34th International Biology Olympiad
United Arab Emirates 2023

Q1-1

Tranditional Chinese (Chinese Taipei (Taiwan))

Ecology and Ethology 生態學和動物行為學

34th International Biology Olympiad

3-10 July 2023, United Arab Emirates University

Practical Exam

Total points: 103 (總分為 103 分)

Duration: 90 minutes (考試時間 90 分鐘)

General Instructions:

You have 90 minutes to complete **FOUR tasks in this practical exam.**

你有 90 分鐘來完成本實作的四小題

You can do the tasks in any order. Note that the formulae for standard deviation and standard error have been provided in Q.1.3.

你可依任何次序操作這些小題。請注意，Q.1.3 中提供了標準差和標準誤的公式。

Task 1: Population estimation (17 points)

第 1 部分: 族群估算 (17 分) **Task 2: Effect of guano on invertebrates (27 points)**

第 2 部分: 鳥糞對無脊椎動物的影響 (27 分) **Task 3: Thermoregulation in cormorants (32 points)**

第 3 部分: 鸕鷀的溫度調節 (32 分) **Task 4: Sexual communication in lizards (28 points)**

第 4 部分: 蜥蜴的性別溝通 (28 分)

Write your answers in the answer sheet. Only answers given in the answer sheet will be evaluated.

把答案寫在答案紙上，只有答案紙上的答案會被評分 Make sure that you have received all the materials and equipment listed. If any of these items are missing, please raise your card immediately.

確定你有所有的材料及器材。若有任何缺少，請立即舉卡通知監考人員 Do not use any other applications or browsers during this exam.

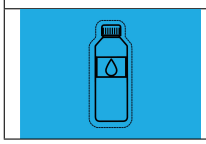
本實作操作期間，不能使用其他應用程式或瀏覽器 If you face any technical issues with your computer, raise your card.

操作電腦時，若有任何技術性問題，舉卡通知監考人員 The speed of the videos in Tasks 3 and 4 can be changed by right clicking on the video in Media Player and selecting the appropriate speed of your choice.

第 3 和 4 題的影片播放速度可以更動，按播放軟體的右鍵，選擇播放速度 During the videos, make sure to keep your cursor on the Media Player task bar.

在影片播放期間，確定游標留在播放軟體的操作條上 Use the following cards to ask for water/washroom/help.

若需要飲用水/洗手間/協助時，使用下列卡片

Drinking Water 飲用水	Washroom 洗手間	Other Queries 其他需求
		

Stop answering as soon as you hear the whistle at the end of the exam.

實作結束的鈴聲響起，立即停止作答 No paper, materials or equipment should be taken out of the laboratory.

不能把紙張、材料或儀器帶出實驗室 **Good luck!**

You are provided with

1. A bag of beads
2. A marker pen
3. A counter

本實驗提供你一袋珠子，一枝麥克筆，一枝計數器。

Before you start, check the items.

在你開始前，請先檢查這些材料。

Task 1. Mark-Release-Recapture Method to Estimate Population Size 第一部分 利用標記-釋放-重新捕獲法來估算族群大小

Mark-release-recapture methods are used to estimate the population size of mobile animals. A known number of individuals of a population are captured and marked, with a ring or an ear tag, which has been tested to not cause any mortality, and then released back into the population. When individuals of the same population are captured again, after giving the individuals sufficient time to mix with the rest of the population, the researchers expect to recapture a certain proportion of the previously marked individuals. The marked individuals represent a proportion of the total population that can be used to estimate the total population of individuals.

標記-釋放-重新捕獲方法用於估計移動動物的族群規模。族群中一些已知數量的個體被捕捉及標示，利用腳環或耳標進行標示 (經測試，此動作不會導致任何死亡)，其後放歸於族群中。經過足以讓這些個體和族群其他個體混和的時間之後，當同族群中的這些個體再度被捕捉，研究者期望捕捉到一定比例的前述標記個體，此標示的個體代表其占整個族群中的比例，可藉此來估算整個族群的數量。

Q.1.1 Given

- “N” is the estimated total population size,
- “M” is the number of individuals captured and marked,
- “C” is the number of individuals captured successively with or without a mark,
- “R” is the number of marked individuals recaptured.

Q1.1 假設

- “N” 是整個族群的估計數量
- “M” 是整個被捕捉個體及標示的個體數量
- “C” 是依次被捕捉的個體中，具有或不具有標示個體的數量

· “R”被再次捕捉的個體中，已具有標示的個體數量

Q.1.1 Write down the formula by which “N”can be estimated. 2.0pt
Q1.1 寫下”N”可以被估算的公式。

Q.1.2 If no marked individuals are recaptured through the above process, we conclude that:

Q.1.2 假設經由上述過程，沒有標示的個體被再度捕捉，我們可以做出下列結論:

Q.1.2 **True or False?** 3.0pt
對或錯

Statement 敘述	**True** 對	**False** 錯
A. The population is infinitely large A. 族群是無限大		
B. The marked individuals have all died B. 標示的個體全部死亡		
C. It is necessary to mark more individuals and make fresh attempts to estimate the size of the population C. 有必要標示更多個體來重新嘗試估算族群大小		

Q.1.3 In your first task, you have a bag, containing a known number of beads, to simulate a population of animals.

1. Take out 20 beads randomly, mark them with the marker provided and then return the marked beads to the bag.
2. Shake the bag well to ensure that the beads are mixed properly.
3. Take out another 20 beads randomly and note how many of them are already marked from your first capture.
4. Mark the unmarked beads from this second capture and then return all the newly marked and previously marked beads back to the bag.
5. Conduct this process for a total of five times. In each event, mark the **unmarked** beads that you capture and return all beads, so that the total number of marked beads increases with each repeat round.
6. Fill the table. Estimate the total population size, mean population estimate and the standard error of the estimate to one decimal place.

Standard deviation,

Q.1.3 在你第 1 個操作，你有 1 袋已知數量的珠子，來模擬一個動物的族群。

1. 隨機取出 20 個珠子，用麥克筆標示珠子，然後，將這些已標示的珠子放回袋中。

2. 充分地晃動袋子，以確定珠子已適當地混合。

3. 隨機取出另 1 批 20 個珠子，記錄其中有多少先前已被標示。

4. 標示第 2 次拿出的珠子中未曾被標示者，然後將這些珠子全部 (包括此次標示，及先前已被標示者) 放回袋中。

5. 重複執行這個操作共 5 次。在每 1 次操作中，將所獲珠子中未標示者予以標示，然後將所有珠子放回袋中，是以在每 1 次重複的過程中，被標示的珠子總數將增加。

6. 計算族群大小、平均族群估算以及此估算的標準誤，估算到小數點後第 1 位，並填入表格。

標準差，

$$\mathrm{SD} = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

Standard error,

標準誤

$$\mathrm{SE} = \frac{\mathrm{SD}}{\sqrt{n}}$$

x_i	the value of the i-th point in the data set 資料中第 i 個點的值
$\bar{x}$	The mean of the data set 資料的算術平均值
n	The number of data points in the data 資料中的資料筆數

Q.1.3.1 4.0pt

Marking event 標放事件	Numbers of individuals captured with or without a mark (C) 捕捉的數量，包括已被標示 (C) 及未標示者。	Number of marked individuals recaptured (R) 遭重複捕捉的個體數量 (R)	Number of individuals newly marked 新被標示的個體數	Total number of individuals captured and marked (M) 被捕捉且被標示的個體總數 (M)	Estimated total population size (N) 預估的整個族群大小 (N)
1	20	-	20	20	-
2	20				
3	20				
4	20				
5	20				
Total 總和	100		X	X	X

Q.1.3.2 1.0pt

Mean population estimate 預估的平均族群大小	

Q.1.3.3 1.0pt

Standard error of the estimate 預估的族群大小的標準誤	

Mark with a cross (X) the correct answer

用 X 標記正確答案

Q.1.3.4 1.0pt

	The final estimate 最終估計數	The mean of the estimates 這些估算的平均值
Which would finally be a better estimate of the total population size? 最終，何者是較佳的整體族群大小估計值?		

In a real population of marked animals, such as the Arabian red fox *Vulpes vulpes arabica*, shown above, various factors can introduce errors in the estimated population size.

Considering the process described above, indicate which of the following factors would introduce an error in the population estimate.

在一個被標示動物的實際族群 (例如上圖所示之阿拉伯紅狐 *Vulpes vulpes arabica*)，各式各樣的因子會導致對族群大小估算的誤差。

如同上述過程，請指出下列因子中，何者有可能導致族群大小估算誤差。

Q.1.3.5 True or False? 5.0pt
對或錯

Factor 因子	**True** 對	**False** 錯
A. The same individual fox is trapped more frequently than others A. 同一隻狐狸個體比其他更常被捕捉		
B. The collar on an individual fox drops off B. 被項圈標示的狐狸個體，其項圈掉落		
C. The collared foxes do **not** emigrate during the experiments C. 在實驗過程中，被項圈標示個體未曾移出		
D. A very small proportion of the fox population is marked at the end of all mark-recapture events D. 在所有標示-在捕捉的事件結束後，只有很小的部分的狐狸族群被標示		
E. The capturing events are carried out in very rapid succession E. 捕捉的歷程是在很快速的時間內連續進行		

Task 2. Response of Terrestrial Invertebrates to Guano Enrichment from Nesting Cormorants 第 2 部分. 陸生無脊椎動物對於繁殖期鸕鷀鳥糞導致環境營養化的反應

The Socotra cormorant *Phalacrocorax nigrogularis*, is a threatened aquatic bird, endemic to the Arabian Gulf and found off the southeast coast of the Arabian peninsula. They usually nest in colonies of tens-to-thousands of nesting pairs. In the breeding season, between August and December, they build cup-shaped nests on the ground, lay eggs, incubate them and tend to their hatchlings, including protecting them from predators, such as the nocturnal Arabian red fox.

Large colonies of breeding Socotra cormorants deposit thousands of tons of faeces (guano), which alter soil chemistry, greatly increasing nutrients, such as nitrogen. This has variable impacts on the soil flora and fauna. Population of some species increase due to the guano enrichment, others decrease, and some remain unaffected.

You are given data showing invertebrates captured in pitfall traps that were placed in a large cormorant colony. Pitfall traps are small, cup-shaped containers, buried up to their rim in the ground, with a liquid preservative in them to prevent insects from escaping when they fall in.

黑喉鸕鷀 *Phalacrocorax nigrogularis* 是一種遭到威脅的水鳥，為阿拉伯灣的本地種，出沒於阿拉伯半島的東南海岸。他們通常以數十到數千的繁殖配對組成群體。在 8-12 月的繁殖季節中，他們在地上建造杯狀巢，產卵，孵蛋且照顧出巢的幼鳥，包括保護牠們不被其他獵食者所害，例如夜行性的阿拉伯紅狐。

繁殖中的黑喉鸕鷀的巨大群體堆置上千噸的鳥糞，造成土壤化學成分的改變，大大的增加了營養鹽，例如氮。這對於土壤的植物相及動物相造成各種不同的衝擊。有些物種族群因為鳥糞營養化而增加，有些則減少，有些則未受影響。

你獲得的是我們在大型鸕鷀群體中設置陷落式陷阱捕捉到的無脊椎動物的數據。陷落式陷阱是小型的杯狀容器，其杯緣以與地表等高的方式埋入，其內放置保存液以防止掉落的昆蟲逃脫。

The image above shows a cormorant nesting area (left) and a non-nesting area (right). Pitfall traps (blue dots) were placed in both areas for one week in the month before the nesting period. The pitfall traps were put back in the same place for another week during the month after the nesting period. The trap contents were collected at the end of the one-week periods. All the collected invertebrates were then identified and counted. These taxa included Coleoptera (beetles), Araneae (spiders), Formicidae (ants) and Argasidae (soft ticks). Their numbers have been reported in Tables 1 and 2 below.

上圖顯示鷸鷉的繁殖區 (左邊) 及非繁殖區 (右邊)。在繁殖期前的那 1 個月，研究者在此二區放置陷落式陷阱 (藍點) 為期一週。繁殖期後的那個月，這些陷落式陷阱被放回原地一週。這些陷阱的內容物在陷阱放置一週後收集。然後，這些被收集起來的無脊椎動物被辨識及計算，其種類包括革翅目 (甲蟲)、蜘蛛目 (蜘蛛)、蟻科 (螞蟻) 以及軟蜱科 (軟蜱)。他們的數量顯示在下表 1 及 2。

Table 1 表 1

Nesting Area –繁殖區 **Before Breeding Season** 繁殖季前					**Nesting Area –繁殖區** **After Breeding Season** 繁殖季後				
Pitfall Traps 陷落式陷阱	Beetles 甲蟲	Spiders 蜘蛛	Ants 螞蟻	Ticks 蜱	Pitfall Traps 陷落式陷阱	Beetles 甲蟲	Spiders 蜘蛛	Ants 螞蟻	Ticks 蜱
Trap 1 陷阱 1	33	13	10	2	Trap 1 陷阱 1	4	1	1	38
Trap 2 陷阱 2	27	17	11	5	Trap 2 陷阱 2	7	2	1	41
Trap 3 陷阱 3	29	18	9	1	Trap 3 陷阱 3	4	2	2	32
Trap 4 陷阱 4	19	18	12	3	Trap 4 陷阱 4	3	3	1	45
Trap 5 陷阱 5	22	14	9	4	Trap 5 陷阱 5	1	1	1	28
Trap 6 陷阱 6	26	19	8	4	Trap 6 陷阱 6	8	4	3	27
Trap 7 陷阱 7	31	15	11	3	Trap 7 陷阱 7	5	6	1	31
Trap 8 陷阱 8	26	14	13	2	Trap 8 陷阱 8	2	2	1	33
Trap 9 陷阱 9	21	19	12	7	Trap 9 陷阱 9	2	3	1	37
Trap 10 陷阱 10	28	20	11	2	Trap 10 陷阱 10	1	3	2	41
Mean 平均值					Mean 平均值	4.1	2.7	1.4	35.3
Standard deviation 標準差					Standard deviation 標準差	2.4	1.5	0.7	6.0

表 2

Non-Nesting Area –非繁殖區 Before Breeding Season 繁殖季前					**Non-Nesting Area –非繁殖區 After Breeding Season 繁殖季後**				
Pitfall Traps 陷落式陷阱	Beetles 甲蟲	Spiders 蜘蛛	Ants 螞蟻	Ticks 蜱	Pitfall Traps 陷落式陷阱	Beetles 甲蟲	Spiders 蜘蛛	Ants 螞蟻	Ticks 蜱
Trap 1 陷阱 1	25	15	7	3	Trap 1 陷阱 1	3	13	14	1
Trap 2 陷阱 2	22	16	10	2	Trap 2 陷阱 2	2	17	11	4
Trap 3 陷阱 3	20	18	11	1	Trap 3 陷阱 3	1	19	12	2
Trap 4 陷阱 4	18	18	13	2	Trap 4 陷阱 4	1	13	10	3
Trap 5 陷阱 5	18	19	10	6	Trap 5 陷阱 5	5	14	10	3
Trap 6 陷阱 6	17	21	11	1	Trap 6 陷阱 6	4	13	12	5
Trap 7 陷阱 7	19	14	13	1	Trap 7 陷阱 7	2	18	11	4
Trap 8 陷阱 8	15	12	9	2	Trap 8 陷阱 8	2	16	12	4
Trap 9 陷阱 9	20	13	13	5	Trap 9 陷阱 9	7	15	10	1
Trap 10 陷阱 10	21	13	12	1	Trap 10 陷阱 10	1	13	9	2
Mean 平均值	19.5	15.9	10.9	2.4	Mean 平均值	2.8	15.1	11.1	2.9
Standard deviation 標準差	2.8	3.0	2.0	1.8	Standard deviation 標準差	2.0	2.3	1.4	1.4

Q.2.1 Calculate the mean and standard deviation of the abundance of beetles, spiders, ants, and ticks in the Nesting Area - Before Breeding Season and write them, rounded to one decimal place in the table. 8.0pt
計算繁殖季前繁殖區的甲蟲、蜘蛛、螞蟻及蜱的豐富度 (數量) 的平均值及標準偏差，計算至小數點後第 1 位後填入表中。

Q.2.2

Calculate the Shannon-Wiener Diversity Index (H') for Trap 1 of pitfall traps in the Nesting Area –Before Breeding Season and in the Nesting Area –After Breeding Season, by first using the following formula:

Q.2.2 利用下列公式計算繁殖季期前及繁殖季後，在繁殖區內陷落式陷阱 1 內生物的 Shannon-Wiener Diversity Index：

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where p_i, the proportion of taxon 'i' relative to the total number of taxa, is computed, and then multiplied by ln p_i, the natural logarithm of this proportion.

Pi 代表所有分類群中計算 i 分類群占有的比例，其後，乘以 ln*pi*(這個值的自然對數)。

Give the answer, rounded to two decimal places, in the boxes below:

將答案計算到小數點後第 2 位，填在下面的空格中：

Q.2.2.1 Nesting Area –Before Breeding Season 2.0pt
繁殖區-繁殖季前

Q.2.2.2 Nesting Area –After Breeding Season 2.0pt
繁殖區-繁殖季後

Q.2.3 True or False?

對或錯

Q.2.3.1 The diversity of taxa, as measured by H', is higher in the Nesting Area –After Breeding Season. 1.0pt
依據 *H*′ 計算出來的生物多樣性顯示，繁殖區在繁殖季後的生物多樣性較高。

True 對	
False 錯	

Q.2.3.2 In general, the H' for a habitat, with only a single species present, is 0. 1.0pt
一般而言，在只有單一物種存在的棲息地中，*H*′ 為 0。

True 對	
False 錯	

Q.2.3.3 H' depends on both species richness, which is the number of species in a particular habitat, and on species evenness, which is the relative abundance of each of the species in that habitat.
H' 係取決於物種豐富度 (某棲地中物種數) 及物種均勻度 (該棲息地中每一物種的相對豐富度)。 1.0pt

True 對	
False 錯	

Q.2.3.4 The H' of a particular habitat decreases as species evenness, in that habitat, increases.
某一棲息地 *H'* 因該棲息地物種均勻度增加而減少。 1.0pt

True 對	
False 錯	

Q.2.3.5 A habitat with a relatively higher H' value, compared to another habitat, is likely to have lower interspecies competition for resources.
一棲息地與另一棲息地比較，在 *H'* 較高的棲息地，物種間對於資源的競爭可能較低。 1.0pt

True 對	
False 錯	

Q.2.4 True or False?

Q.2.4 對或錯

Q.2.4.a The observed differences in arthropod abundance before and after the breeding season in the nesting area could be attributed to the following factors.
所觀察到繁殖季前後在繁殖地節肢動物豐富度差異可能是由下列因子造成的。 4.0pt

Factor 因子	**True** 對	**False** 錯
A. Guano deposition 鳥糞堆積		
B. Soil pH 土壤酸鹼度		
C. Ambient temperature 環境溫度		
D. Soil disturbance due to nesting 繁殖時遭遇的土壤干擾		

Q.2.4.b The effects of guano deposition on arthropod abundance can be evaluated only by analyzing Trap from all four experimental situations. 1.0pt
鳥糞堆積對節肢動物豐富度的影響，只能藉由分析此 4 個實驗情境的陷阱來評量。

True 對	
False 錯	

Q.2.5 Conduct a t-test to determine if there is a significant difference in ant abundance before and after the breeding of cormorants in the nesting area, using the following formula:

Q.2.5 透過 t-test 計算鷗鷺繁殖區的螞蟻豐富度在繁殖季前後是否有顯著差異，利用下列公式：

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(SD_1)^2}{n_1} + \frac{(SD_2)^2}{n_2}}}$$

t	Test statistic t 統計值
x_1 and x_2	The means of Samples 1 and 2 respectively 樣本 1 及樣本 2 的個別平均值
SD_1 and SD_2	Standard deviations of Samples 1 and 2 respectively 樣本 1 及樣本 2 的個別標準差
n_1 and n_2	The sample sizes of Samples 1 and 2 respectively 樣本 1 及樣本 2 的個別樣本數

Q.2.5.a Put the t value, rounded to two decimal places 2.0pt
將 t 值計算至小數點後第 2 位

Q.2.5.b Given that the degrees of freedom for this test is 12, use Table 3 below to determine whether your t-test shows a statistically significant difference in ant abundance in the nesting area before and after cormorant breeding. 2.0pt
假設此測試的自由度為 12，利用下表 3 確認繁殖區螞蟻豐富度在繁殖季前後的 t-test 結果是否具有統計上的顯著差異
Is the t-value statistically significant at $p < 0.05$?
t 值是否達到 $p<0.05$ 的顯著水準?

Yes 對	
No 錯	

A	B					
	20% (0.20)	10% (0.10)	5% (0.05)	2% (0.02)	1% (0.01)	0.1% (0.001)
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850
21	1.323	1.721	2.080	2.518	2.831	3.819
22	1.321	1.717	2.074	2.508	2.819	3.792
23	1.319	1.714	2.069	2.500	2.807	3.767
24	1.318	1.711	2.064	2.492	2.797	3.745
25	1.316	1.708	2.060	2.485	2.787	3.725
26	1.315	1.706	2.056	2.479	2.779	3.707
27	1.314	1.703	2.052	2.473	2.771	3.690
28	1.313	1.701	2.048	2.467	2.763	3.674
29	1.311	1.699	2.043	2.462	2.756	3.659
30	1.310	1.697	2.042	2.457	2.750	3.646
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.158	2.617	3.373
∝	1.282	1.645	1.960	2.326	2.576	3.291

Table 3. Student's t table

表 3，t-test 表

A	Degree of freedom 自由度
B	Significance level 顯著水準

Task 3. Gular Fluttering in Socotra Cormorants 第 3 部分 黑喉鸕鶿的喉部震動

During the early part of the breeding season, cormorants experience temperatures as high as 40°C during the day. Birds that are heat-stressed carry out gular fluttering, continuously flexing a patch of bare skin on their neck.

繁殖期早期，鸕鶿在白天面臨高達 40 度 C 的溫度。遭受熱緊迫的鳥類個體產生喉部震動，即持續地擺動頸部的裸露肌膚區。

Q.3.1 Observe gular fluttering in two individual cormorants, labelled 1 and 2, in Video 1.

Q.3.1 在第 1 個影片中觀察標示為 1 和 2 的兩個個體的喉部震動。

Count the number of visible flutters in the gular of both Cormorants 1 and 2 in the suggested 10-second segments of your choice in Task 3-Video 1. Each gular flutter can be counted as one when it returns to its starting position. You can use the counter, which is provided to you and the timeline, available below the video, to aid in the counting process. You can also change the speed of the video, if you would like to.

Subsequently, calculate the gular fluttering rates of the two birds in terms of the number of flutters / minutes, in the table below. Calculate the mean and standard error of these rates for the two birds and round them to two decimal places.

在 Task 3-第 1 個影片中，以 10 秒為 1 個區間，計算 1 及 2 兩隻鸕鶿可見的喉部震動數。每個喉部震動計算 1 次，此震動回復其起始狀態時，才算完成 1 次喉部震動。你可以使用提供給你的計數器，以及影片內提供的時間軸，來協助進行計次。你若願意，也可以改變影片播放速度。

其次，在下表中以振動數/分鐘的方式計算這兩隻鳥的喉部震動頻率。計算這兩隻鳥喉部震動頻率的平均值及標準誤至小數點後第 2 位。

Q.3.1.1 18.0pt

	Cormorant 1 鸕鷀 1			**Cormorant 2** 鸕鷀 2		
Segment 區間	Time observed (seconds) 觀察時間 (秒)	Number of flutters 震動次數	Flutters / minute 震動/分鐘	Time observed (seconds) 觀察時間 (秒)	Number of flutters 震動次數	Flutters / minute 震動/分鐘
1	0:35-0:45			0:11-0:21		
2	0:47-0:57			0:45-0:55		
3	1:04-1:14			0:56-1:06		

Number of flutters: 2 points each = 12 points
Flutters/minute: 1 point each = 6 points
震動次數：每格 2 分，共計 12 分。震動次數/分鐘：每格 1 分，共計 6 分。

Q.3.1.2 4.0pt

	Cormorant 1 鸕鷀 1	Cormorant 2 鸕鷀 2
	Flutters/minute 震動次數/分鐘	
Mean 平均值		
Standard error 標準誤		

Mean: 1 point each = 2 points
Standard error: 1 point each = 2 points
平均值：每格 1 分，共計 2 分。標準誤：每格 1 分，共計 2 分。

Q.3.2 The average gular fluttering rate of a group of cormorants was calculated through the day and plotted in Figure 1 below. The air temperature surrounding the cormorants was also plotted.

Q.3.2 一群鸕鷀白天平均喉部震動頻率經計算後，展示於下圖 1。鸕鷀周遭氣溫也展示於圖中。

Figure 1

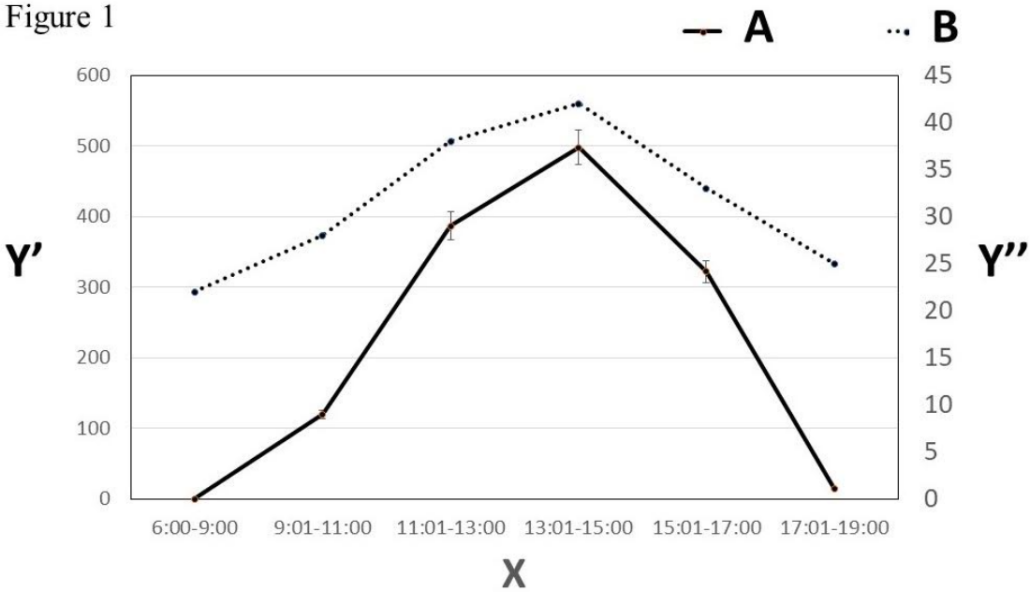


Figure 1

圖 1

A	Gular fluttering rate 喉部震動頻率
B	Temperature 氣溫
X	Time of the day 時序
Y'	Numbers per minute 每分鐘次數
Y"	Temperature ($^{\circ}C$) 氣溫 ($^{\circ}C$)

True or False?

對或錯

Q.3.2 5.0pt

Statement 敘述	**True** 對	**False** 錯
A. Gular fluttering rate increases with the time of day A. 喉部震動頻率隨著白天時序增加而增加		
B. Gular fluttering is likely to be an adaptive response to both extremely high and low temperatures B. 喉部震動很可能是對於極端高溫及低溫的適應反應		
C. Increasing temperature causes an increase in gular fluttering rate, as the latter enhances conductive heat loss from throat tissues C. 氣溫升高導致喉部震動率的提高，係藉由喉嚨組織的喉部震動的熱傳導，促進熱排放。		
D. Gular fluttering promotes water loss from throat tissues. D. 喉部震動促進喉嚨組織的水分流失。		
E. Larger cormorant species spend a relatively greater proportion of time gular-fluttering for a particular temperature E. 在同樣的氣溫下，較大的鸕鷀種類花費較多的時間比例在喉部震動上。		

Q.3.3 In Video 1, that several cormorants were sitting in their nests while others were standing in them. The percentage of individual cormorants that were sitting or standing was recorded across the day (Figure 2 below).

Q.3.3 在第 1 部影片中，好幾隻鸕鷀坐在巢中，而其他鸕鷀站在巢上。個別鸕鷀 1 整天站或坐的比率記錄如下表 2。

Figure 2

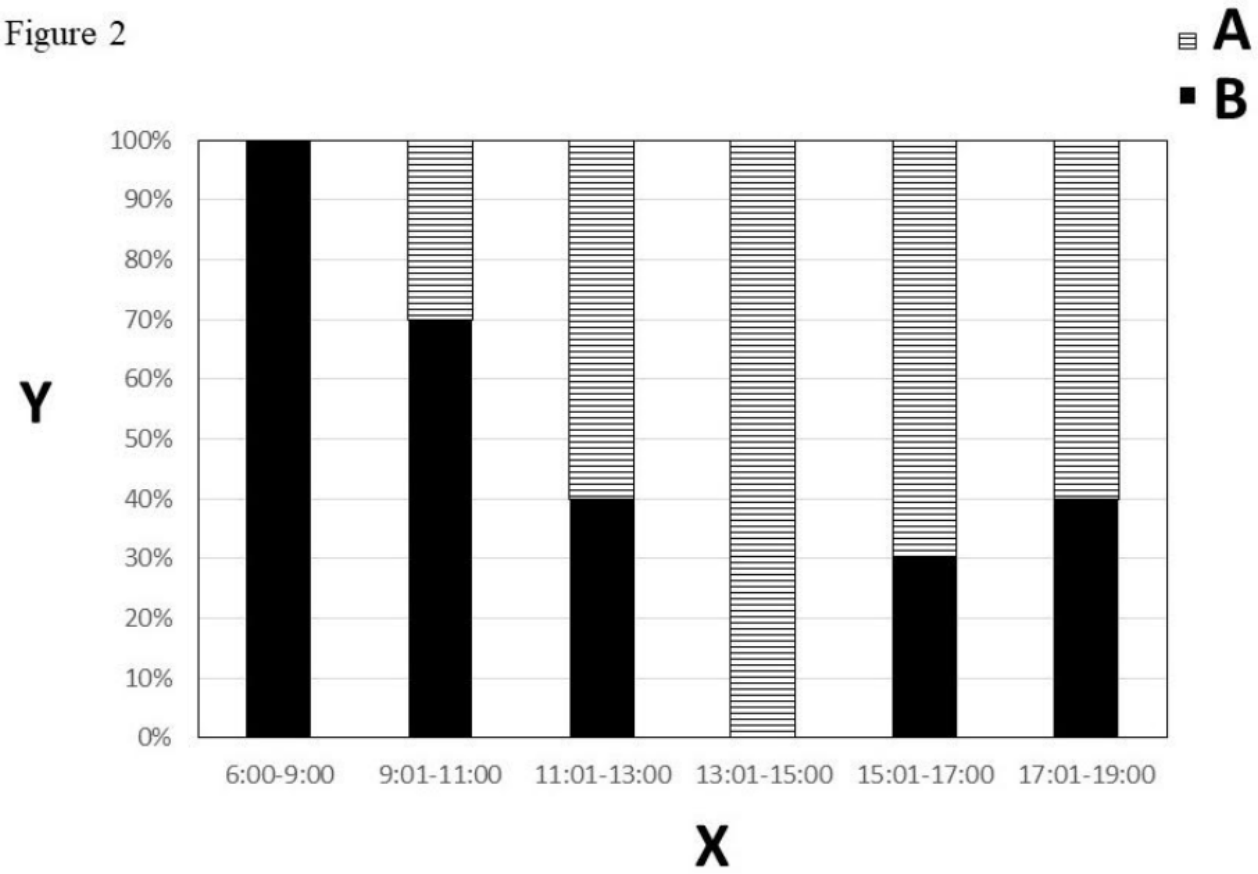


Figure 2

圖 2

A	Standing 站
B	Sitting 坐
X	Time of day 時序
Y	Proportion of individuals 站/坐比率

True or False?

對或錯

Q.3.3 5.0pt

Statement 敘述	**True** 對	**False** 錯
A. Cormorants prefer to sit in their nests, during morning hours to protect their chicks from predators, who are typically active at that time A. 早上鸕鷀喜好坐在巢中來保護在此時較為好動的幼鳥，使其不受掠食者攻擊。		
B. Gular fluttering rates are likely to be high in individual cormorants that spend more time sitting in their nests than do their standing neighbours B. 花較多時間坐在巢中的鸕鷀個體，其喉部震動頻率似乎高於站著的個體。		
C. Standing allows for better airflow between the legs of cormorants, promoting more efficient loss of heat from the body C. 站立允許鸕鷀兩腿間有較佳的空氣流通，提供身體更有效的散熱。		
D. Cormorants stand in their nests to prevent heat loss from the bodies of their chicks D. 鸕鷀站立於巢中以防止幼鳥身體熱量的流失。		
E. Parent cormorants are often likely to trade-off thermoregulatory demands against offspring survival when they adopt certain body postures in their nests E. 鸕鷀親鳥之所以在巢裡採取某種身姿，通常是在自身熱量調整的需求與幼鳥存活間進行取捨。		

Task 4. Inter- and Intrasexual Communication in Fan-Throated Lizards 第 4 部分. 扇喉蜥蜴的性間及性內溝通

The superb fan-throated lizard *Sarada superba*, discovered in 2016, lives in semi-arid habitats on a single mountain plateau of the Western Ghats mountains, a global biodiversity hotspot, in India. The males have a tricoloured dewlap, shown below –an extendible flap of skin, usually folded under the throat – with blue, black and orange patches, which they flap during social interactions. The females have a rudimentary white dewlap.

巨扇喉蜥蜴 Sarada superba 發現於 2016 年，生活在印度西高止山的一處半乾旱的高原上，此處為世界生物多樣性熱點所在區之一。雄性具有三色喉垂 (如下圖)，是一個可延展的皮褶，經常收褶於喉下，具有藍、黑及橘黃 3 個色塊，其於社交互動中開展 (來回伸縮)。雌性有發育不全的白色喉垂。

The objective of this task will be to extract, analyze and interpret behavioral data from social interactions of individual lizards of this species.

You have been given four videos of male lizards in the wild. In each of two videos –Task 4-Videos 1 and 2 –a male is socially communicating with another male, who has been introduced into his territory in a transparent box. In each of the two other videos –Task 4-Videos 3 and 4 –a male is communicating with a female, although you cannot see the box with the female in the video frame.

None of the lizards were harmed during these experiments, and the boxed lizards were quickly returned to their own territories.

此操作的目標是擷取、分析及解讀此物種蜥蜴個體的社會互動行為的資料。我們將提供 4 部雄性蜥蜴在野外的影片。在影片 1 及 2 為 1 隻雄性面對另 1 隻雄性個體的社會溝通，後者係裝在一個透明盒子中，被置放於前者的領域中。影片 3 及 4 為 1 隻雄性與 1 隻雌性個體的社會溝通，雖然在影片中你不會看見在盒中的雌性。在此實驗過程中，沒有任何一隻個體受到傷害，且在盒中的蜥蜴也會很快地釋放回他的領域中。

Q.4.1 Count the number of dewlap flaps made by the males in these four videos and calculate the number of flaps per minute in each case. Only count the displays of the two free-ranging males in Task 4-Videos 1 and 2; do **not** count that of the boxed males. In all videos, only count flaps that completely extend the dewlap. For examples of such complete extension, see Second 3 in Task 4-Video 2 or Second 8 in Task 4-Video 3. For partial extensions, which should **not** be counted, see Second 8 in Task 4-Video 1 or Seconds 12 and 13 in Task 4-Video 3.

Q.4.1 計算這 4 個影片中雄性喉垂開展的次數，及在每種情況下喉垂每分鐘開展的次數。只計算影片 1 及 2 可自由活動的雄性個體的開展數；不用計算盒中雄性的。在所有影片中，只計算喉垂完全開展的狀態。完全開展的例子，見諸影片 2 的第 3 秒或影片 3 的第 8 秒。喉垂部分開展的狀態則不納入計算，例如影片 1 的第 8 秒及影片 3 的第 12、13 秒。

Fill in the table below. 填報下表。

Q.4.1.1 14.0pt

	Number of flaps 開展次數	Time observed (seconds) 觀察時間 (秒)	Flaps / minute 開展次數/分鐘
Social communication with males 與雄性的社會溝通			
Video 1 影片 1			
Video 2 影片 2			
Social communication with females 與雌性的社會溝通			
Video 3 影片 3			
Video 4 影片 4			

Number of flaps observed: 2 points each = 8 points
Time observed: 0.5 point each = 2 points
Flaps/minutes calculated: 1 point each = 4 points
觀察到的開展次數：每格 2 分，共計 8 分。觀察時間：每格 0.5 分，共計 2 分。計算的開展次數/分鐘：每格 1 分，共計 4 分。

Q.4.2 Use the chi-square test for goodness of fit to determine whether the difference in the mean rate of dewlap flaps per minute, displayed by male lizards to other males versus that to females is significantly different from the null hypothesis that there are no differences in such displays to the two sexes.

Q.4.2 使用卡方分析適配度檢定，來檢視雄對雄、雄對雌每分鐘喉垂開展次數的平均的差異是否與虛無假說 (性別及性別間無顯著差異) 有顯著差異。

To carry out the test, fill in the appropriate values in the table below and compute the chi-square statistic

by using the following formula:

執行此一分析，在下表中填入適當的數值，並利用下列公式計算卡方統計值：

$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$

- χ^2 is the chi-square statistic,
- O_i is the number of observations of type *i*,
- E_i is the expected count of type *i.*

Q.4.2.1 7.0pt

	當與雄性或雌性個體溝通時，每分鐘喉垂平均開展頻率：	
	Males 雄性	**Females** 雌性
Observed 觀察值		
Expected 期望值		
Chi-square statistic, χ^2 rounded to two decimal places 卡方分析統計值，計算至小數點後第 2 位。		
Degrees of freedom 自由度		

Use the table below to determine whether your chi-square test shows a statistically significant difference in the mean rate of dewlap flaps displayed by males to other males versus that to females.

使用下表決定你的卡方分析在雄對雄與雄對雌的喉垂平均開展率是否具有統計顯著差異。

Q.4.2.2 Is the chi-square value statistically significant at $p < 0.05$? 1.0pt
所得的卡方值是否達到 P<0.05 的顯著性?

Yes 是	
No 否	

Critical values of the Chi-square distribution with d degrees of freedom

d	0.05	0.01	0.001	*d*	0.05	0.01	0.001
1	3.841	6.635	10.828	11	19.675	24.725	31.264
2	5.991	9.210	13.816	12	21.026	26.217	32.910
3	7.815	11.345	16.266	13	22.362	27.688	34.528
4	9.488	13.277	18.467	14	23.685	29.141	36.123
5	11.070	15.086	20.515	15	24.996	30.578	37.697
6	12.592	16.812	22.458	16	26.296	32.000	39.252
7	14.067	18.475	24.322	17	27.587	33.409	40.790
8	15.507	20.090	26.125	18	28.869	34.805	42.312
9	16.919	21.666	27.877	19	30.144	36.191	43.820
10	18.307	23.209	29.588	20	31.410	37.566	45.315

Q.4.3 True or False?

對或錯

Q.4.3 2.0pt

Statement 敘述	**True** 對	**False** 錯
A. Strong male–male competition could promote sexual selection in these lizards and the capability to repeatedly flap the dewlap could signal a male’s relatively greater fighting ability to potential competitors A. 強的雄對雄競爭可促進在這種蜥蜴中的性擇，以及重複地開展喉垂的能力可能顯示雄性相對於潛在競爭者，有相對較強的戰鬥能力。		
B. Enhanced dewlap-flapping towards other males could be a mechanism to facilitate species recognition when closely related species are sympatric, that is, living in the same area B. 當親緣關係非常相近的物種共域 (生活在相同的空間) 時，對其他雄性個體的喉垂展示增強，可能是促進物種間辨識的機制。		

Q.4.4 Superb fan-throated lizards exhibit sexual dimorphism, with the males possessing tricoloured dewlaps while those of the females are white.

Q.4.4 巨扇喉蜥蜴展現性別二型性，雄性個體具有三色喉垂，而雌性為白色喉垂。

True or False?

對或錯?

Q.4.4 2.0pt

Statement 敘述	**True** 對	**False** 錯
A. The evolution of the tricoloured dewlap in the males could be attributed to the differential response of females and males to the differently coloured patches on the male dewlap A. 雄性演化出三色喉垂，歸因於雌性與雌性對於雄性喉垂不同顏色區塊的不同反應。		
B. The multiple colours of the dewlap could serve to improve signal detection for the receivers of the signal B. 喉垂的複合顏色可能增進受訊者對此訊號的偵測。		

Q.4.5 Why do males flap their dewlap, rather than continuously keep it extended?

Q.4.5 為何雄性開展他的喉垂，而非持續維持擴展狀態。

True or False?

對或錯?

Q.4.5 2.0pt

Statement 敘述	**True** 對	**False** 錯
A. Leaving the dewlap extended is much more energetically demanding than flapping it A. 持續維持擴展狀態相較於開展，較為耗能。		
B. Leaving it extended would attract more predators than flashing it B. 持續維持擴展狀態，相較於開展 (來回伸縮) ，會引來更多掠食者。		