.1. Study sites and research period

2.1.1. **Study sites:**At streams in the evergreen forests of A Luoi, Nam Dong and Phong Dien district. Interviews the hunterofthe status of hunting and trade *P. cocincinus*in study sites and restaurants in Hue City (Figure 2.1).

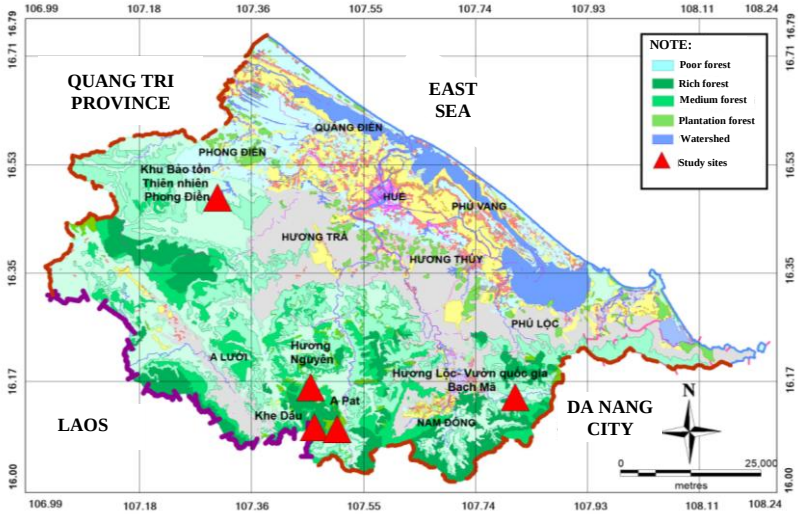

Figure 2.1. The map of survey sites, study on *Physignathus cocincinus* in the mountain region of Thua Thien Hue province

2.1.2. Research period:This thesis was conducted from August 2014 to August 2017.

2.2. *Study object:**Physignathus cocincinus* (Cuvier, 1829), Agamidae, Squamata, Reptilia.

2.3. Research methods

2.3.1. Survey fields

2.3.1.1. Instruments: Camera, spotlights, GPS, electronic rulers, electronic scales, device of temperature and humidity, device of measure body temperature and surfaces temperature of substrate where P. cocincinus lived in. Eraser to make a mark and marked labels tie to the position of *P. cocincinus*. The plastic bottle wasmarked labels tocontain food, 70% alcohol, and stomach-flushing device.

2.3.1.2. Field survey: Survey 11 routes along streams in three habitats: primary forest habitats, primary forest habitats alternated with secondary forests, secondary forest habitats alternated with plantation forest (Table 2.1).

2.3.1.3. Data collection for microhabitat and sample of the Asian Water Dragon:

- Record microclimate conditions: Measure the air temperature and humidity. Record weather such as rainy, sunny, murky. Measure the temperature of substrate where*P. cocincinus* lived at; Measure airtemperature and temperature of *P. cocincinus* to evaluate the change of the body temperature of *P. cocincinus* according to the temperature of the environment, record about weather conditions.

- Record microhabitat: Substrate type: rock; dead wood; branch; bamboo; leaf; sand; water; convolve; ground; Measure the distance from the animal to the water surface (m), the distance is calculated perpendicular from the position of the animal to the middle of the stream. Estimate the forest cover (%) where the animal lived in, note the coordinates and altitude at the position of *P. cocincinus*.

- Observe theforaging mode and morphological characteristics: foraging mode such as predatory behavior, observation and waiting behavior, bask behavior, fighting and reproduction activities, recording microclimate conditions and microhabitat. Collecting *P. cocincinus*, observation of secondary reproductive characteristics such as body color, developmental level of spine, chin scales, weight and measurement morphology.

- Collect the stomach-flushing method of Solé et al. (2005) to obtain stomach contents without sacrificing lizards.

- Estimate population density and sizes of *P.cocincinus* by "Capture-recapture Method" (Van Schingen et al., 2014).

Table 2.1. The routes (streams) surveyed in Phong Dien, Nam Dong and A Luoi, Thua Thien Hue province

Sites	Routes	**Coordinates of first point**	**Coordinates final point**	**Altitude (m)**	**Length of routes (m)**
Phong Dien	T-1	N 16°28' 24.9" E 107°18'08.9"	N 16°28' 04.8" E 107°18'54.7"	44-90	860
	T-2	N 16°28' 06.2" E 107°18'38.5"	N 16°28' 04.8" E 107°18'5.4"	43-75	1.300
A Luoi	T-3	N 16°04'55.3" E 107°28'87.9"	N 16°04'61.9" E 107°28'87.9"	706-780	320
	T-4	N 16°05'14.1" E 107°27'32.6"	N 16°05'21.2" E 107°27'33.6"	720-820	250
	T-5	N 16°05'12.6" E 107°28'67.6"	N 16°05'26.4" E 107°28'86.1"	623-770	420
	T-6	N 16°09'27.4" E 107°27'01.0"	N 16°09'17.3" E 107°26'48.1"	176-250	950
	T-7	N 16°09'20.2" E 107°27'15.1"	N 16°09'10.8" E 107°27'03.9"	179-214	700
Nam Dong	T-8	N 16°07'55.9" E 107°48'11.2"	N 16°07'32.9" E 107°48'06.5"	129-179	1.400
	T-9	N 16°08'22.6" E 107°48'52.9"	N 16°08'51.4" E 107°48'56.9"	173-269	1.300
	T-10	N 16°08'11.4" E 107°47'57.8"	N 16°08'22.6" E 107°48'16.9"	111-145	1.000
	T-11	N 16°08'22.9" E 107°47'22.2"	N 16°08'32.6" E 107°47'18.2"	105-129	460

2.3.2. Assessment of population status and dietary composition

2.3.3.1. Age determination: We divided them into three age groups: Adult with SVL > 140 mm, sub adult with 100 mm < SVL ≤ 140 mm and juvenile with SVL ≤ 100 mm.

2.3.2.2. Sex determination: Sex determination is based on SVL and secondary sexual characteristics. Estimating Sexual Size Dimorphism (SSD) between males and females according to Cox et al. (2003), Ngo Dac Chung and Nguyen Quang Truong (2015):

SSD = [SVL mean of male/SVL mean of female] - 1

2.3.2.3. Population density estimation: Applying Regas & Yirga (2013) as follows: D = n × s/(2L × W), adapted to behavior of this speciesD = n × s/[L × (W1 + W2)].

Where: D is the estimated population density; n is the number of visible groups; s is the average number of individuals/groups; L is the length of routes; W_1 and W_2 are the average distance (perpendicular) of the visible group to the right and left of the routes.

2.3.2.4. Estimation of population size

- Schnabel index: According to the following formula (The routes were surveyed repeatedly many times):

$$N = \frac{\sum_{i=1}^{m} M_i C_i}{\sum_{i=1}^{m} R_i}$$

Where: N is the estimated population size; M_i is the total number of individuals marked at the i^{th} survey; C_i is the number of individuals captured at the i^{th} survey; R_i is the number of individuals recaptured at the i^{th} survey.

With the error was calculated (Schlüpmann, Kupfer 2009):

$$VB(95\%) = \overline{P} \pm 1{,}96\sqrt{\frac{1}{k(k-1)}\sum^{k}\left(P_i - \overline{P}\right)^2}$$

Where: k is the number of individuals recaptured; P_i is the number of individuals captured in the i^{th} survey.

- Lincoln & Petersen Index (The routes only were surveyed once times):

$$P = \frac{n_1 \times n_2}{m_2}$$

Where: P is the estimated population size; n_1 is the number of individuals marked and dropped during the first survey; n_2 is the number of new individuals marked in the second survey; m_2 is the number of individuals recaptured.

2.3.2.5. Identification of prey categories: Millar et al. (2000), Triplehorn & Johnson (2005) and Edward et al. (2004).

- The volume of prey categories was calculated according to the following formula:

$$V = \frac{4}{3}\pi \times \frac{L}{2} \times (\frac{W}{2})^2$$

Where: V is the volume of prey (mm^3), L is the length of the prey (mm), W is the width of the prey (mm, the widest part) (Magnusson et al., 2003).

- Index of Relative Importance (IRI)

$$IRI = \frac{F\% + N\% + V\%}{3}$$

Where: IRI is relative importance index for each prey category, *F*% is occurrence percentage, *N*% is numeric percentage, and *V*% is volumetric percentage.

- We use the reciprocal Simpson's heterogeneity index, 1/*D*, to calculate dietary prey heterogeneity:

$$D = \sum \frac{n_i(n_i - 1)}{N(N - 1)}$$

Where: D is Simpson's index, n_i is the number of prey items in the i^{th}prey category and N is the total number of prey categories (Krebs, 1999). To estimate prey evenness, we used the Shannon's evenness. The evenness is calculated from the equation: $H' = H_{max} = \ln S$, S is the total number of prey taxa and H' is the Shannon-Weiner index of taxon diversity. Here, the value of H' is calculated from is the proportion of total food items the equation $H' = -\Sigma p_i \times \ln p_i$ where the quantity p_i is the proportion of total food items belonging to the taxon for the total food items of the sample i^{th}.

The rarefaction method was used to estimate the diversity of diet among adults, subadults, and juveniles. We standardized all diet samples from the rarefaction method using the modified algorithm by Hurtlbert (1971) and Simberloff (1972) as follows:

$$E(S_n) = \sum_{i=1}^{S} \left[1 - \frac{\binom{N - N_i}{n}}{\binom{N}{n}} \right]$$

Where:$E(S_n)$ is the expected number of prey taxa in a random sample of nprey items, *S* is the total number of prey taxa in the entire collection from stomach contents, N_i is the number of prey items in the i^{th} taxon *N* is the total number of prey items in the entire collection ($=\Sigma N_i$) *n* is the value of sample size (number of prey items) chosen for standardization ($n = N$) and $\binom{N}{n} = N!/n!\,(N\ n)!$isthe

number of combinations of *n* prey items that can be chosen from a set of *N* prey items (Krebs, 1999).

2.3.2.6. Determination of the threat factors and propose conservation measures

- Determine thefactors affect the microhabitat of the species.
- Evaluate of hunting and trade status.
- Identify theprioritysconservation sites by making criteriascore for each study site.

2.3.2.7. Data processing and statistical analysis: Significant difference was detected by software MINITAB 16.0 and SPSS 19.0. The charts were drawn on the software OriginPro 8.5.1 and SigmaPlot 12.0.

CHAPTER 3
RESULTS AND DISCUSSIONS

3.1. Population status

3.1.1. Population structure

3.1.1.1. Morphological characteristics

Thanks to the data, we determined the weight and 15 morphological indexes of 250 individuals of*P. cocincinus*in three age groups and sexes in three study sites. In terms of sex differences, the adult males are larger than the females (Figure 3.1).

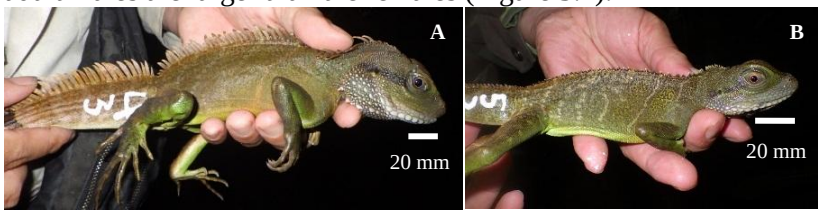

Figure 3.1. *Physignathus cocincinus*(A: male, SVL = 260 mm; B: female, SVL = 165 mm)

Based on length of SVL, individuals with SVL of 140 mm or more are adult males, as secondary genital characteristicswere fully developed and can be clearly distinguished sex of each individual (Figure 3.2).

3.1.1.2. The relationship between bodysize and body weight

The SSD was positive (SSD = 0.21), indicating that there was a difference in SVL between males and females. Indicators of size such as AG, HL, HW, HH in males are larger than females.

Correlation between SVL and body weight (W) of*P. cocincinus*was expressed by linear regression equation: W = 1.987 × SVL - 2.226 ($F_{1,200}$ = 353.76, P< 0.0001), with R^2 = 0.64 was considered to have a close correlation. The correlation between SVL and HL was expressed by the linear regression equation: HL = 0.936 × SVL - 0.402, with R^2 = 0.943 ($F_{1,197}$ = 211.60, P< 0.0001). The correlation between SVL and HW was expressed by the linear regression equation: HW = 0.479 × SVL - 0.243, with R^2 = 0.892 ($F_{1,197}$ = 1,620.96, P< 0.0001). The correlation between SVL and HH was also shown by the regression equation: HH = 0.817 × SVL – 0.427, with R^2 = 0.891 ($F_{1,196}$ = 1,598.62, P< 0.0001).

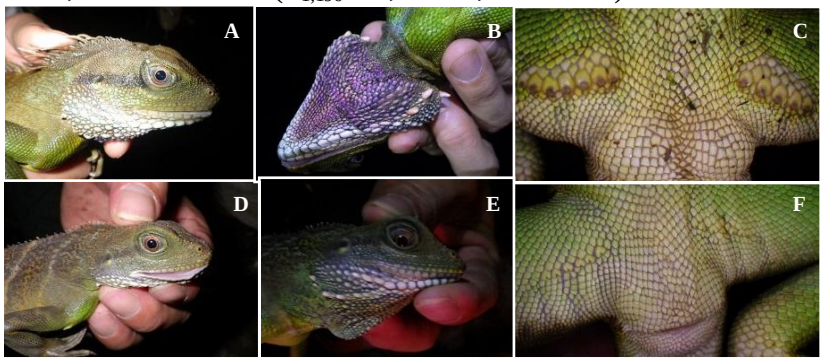

Figure 3.2. Male: crest (A), scales under the chin (B), femoral hole (C); Female: crest (D), scales under the chin (E), femoral hole (F)

3.1.1.3. Population structure

- Age structure:

In A Luoi: In 2016, the results of the two surveys recorded the number of the largest wasthe juveniles(46.6%), followed by the sub adults (31.4%), the lowest was the adults (22.0%).

In Phong Dien: In 2017, the age structure of *P. cocincinus*changed with time: in April recorded the number of the largest was juveniles, followed by adults; in June, the number of the largest was sub adults, then the adults. In the two surveys, the largest was juveniles(45.9%), followed by the sub adults (29.6%), the lowest was adults (24.5%). Age structure of *P. cocincinus*at these routes changed in a stable direction.

In Nam Dong: In 2017, the number of individuals of all age groups declined on the survey routes, especially the adult population

decreased. The number of juvenileswas the most (60.0%), followed by the subadults (24.9%), the lowest was the adult group (9.1%). Age structure of *P. cocincinus*changed unstable.

- Sex structure:

In A Luoi: The two surveys recorded more females (19.5%) than males (18.6%), however, the difference between males and females was not much. In Phong Dien: two surveyswere recorded the number of females (24.0%) more than 1.5 times that of males (14.8%). In Nam Dong: two surveyswere recorded more than twice as many females (15.4%) as males (6.6%). Thus, the sex structure at the three study sites (A Luoi, Phong Dien and Nam Dong) was females (13.4%) more than males (13.1%).

3.1.2. Population density

3.1.2.1. In Phong Dien: In 2017, the estimated population density of *P. cocincinus*in the two routes in April was 93 individuals/10,000 m^2, in June, 101 individuals/10,000 m^2. April and June average about 97 individuals/10,000 m^2. Population density of *P. cocincinus*increased but not significantly.

3.1.2.2. In A Luoi: The estimated population density of *P. cocincinus*in five routes in April and June 2016 about 44 individuals/10.000 m^2. In 2017, estimated the density of populations in June were about 64 individuals/10,000 m^2.

3.1.2.3. In Nam Dong: In April and June 2017, the estimated the density of populations on four routeswere about 28 individuals/10,000 m^2. The population density of *P. cocincinus*in June tended to decrease compared to April in the same year, mainly due to over hunting, especially in Nam Dong and A Luoi. In Phong Dien, theestimated the population density was the highest (about 97 individuals/10,000 m^2), A Luoi (44 individuals/10,000 m^2) and Nam Dong (28 individuals/10,000 m^2). The population density of *P. cocincinus*was distributed at altitudes below 100 m (97 individuals/10,000 m^2) more than twice at altitudes of 100-300 m (48 individuals/10,000 m^2) and more than triple compared to the altitude of 600-800 m (27 individuals/10,000 m^2).

3.1.3. Population size

3.1.3.1. In A Luoi: In 2016, the research was surveyedat five routes (2,640 mlong). In April,the largest population size was estimated at T-7 (38 individuals), followed by T-6 (35 individuals), T-5 with 12

individuals, T-3 and T-4 were 6 individuals/route. In April,the estimated the size of *P. cocincinus*was 97 individuals in total. In June, the largest population size was at T-6 (42 individuals), followed by T-7 with 33 individuals, T-4 with 9 individuals, T-5 with 6 individuals and at least T-3 (5 individuals), the individuals indicated a totalof 95 in June. On average, in April and June 2016, the populationsizes of *P. cocincinus*were 96individuals/5 routes.

In June 2017, two routes were conducted (T-6 and T-7, 1,650 m long), estimated the populationsize at the T-6 was 35 individuals, T-7 was 24 individuals. In June, estimated dataat T-6 and T-7 were 59 individuals. Comparing to the two T-6 and T-7 routes of 2016 (75 individuals) and 2017 (59 individuals), it was clear that the population size of *P. cocincinus*was affected.

3.1.3.2. In Phong Dien: In 2017, the research sites were two routes (T-1 and T-2, 2,160 m long). In April, the population size of *P. cocincinus*at T-2 was 124 individuals. In June, at T-1 route was 56 individuals, T-2 was 87 individuals. In June, the population size of *P. cocincinus*atT-1 and T-2were 143 individuals. In April and June, the average population size at T-1 and T-2 were 81 individuals.

3.1.3.3. In Nam Dong: In 2107, T-8, T-9, T-10 and T-11 (4,160 m long) were surveyed. In April, T-8 and T-9 routes (2,700 m long) were surveyed and the results were 74 individuals at T-8, 52 individuals at T-9. In April, the population size of *P. cocincinus* was 126 individuals/2 routes. In June, surveyed two routes (T-10 and T-11), at T-11 only was surveyed once, so there was no estimate of the population size of *P. cocincinus*. Estimated at the T-10 (1,000 m long) was 30 individuals. On average, in April and June, estimated the population size of *P. cocincinus* at the three routes were78 individuals.

A survey of 10 routes in three study sites showed that the majority of the population of *P. cocincinus* at all routes in June tended to decrease in comparison with April. The main reason was that in May and June, *P. cocincinus* was hunted by hunter in the local.

Thus, the populationsize of *P. cocincinus*in 2016was estimated 96 individuals/5 routes (2,640 m long), on average of 28 m caught 1 individual. In 2017, there were about 59 individuals/2 routes (1,650 m long) in A Luoi, on average of 30 m caught1 individual. There was about 78 individuals/3 routes (3,700 m long) in Nam Dong,on average of 48 m caught 1 individual; in Phong Dien was about 81

individuals/2 routes (2,100 m long) on average of 26 m caught 1 individual. Thus, it was estimated that the population size of *P. cocincinus*at the routes in Phong Dien was the largest, followed by A Luoi and the lowest was in Nam Dong. In total, it was estimated that the population size of *P. cocincinus*at the routes in 2016-2017 was 314 individuals (the error rate is 314 ± 16 individuals).

3.2. Habitat, foraging mode and distribution characteristics

3.2.1. Use of microhabitat

3.2.1.1. Daytime

- The type of microhabitat: Observed the total of 102 times of individuals of *P. cocincinus*shownthat this species was active in six types of microhabitat: branches, leaf, convolve, rocks, sand and grasses along the stream and other microhabitats. Branches were most commonly used (31.3%) ($F_{2,15}$ = 9.49, P = 0.003).

- The height of perches compared to water surface: The adults (2.26 ± 0.87 m) livedat higher than the juveniles (1.12 ± 0.67 m; $F_{1,101}$ = 49.59; P<0.0001). The height from 0.00 to 2.00 m recorded mainly juveniles, the height from 2.01 m to above 3.00 m recorded mainly adults individuals.

- The canopy at the active position of *P. cocincinus*was about 32.3 ± 29.0%; the adults individuals (26.1 ± 30.2%) was lower than the juveniles (34.7 ± 28.4%),($F_{1,101}$ = 1.79, P = 0.18). During the day, *P. cocincinus*tended to activity in airy position, where there was a lot of light and the air temperature raised, humiditydecreased.

3.2.1.2. Night-time

- The type of microhabitat: Observed the total of 494 times of individuals of *P. cocincinus*shown this species was active in 5 types of microhabitat:branches, leaf, convolve, rocks and other microhabitats (in tree niches, swimming in stream...). Branches and leaf were used the most ($F_{1.9}$ = 0.80, P = 0.40). At night, *P. cocincinus*lived at branches, leaf, convolveon the banks of streams to sleep. None of *P. cocincinus*were found in the grass and sand along the stream, indicating that the spawning activities of this species took place mainly during the day.

- The height of perches compared to water surface: Observed the total of 494 times of individuals of *P. cocincinus*. On average,*P. cocincinus* lived at 1.81 ± 1.14 m compared to the water surface. The adults lived at 2.78 ± 1.44 m, the juvenileslived at1.54 ± 0.87

m ($F_{1,493}$ = 122.26, P< 0.0001). The juvenileslived at altitudes ranging from 0.00 m to over 3.00 m in decreasing, the adults lived at from 0.51 m to 3.00 m in increasing. The homerange of activity was about 4.7 ± 6.1 m, the adults moved away from perchesfurther than the juveniles.

- Type of stream: Running stream and pool were recorded the mostof number of *P. cocincinus*; in the waterfalls, we did not record any individual in both of age groups.

- Measurement of air temperature at the position of the adults and the juveniles are in the orders: 27.2 ± 1.5°C, 27.4 ± 1.1°C. Body temperature in the adult group (23.9 ± 1.1°C) was approximately equal to that of the juveniles (23.8 ± 1.5°C). The surface temperature at perches of the adult and juvenile groups were 23.8 ± 1.5°C and 23.4 ± 1.5°C. The air temperature, body temperatureof *P. cocincinus*and surface temperature of perches at the position of *P.cocincinus*between the two age groups were not significantly.

- Canopy at the position of *P. cocincinus*lived at about 66.8 ± 29.2%. The adult group lived at higher (77.3 ± 25.7%) than the juveniles(64.4 ± 29.5%; $F_{1.430}$ = 13.50, P<0.0001).

3.2.2. Foraging mode

3.2.2.1. Daytime: *P. cocincinus* was mainly active in sunny, less active during darksky, especially when it rains. Active time was from 8:00 to 16:00 hours, the strongest activity was from 12:00-14:00 hours. According to Döring (2015), *P. cocincinus* lived in the area with average humidity of 40-80% and air temperature of 26-32°C. In this study, the average air temperature at the time of the strongest activity of *P. cocincinus* was about 30.6 ± 1.4°C, the average humidity of 65.3 ± 10.6%. *P. cocincinus* hunted the prey accounts for the highest proportion, followed by bask and drinking, this behavior issuitable for the "*wide forager*" model rather than the "*sit-and-wait"* model, which was also suitable for some studies results on the common foraging mode of the group of lizards.

3.2.2.2.Night-time: From 20:00 to 21:30 hours recorded the number of *P. cocincinus*appearing the most on the perchesof streams in two age groups. The juveniles recorded as early as 19:31, and the adults recorded after 20:00 hours($F_{1.19}$ = 2.86, P<0.0001).

3.2.3. Distribution by altitude and habitat

3.2.3.1. According to the altitude: The Asian Water Dragonmainly lived at altitudes below 300 m, less lived at altitudes above 600 m. Bain and Hurley (2011) noted that the recorded lizards mainly lived at altitudes below 300 m, at altitudes from 300-800 m recorded small numbers of species.

3.2.3.2. According to the habitat distribution: The Asian Water Dragonis mainly distributed in the secondary forest habitat alternated with plantation forest and primary forest habitat alternated with secondary forest, little distribution in the primary forest habitat.

3.3. Dietary composition

3.3.1. The prey categories in study sites

The Asian Water Dragonconsumed20 prey categories include 18prey categories of insects and other invertebrates, one being plants and one being unknown prey categories (Figure 3.3). IRI (Index of Relative Importance)of the four prey categories was the most of all included: Isoptera (37.35%), Formicidae (14.10%), Orthoptera (9.30%),Insect larvae (7.32%).

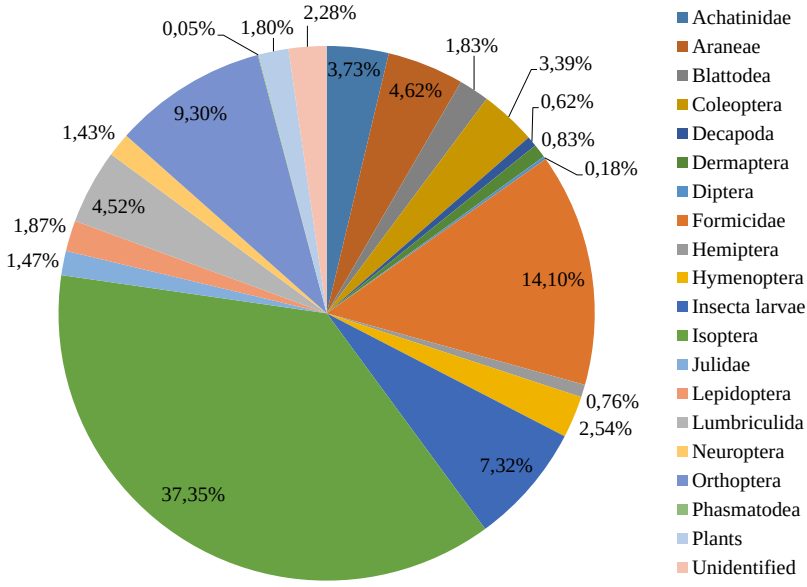

Figure 3.3. Index of Relative Importance(IRI) of prey categories of *Physignathus cocincinus* in Thua Thien Hue province (n = 291)

Ngo Dac Chung et al. (2007) recorded in captivity, the Asian Water Dragonconsumed maintly insects (56.47%), followed by earthworms (24.25%), the adult consumed 16/22 prey categories,the juvenilesconsumed only 11/14 prey categories.

In this study, the *P. cocincinus*consumed20 prey categories, mainly insects (termites, ants), spiders, Insect larvae, crickets and grasshoppers (Orthoptera); earthworms occupied a very low rate, plants were also food of this species. Huey & Pianka (1981) argued that lizard species hunted prey with *widely foraging*model, consumed mainly theprey categoriesin Isoptera.

3.3.2. The prey categories in each study sites

3.3.2.1. A Luoi: *P. cocincinus*consumed20 prey categories, IRI of sixprey categories were the most of all, including: Isoptera(35.57%), Formicidae(14.00%), Orthoptera (9.31%) Insect larvae (6.66%), Lumbriculida (6.29%) and Araneae (5.36%).

3.3.2.2. Nam Dong: *P. cocincinus*consumed 17prey categories, IRI of fourprey categories were the most of all, including: Isoptera (32.30%), Formicidae(22.37%), Orthoptera(10.09%) and Insect larvae (9.55%).

3.3.2.3. Phong Dien: *P. cocincinus*consumed 18prey categories, IRI of sixprey categories were the most of all, including:Isoptera (44.69%), Orthoptera(8.59%), Plants (7.93%), Insect larvae (7.05%), Coleoptera (6.98%) and Formicidae(5.72%).

The prey categoriesin the three study siteswere quite similar. There was four the prey categoriesappearing in three study sites: Isoptera, Formicidae, Insect larvae, and Orthoptera.

In Nam Dong, in the stomach of *P. cocincinus*had the largest volume of food items; followed by Phong Dien and lowest is A Luoi ($F_{2,290}$ = 2.97, P = 0.05). The largest of food items in A Luoi (16.4 ± 32.2 items), followed by Phong Dien (15.4 ± 36.7 items) and lowest in Nam Dong (13.9 ± 16.1 items;$F_{2,290}$ = 0.14, P > 0.05).

In Nam Dong, length, width and volume of food items in the stomach of *P. cocincinus*was the heightest, followed by Phong Dien and the lowest is A Luoi (length: $F_{2,485}$ = 16.07, P<0.0001; width: $F_{2,4.585}$ = 159.24, P<0.0001 and volume: $F2,4.585$ = 10.14, P< 0.0001). Simpson index of prey categories of *P. cocincinus*were the most abundant in Nam Dong(3.11), followed by A Luoi (2.04) and Phong Dien (1.52).

3.3.3. The prey categories by habitat

3.3.3.1. Secondary alternated plantation forest: The four prey categories(IRI ≥ 5.0%) of *P. cocincinus*wereIsoptera (38.85%), Formicidae (14.48%), Orthoptera(9.47%), Insect larvae (8.46%).

3.3.3.2. Primary alternatedsecondary forest:Six prey categories(IRI ≥ 5.0%) of *P. cocincinus*were: Isoptera (36.36%), Formicidae (14.91%), Lumbriculida (9.06%) Insect larvae (7.82%), Orthoptera(5.84%) and Araneae (5.61%).

3.3.3.3. Primary forest: Six prey categories (IRI ≥ 5.0%) of *P. cocincinus* were: Isoptera(34.41%), Formicidae (12.62%), Orthoptera (14.45%), (5.96%), Araneae (5.00%) and Insects larvae (5.00%).

The secondary alternated plantation foresthabitats had the lowest number of food items (14.6 ± 27.7), the primary alternatedsecondary forest (16.6 ± 29) and the primary forest habitat (16.1 ± 36.4). However, the volume of food items in the stomach of *P. cocincinus*in the secondary alternatedplantation forest habitat (4,106.4 ± 5,931.4 mm^3), followed by the primary alternatedsecondary forest habitat (3,131 , 3 ± 5,195.3 mm^3), the lowest is primary forest (2,921.6 ± 3,151.2 mm^3). Difference in the number of food items and the volume of food items in the stomach of *P. cocincinus*in three habitat did not significantly.

The diversity index of prey categories in the plantation alternated secondary forest were the most abundant (2.56), followed by primary secondary forest (2.09) and the smallest primary forest (1.97). In the plantation alternatedsecondary forest habitats, food items: 12.3 ± 7.6 mm in length, 4.5 ± 2.6 mm in width, and 281.0 ± 684.8 mm^3in volume were the largest; length, width and volume of food items between primary alternated secondary forest and primary forest habitats were not much different (length: $F_{2,485}$ = 14.20, P< 0.0001, width: $F_{2.4858}$ = 146.94, P < 0.0001 and volume: $F_{2.4855}$ = 5.40, P = 0.005).

3.3.4. The dietary composition P. cocincinus by age groups

The adults consumed four prey categories (IRI ≥ 5.0%) were: Isoptera (43.79%), Formicidae (13.46%), Orthoptera(6.97%), insects larvae (5.86%). The subadults ate five prey categories were: Isoptera(43.12%), Formicidae (9.91%), Orthoptera(10.20%), Araneae (5.39%) and Insect larvae (5.72%). The juvenilesconsumed six prey categories: Isoptera (22.52%), Formicidae (21.11%), Orthoptera (9.98%), Insects larvae (10.53%), Lumbriculida (7.81%)

and Araneae (5.76%).Four prey categories: Isoptera, Formicidae,Orthoptera and Insects larvae were recorded in the stomach in all three age groups. According to Pough et al. (1998),the most adult lizards consumed the same prey categories as juveniles, but in the development stage they only need to eat some other food items. This study also showed that in addition to the main food items were insects, the subadultsand the juvenilesconsumedsome prey categories (earthworms, spider).

The adultsconsumed the food items the largest in length, width and volume, the subadults and juvenilesconsumed the approximately equal size the food items in length, width and volume (length: $F_{2.485}$ = 166, P<0.0001; as such, *P. cocincinus*consumed different sizes and volumes of food items depend on age groups.

On average, the number of food items per stomach of sub adultswas the highest (21.7 ± 44.9), followed by the adults (15.0 ± 20.1) and the smallest was the juveniles (11.0 ± 19.3, $F_{2,290}$ = 3.50, P = 0.03). The volume of food items in per stomach of the adults (4,447.2 ± 6,330.3 mm^3) and the subadults (4,175.7 ± 5,514.3 mm^3) were not much different. The volume of food items in the stomach of juveniles were the smallest(2,257.2 ± 3,359.9 mm^3, $F_{2,29}$ = 5.94, P = 0.003). The subadults consumed a much larger food items than adults and juveniles. Simpson index of thejuveniles was the most abundant (3.12), followed by the adults (2.06) and the subadults (1.76). Results from the Rarefaction analysis showed that juveniles and adult consumed a more food items than subadults. The adults and subadultsconsumed equallymore food items than the juveniles

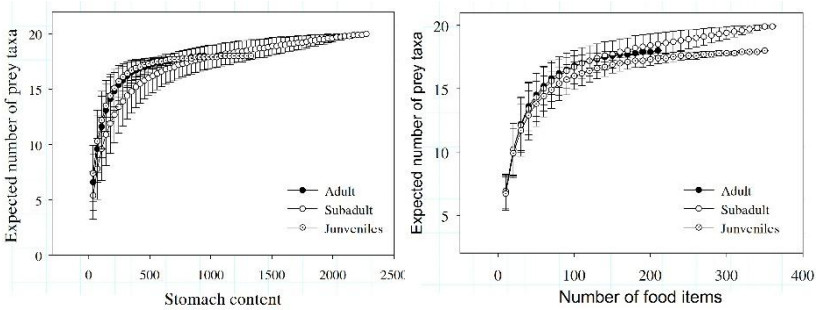

Figure 3.4.Expected prey-taxon accumulation curves from the data of stomach contents (A) and food items(B) by *Physignathus cocincinus*

3.3.5. The dietary composition by sex Physignathus cocincinus

The males consumedfivemainly prey categories: Isoptera (45.16%), Formicidae (9.79%), Plants (5.91%), Orthoptera(5.55%) and Insect larvae (5.29%). The females consumed six mainly prey categories: Isoptera (42.17%), Formicidae (17.23%), Orthoptera(8.33%), Insect larvae (6.50%) and Hymenoptera (5.53%).

On average,the number of food itemsin per male stomach more than female, but was not significant ($F_{1.62}$ = 0.17, P = 0.678). The volume of food itemswere consumed by females was larger than that of males but not significant ($F_{1.62}$ = 0.08, P = 0.781). Simpson index shown that: females (2.24) consumedthe abundant of food itemsmore than males (1.88). Males tended to consumethe food items more equallythan females shown by Evenness index (female: 0.21 and males: 0.19). The mouth width of the largest adult male (25.5 ± 7.3 mm), followed by adult females (22.5 ± 3.1 mm) and juveniles (16.2 ± 1.9 mm). The malesconsumed the largestof food items in length, width and volume, followed by females and juveniles($F_{3,1.404}$ = 20.32, P<0.0001).

3.3.6. Comparison of dietary composition in captivity and in nature

*P. cocincinus*consumed 20 prey categories as insects, invertebrates and plants, seven mainly prey categories: termites (Isoptera), ants (Formicidae), earthworms(Lumbriculida), spiders (Araneae), Insect larvae, some species of Coleoptera and plant. In captivity, *P. cocincinus*consumed 26 prey categories, there are fiveprey categories were insects and invertebrates and four favorite food items are fruits (bananas, mangos, jackfruit, papaya).

3.4. Evaluate the impact factors and propose recommendations for the conservation and sustainable use of *Physignathus cocincinus*

3.4.1. Impact factors

3.4.1.1. Over-hunting

- In A Luoi: Hunting the Asian Water Dragonfrom February to October every year, especially from April to August. A total of seven households hunted about 364.5 kg the Asian Water Dragon/year. The eggs of the Asian Water Dragon were taken.

- In Nam Dong: Hunting time was also from February to October every year. On average in 2016, eight households hunted 224 kg, mainly juveniles and subadults.

- In Phong Dien: The Asian Water Dragonwas harvested the highest quantities from May to July (June: 82 kg), the lowest in October (10 kg). In 2016, six households hunted 400.5 kg. A total quantitieswas estimated about 989 kg/year (Table 3.1).

Table 3.1. Estimated quantities of *Physignathus cocincinus*was hunted in A Luoi, Nam Dong and Phong Dien district in 2016

Month	Average quantities (kg)			
	A Luoi	Nam Dong	Phong Dien	Total
2	11	5	10	26
3	27	12	34.5	73.5
4	47.5	28	62	137.5
5	72	51	66	189
6	80	57	82	219
7	64.5	35	74	173.5
8	37,5	24	48	109.5
9	18	8	18	44
10	7	4	6	17
Total	**364.5**	**224**	**400.5**	**989**

Figure 3.5. *Physignathus cocincinus*at A Luoi market (A);

***Physignathus cocincinus*at restaurants in Hue city (B, C, D)**

- Situation of use: There are 13 restaurants that sold *P. cocincinus* irregularly (Phong My commune: 2 restaurants, A Luoi district: 4 restaurants, Khe Tre town: 3 restaurants,Huecity: 5 restaurants, the Asian Water Dragon was processed into a variety of dishes (Figure 3.5).

3.4.1.3. Impact on habitats

- Timber and non-timber forest product exploitation: The results of the study on microhabitatof *P. cocincinus*shown that this species mainly distributed at altitudes below 300 m, logging activities, burning forest for cultivation ... has negatively affected the habitat of *P. cocincinus*.

- Building traffic through the forest.

3.4.2. Propose recommendations for the conservation and sustainable use of Physignathus cocincinus

3.4.2.1. Exclusion of priority protected areas

In order to preserve the population of *P. cocincinus* in A Luoi, Nam Dong and Phong Dien districts in Thua Thien Hue province, managers should prioritize the preservation of the area of the routes in the following order: The first is T-2 and T-1 routes; followed by T-7, T-6; to the T-3, T-4, T-8; the finally is the T-5, T-9, T-10 and T-11 (Figure 3.6).

3.4.2.2. Captivation for conservation and economic development

Captivate the *P. cocincinus*is one of the measures to limit hunting of this species in the wild, and helping to develop the economyofhousehold at mountain regions.

3.4.2.3. Solutions

- Control illegal hunting and trading.

- Strengthen patrols to prevent violations that have a negative impact on the habitats and populations of forest animals, including *P. cocincinus*, especially in Nam Dong and A Luoidistricts.

- Protect and restore the natural forest ecosystems.

- Establish the forest corridors to link isolated forest areas to expand habitats and create space for exchanging genetic resources among animal populations, including *P. cocincinus*.

- Control the illegal trade and use wildlife at the restaurants and have the right punishments.

- Raise the awareness of the wildlife protection: Local authorities should have a propaganda program to reduce the demand

for the wildlife, especially at the commune level.

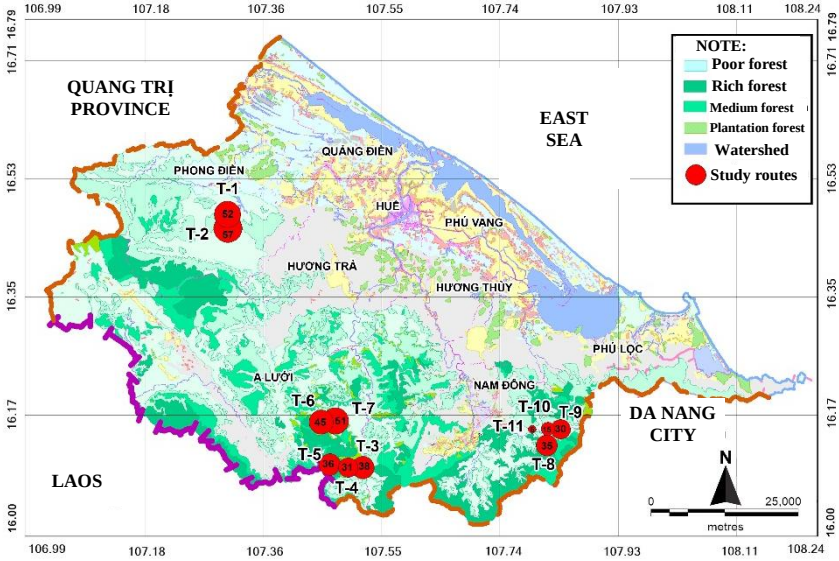

Figure 3.6. Enclosed the conservation area of *Physignathus cocincinus* in Thua Thien Hue

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSION

1.1. Population status

- The size of population at the surveyedroutes in Phong Dien was the largest, about 81 individuals/2 routes (2,100 m long), on average 26 m/one individuals; In A Luoi, in 2016, 96 individuals/5 routes (2,640 m long), on average 28 m/one individuals, in 2017, 59 individuals/2 routes (1,650 m long),on average 28 m/1 individual; In Nam Dong 78 individuals/3 routes (3,700 m long), on average 48 m/one individual. In total, estimated the size of population the three study sites in 2016-2017 was 314 individuals (314 ± 16 individuals).

- The density of populations:in Phong Dien estimated 97 individuals/10,000 m^2, in A Luoi: 44 individuals/10,000 m^2, in Nam Dong: 28 individuals/10,000 m^2.

- The structure of populations at the surveyed sites in the three study sites recorded:the number ofjuvenileswas the highest (52.9%),

followed by the subadults (28.6%), the lowest adultsaccounted for 18.5%. Thus, from April to June population of *P. cocincinus*wasin the development stage. The sex structure at the surveyedroutes in the three study sites weredeterminedwith ratiothe males: females was 13.1: 18.4.

1.2. Characteristics of microhabitats, foraging modes and distribution

- Characteristics of microhabitats: During the day, *P. cocincinus*livedon ground and on the trees in six microhabitat types: branches, leaf, convolve, rocks, sand, grass and microhabitat other. At night, this species lived on the branches, leaf, convolve along the stream. The adults usually lived at higher position than the juveniles. In daytime, the level of forest cover at positionof the adults was lower (26.1%) compared to juveniles (34.7%). At night(77.3%) the level of forest cover at positionof the adults was higher than the juveniles (64.4%).

- Foraging mode: Daytime, *P. cocincinus*was recorded from 8:00 to 16:00 (air temperature: from 28.3-30.6^{o}C, humidity: 65.3-85%), recorded most of the time from 12:00-13:00 (air temperature: 31.4^{o}C, humidity: 61%) when it was sunny, mainly activities: hunting prey, spawning, layering, bask and drinking. At night, *P. cocincinus*lived atbranches, leaf, convolvealong the stream to sleep.

- Distribution: *P. cocincinus*lived in mainly the altitude of less than 300 m, less lived in the altitude of 600 m or more. *P. cocincinus*was recorded mainly in and plantationalternatedsecondary forest habitat, with primary alternatedsecondary forest habitat and less distribution in primary forest habitats.

1.3. The dietary composition

- *P. cocincinus*consumed 20 prey catergories, mainly insects (termites, ants), spiders, Insect larvae, crickets and grasshoppers (Orthoptera), termites and ants are two favorite prey catergories, someof earthworms, plants were also the food items of this species.

- The adultsconsumed sixfavorite prey catergories: Isoptera, Formicidae, Orthoptera, Insect larvae; the subadults consumedfiveprey catergories: Isoptera, Formicidae, Orthoptera, Araneae and Insect larvae; the juvenilesconsumedsixfavorite prey catergories: Isoptera, Formicidae, Orthoptera, Insect larvae, Lumbriculida and Araneae. The subaduts consumed more than adults and juveniles.

- The males consumedfivefavorite prey catergories: Isoptera, Formicidae, Plants, Orthoptera, Formicidae, Insect larvae. The femalesconsumedsix favorite prey catergories: Isoptera, Formicidae, Orthoptera, Coleoptera, Insect insects, Hymenoptera.

1.4. Impact factors, conservation and develop *Physignathus cocincinus*

- Impact factors on the Asian Water Dragon mainly due to over hunting for food and trade, estimated in 2016 in A Luoi hunting 364.5 kg/year, Nam Dong 224 kg/year, Phong Dien 400.5 kg, and the three study sites about 989 kg/year. Narrowing forest, deforestation, habitat fragmentation was also the impact factors to the habitat of this species.

- Conservation locations are as follows: Routes T-2, T-1; T-7, T-6, T-3, T-4; T-8, T-5, T-9, T-10 and T-11.

2. RECOMMENDATIONS

2.1. Suggestion for further studies

It is necessary to continue monitoring the population of *P. cocincinus*in Thua Thien Hue province to update the variation in the number of individuals. Based on that, appropriate conservation planning solutions will be developed.

2.2. Suggestion for conservation

- Review and evaluate the conservation status of *P. cocincinus*speciesto add them on to the IUCN Red List and the list of species that are restricted for commercial purposes.

- Make the priority sites for conservation: Huong Nguyen, A Roang, Khe Dau (A Luoi), Huong Loc (Nam Dong), Phong Dien.The biodiversity conservation in these areas should be protected including the populations of *P. cocincinus.*

- *Raise the awareness of* local communities to reduce the hunting of wild animals, including the *P. cocincinus.*

- Control the exploitation and use of excess *P. cocincinus*, especially in the breeding season.

- Consider thereproduction*P. cocincinus*to decrease hunting in the wild.

PUBLISHED STUDIES

1. Ngo Van Binh, Nguyen Cong Luc, **Nguyen Van Hoang**, Ngo Dac Chung, Nguyen Quang Truong (2016), "Microhabitat use and foraging mode of the Green Water Dragon (*Physignathus cocincinus* Cuvier, 1829) in Thua Thien - Hue Province", *Proceeding of the 3th National Scientific Conference on Amphibians and Reptiles in Vietnam*, Publishing House for Science and Technology, Ha Noi, pp. 175-180.

2. **Nguyen Van Hoang**, Ngo Dac Chung, Ngo Van Binh, Nguyen Quang Truong(2017), "Day and night activities of the Green Water Dragon (*Physignathus cocincinus* cuvier, 1829) in the mountain region of Thua Thien Hue province", 126(1A), *Hue University Journal of Science: Natural Science;ISSN 1859-1388*, Published by Hue University, pp. 104-112

3. **Nguyen Van Hoang**, Ngo Van Binh, Ngo Dac Chung, Nguyen Quang Truong(2018), "Diet of the Indochinese Water Dragon *Physignathus cocincinus* Cuvier, 1829 (Squamata: Agamidae) from Thua Thien Hue Province, Vietnam", *Russian Journal of Herpetology*,(Accepted).

4. Truong Quang Nguyen, Hai Ngoc Ngo, Cuong The Pham, **Hoang Nguyen Van**, Chung Dac Ngo, Mona van Schingen, Thomas Ziegler (2018), "First population assessment of the Asian Water Dragon (*Physignathus cocincinus* Cuvier, 1829) in Thua Thien Hue Province, Vietnam", *Nature Conservation*, 26 :1-14, doi: 10.3897/natureconservation.26.21818 http://natureconservation.pensoft.net.