Country Code: _____	Student Code: _____

The 21st INTERNATIONAL BIOLOGY OLYMPIAD

11th – 18th July, 2010

Changwon, KOREA

PRACTICAL TEST 4

ECOLOGY

Total Points: 51

Duration: 90 minutes

Dear Participants,

- In this test, you have been given the following 4 tasks:
  在此次考試，你需要完成下列 4 項題目：
  Task I: Characteristics of Coastal Animal Communities (16 points)
  項目**I**：海岸動物群集的特徵
  Task II: Mark and Recapture Method (8 points)
  項目**II**：標識及再捕捉法（捉放法）
  Task III: Interspecific Interaction (14 points)
  項目**III**：物種間之交互作用
  Task IV: Prey Choice Model (13 points)
  項目**IV**：對獵物選擇之模式

- Write down your results and answers in the **Answer Sheet. Answers written in the Question Paper will not be evaluated.**
  在答案紙上寫下你的答案，答案寫在試題卷上者，不予計分。

- Please make sure that you have received all the materials listed for each task. If any of the listed items is missing, please raise your hand.
  檢查桌面，確認你的材料是否齊全，若有缺少，請舉手。

- Stop answering and put down your pencil **immediately** after the end bell rings. The supervisor will collect the Question Paper and the Answer Sheet.
  結束鈴響時，放下鉛筆立刻停止作答，工作人員將來收取試卷及答案紙。

Good Luck!!

TASK I. (16 points) Characteristics of coastal animal communities

項目 I（16 分）海岸動物群集的特徵

Materials □ □	Quantity
1. Community model board (40 x 37 cm) 群集模式圖版	1
2. Transparent quadrat board (37 x 37 cm) 透明方格圖版	1
3. Electronic calculator 計算機	1

Introduction 前言

A population is defined as a group of individuals of a single species inhabiting a specific area, and a community is a group of populations of different species inhabiting a specific area. Identification of the characteristics of populations and communities is a basic element in predicting ecological change due to environmental factors.

一個族群係一群居住在特定區域之同種生物個體，而一個群集則係特地區域內，由一群不同物種所形成的群體。辨識族群及群集的特性是預測環境因子影響生態變化的基礎。

Using Calculator 計算機之使用

1. Press **ON** to turn on the calculator

   請按**ON**開機

2. Calcuation Examples計算範例

   To calculate 1 + 1 , press **1 + 1 =**

   計算 1 + 1，按 **1 + 1 =**

   To calculate ln 90 (= $\log_e$ 90), press **ln 9 0 =**

   計算ln 90 (= $\log_e$ 90)，按**ln 9 0 =**

   To calculate $\sqrt{\frac{2^2}{5^2}}$, press **√ (2 x^2) ab/c (5 x^2) =**

   計算$\sqrt{\frac{2^2}{5^2}}$，按**√ (2 x^2) ab/c (5 x^2) =**

3. To correct characters, move the cursor by pressing ◄ or ►, and press **DEL** to delete the character or **SHIFT DEL** to insert character

   要修改數據，移動游標按 ◄ or ►，按**DEL**以刪除數據或按**SHIFT DEL**以插入數據。

4. To clear all of the calculation you have entered, press **AC**.

   要清除你輸入的所有數據，按**AC**。

5. Press **Shift AC** to turn off the calculator. Calculator will automatically turn off if you do not perform any operation for about 10 minutes.

   按**Shift AC**關機。倘若你不使用計算機，其於 10 分鐘後也會自動關機。

Q1. (4 points) The model provided on the board is a coastal community consisting of nine animal species. Determine the population size (abundance, N) of each species in the community using a complete enumeration survey and the population density (per unit area, 1 m^2) of each species. The size of each quadrat is 1 m x 1 m. Round values to the nearest hundredth (two decimal places) during your calculations, and record the values in the answer sheet.

（4 分）圖版上所顯示的海岸群集中有 9 種動物。請利用直接計數法計算各物種之族群大小（量，N）及其密度（每平方米之數量）。此透明方格圖版中每一格為一平方米（1 m x 1 m）。請將你的答案計算至小數點後 2 位，並將所得數據填於答案卷上。

Species	Population size 族群大小
Starfish 海星 	
Razor clam 刀蛤 	
Sea slater 海蟑螂 	**15**
Sea urchin 海膽 	
Fiddler crab 招潮蟹 	**13**
Octopus 章魚 	
Oyster 牡蠣 	
Mudskipper 彈塗魚 	
Sea anemone 海葵 	**13**

Q2. (2 points) The table below records species' population sizes in two different coastal communities. Calculate 'the proportion of relative abundance' of each species. Round values to the nearest hundredth (two decimal places) during your calculations, and record the values in the answer sheet.

（2 分）下表記錄了 2 處不同海岸群集的種類及其族群數。計算每種物種在其所屬的群集中所佔的相對比例。請將你的答案計算至小數點後 2 位，並將所得數據填至答案卷上。

Community A		Community B	
Species	Population size	Species	Population size
Starfish 海星	13	Fiddler crab 招潮蟹	2
Razor clam 刀蛤	18	Barnacle 藤壺	18
Sea slater 海蟑螂	13	Sea anemone 海葵	15
Sea urchin 海膽	12	Sea cucumber 海參	2
Fiddler crab 招潮蟹	11	Hermit crab 寄居蟹	5
Gastropod 腹足類	8	Gastropod 腹足類	8
Oyster 牡蠣	12		
Mudskipper 彈塗魚	9		
Sea anemone 海葵	10		
Total	106	Total	50

Q3. (4 points) A rank-abundance curve is a chart that displays the species in a community ordered from most abundant to rare based on relative abundance. Using the relative abundances you previously calculated (in Q2), make a rank-abundance curve for each community on the grid-line in the answer sheet. Indicate community A as 'A' and community B as 'B' on the curve, and write appropriate titles and scales for the X-axis and the Y-axis.

（4 分）物種分佈位序圖是一種根據各物種所佔相對數量比例，並將之由大至小排列的圖表。請在答案卷上所附之方格表中，依據你上一題所計算得到之數據，繪製一份物種分佈位序圖。請分別以 A 及 B 標示曲線所代表之群集類群，並註明 X 及 Y 軸的單位及名稱。

Q4. (4 points) Calculate the Shannon-Wiener species diversity index (H′) for each of the two coastal communities using the following equation. Round values to the nearest hundredth (two decimal places) during your calculations. Put the values in the box in the answer sheet.

（4 分）利用下列公式計算上述兩海岸之 Shannon-Wiener 物種多樣性指標 (H′) ，請計算至小數點後 2 位，並填入答案卷中。

$$H' = -\sum_{i=1}^{n}(p_i \ln p_i)$$

where,

p_i = the proportion of the i^{th} species

在一群集中第i^{th}物種之數量佔全體物種總個體數之比例

ln p_i = the natural logarithm of p_i

p_i之自然對數

n = the number of species in the community

群集中有多少物種

Q5. (1 point) Which statement is/are correct for your rank-abundance curves? Put checkmark(s) (√) in all appropriate boxes in the answer sheet.

（1 分）根據你所繪之物種分佈位序圖，下列敘述中勾選（√）有哪個或哪些是對的。

A. Species evenness is higher in community A than in community B.

群集 A 物種的均勻度高於群集 B。

B. Species evenness is lower in community A than in community B.

群集 A 物種的均勻度低於群集 B。

C. Species richness is higher in community A than in community B.

群集 A 物種的豐富度高於群集 B。

D. Species richness is lower in community A than in community B.

群集 A 中物種豐富度低於群集 B。

Q6. (1 point) Which statement is correct for the species diversity index of the two communities? Put a checkmark (√) in the appropriate box in the answer sheet.

（1 分）關於二群集的物種多樣性指標，下列敘述何者正確？請在答案卷上勾選（√）

A. The area with the higher diversity index (H') should be conserved.

具有較高物種多樣性指標(H')的群集應被保護。

B. The species diversity index (H') indicates the species number inhabiting the coastal area.

物種多樣性指標(H')是指居住在海岸地區之物種數。

C. The species diversity index (H') is inversely proportional to species evenness in an area.

某地之物種多樣性指標(H')與該地之物種均勻度呈反比。

D. The species diversity index (H') depends on both species richness and species evenness.

物種多樣性指標(H')係同時考量物種豐富度（物種數）及物種均勻度。

TASK II. (8 points) Mark and recapture method

項目 **II**：標識及再捕捉法（捉放法）

Materials	Quantity
1. Pottery with beads 塑膠罐內有塑膠塊	1
2. Sampling net (100 ml) 取樣網瓢(100 ml)	1
3. Electronic calculator 計算機	1

Introduction 前言

A few individuals are captured, marked and released back into the population. The population is sampled again and the numbers of marked individuals in this sample counted. Assuming an equal recapture rate for all individuals and without repetitive counting of the same individual, the population size can be simply estimated by using a modified Lincoln Index as follows:

一些個體被捕獲，標識後放回原有族群內。從此族群內再取樣，計算此樣本內具有標識的個體。假設所有的個體其被捕捉的機會是相同的，且同一個體不會重複計算，則族群數量的估算可用修正後的 Lincoln Index 來計算，其公式如下：

$$N = \frac{(M+1)(S+1)}{(R+1)} - 1$$

N: Estimation of population size

所估算之族群大小

M: Number of individuals marked

被標識個體數

S: Number of individuals captured in the second sample

在第二次取樣中所捕獲之個體數

R: Number of marked individuals recaptured

第二次取樣中，所再捕獲之被標示個體數

In this task, the pottery represents a pond with a diving beetle population (the beads). One bead represents one diving beetle. This population contains 40 individuals marked with a red sticker that had been captured during the first sampling. You will be performing the second sampling of this population.

在此考項中，塑膠罐代表一個具有一水生甲蟲族群（塑膠塊）之水塘，一塑膠塊即代表一隻甲蟲。此一族群中有 40 隻個體（具有紅色標記）係為第一次捕捉所標放者，請你進行第二次取樣。

Q7. (4 points) Using the sampling net, capture a sample of diving beetles from the pond (the second sampling). Take two full scoops and combine them. (Assume this population does not have birth, death, emigration, or immigration of individuals between the first and the second sampling events). Estimate population size to the nearest tenth (one decimal place) and record your result in the answer sheet.

（4 分）用取樣網瓢，由池塘中捕捉一批水生甲蟲的樣本（此為第二次取樣）。用取樣網瓢取滿兩瓢的個體數合併計算為一樣本（假設此族群在第一次上標後到此次取樣間沒有出生、死亡、移出、移入的現象）。估算族群數量到小數點後 1 位，將答案寫在答案卷上。

Q8. (4 points) The mark and recapture method has a degree of uncertainty because it is an estimation by sampling, not by a total population count. We can measure uncertainty through the calculation of standard error (SE). Standard error (SE) can be obtained by the function given below.

（4 分）捉放法有一定程度之不確定性，因其係藉由樣本來估算族群數量，並非整個族群的計數。我們可藉由計算標準偏差(SE)來估算此一不確定性。標準偏差(SE)公式計算如下：

$$SE = \sqrt{\frac{M^2(S+1)(S-R)}{(R+1)^2(R+2)}}$$

The 95% confidence interval can be obtained by this calculation: $N \pm t \cdot SE$. The 95% confidence interval means that the size of original population is within the range of the confidence interval with 95% certainty. The *t*-value is the Student's *t*- value when the degree of freedom is infinity. (At

infinity, the Student's *t*-value is also refer to as Z-value). The critical values of the Student's *t* distribution are provided.

Find the appropriate *t* in the table and calculate SE and the 95 % confidence interval for your estimate of population size. Enter the numbers you obtain in the table in the answer sheet. Round your value to the nearest hundredth (two decimal places) during your calculations and record your values in the answer sheet.

95%的信賴間隔（區間）可藉：$N \pm t \cdot SE$ 獲得。此 95%的信賴區間是指所估算之族群量座落在此數值範圍（信賴區間）內的機會達 95%。當 Student's *t*-值之自由度為無窮大時，*t*-值即是 Z-值。下表提供了重要的 Student's *t*-值的資訊。

由表中找出適當的 *t*-值來計算你所估算之族群數量的 95%信賴區間，將你由表中所選的數字填在答案卷上，另將你所得數據四捨五入至小數點後 2 位，填在答案卷上。

Critical Values of the Student's *t* Distribution

關鍵 t 值分佈表

Degree of freedom 自由度	$\alpha = p = P(t > t_{critical})$			
	0.1	0.05	0.01	0.001
1	6.31	12.71	63.66	636.62
2	2.92	4.30	9.93	31.60
3	2.35	3.18	5.84	12.92
4	2.13	2.78	4.60	8.61
5	2.02	2.57	4.03	6.87
6	1.94	2.45	3.71	5.96
7	1.89	2.37	3.50	5.41
8	1.86	2.31	3.36	5.04
9	1.83	2.26	3.25	4.78
10	1.81	2.23	3.17	4.59
11	1.80	2.20	3.11	4.44
12	1.78	2.18	3.06	4.32
13	1.77	2.16	3.01	4.22
14	1.76	2.14	2.98	4.14
15	1.75	2.13	2.95	4.07
16	1.75	2.12	2.92	4.02
17	1.74	2.11	2.90	3.97
18	1.73	2.10	2.88	3.92
19	1.73	2.09	2.86	3.88
20	1.72	2.09	2.85	3.85
21	1.72	2.08	2.83	3.82
22	1.72	2.07	2.82	3.79
23	1.71	2.07	2.82	3.77
24	1.71	2.06	2.80	3.75
25	1.71	2.06	2.79	3.73
26	1.71	2.06	2.78	3.71
27	1.70	2.05	2.77	3.69
28	1.70	2.05	2.76	3.67
29	1.70	2.05	2.76	3.66
30	1.70	2.04	2.75	3.65
40	1.68	2.02	2.70	3.55
60	1.67	2.00	2.66	3.46
120	1.66	1.98	2.62	3.37
∞	1.65	1.96	2.58	3.29

TASK III. (14 points) Interspecific interaction

項目 III（14 分）：物種間之交互作用

Materials	Quantity
1. Two species model board (30 × 32 cm) 二物種模式圖版	1
2. Transparent quadrat board (30 × 30 cm) 透明方格圖版	1
3. Electronic calculator 計算機	1

Introduction 前言

Spiral shellfishes and clams live in the same habitat. In order to know whether there is an interaction between these two species, we examine the distribution of each species in that habitat.

旋螺及蛤居住在同一環境，欲瞭解兩者間有無關連性，我們可檢測此二物種在環境中的分佈狀況。

Q9. (2 points) Using the given quadrat board, observe whether the spiral shellfish and the clam are absent and/or present in each quadrat. Write the number of quadrats you have observed in the box in the answer sheet.

（2 分）用透明方格圖版來判別上述二物種在各方格內的有無情形。請將你所統計之方格數（有/無）填入答案卷中。

Q10. (2 points) The significance of the species' distributions measured in this habitat can be examined by using the Chi-square (χ^2) test. The null hypothesis for the χ^2 test in this situation is that the distribution of each species:

（2 分）卡方分析（ Chi-square (χ^2) test）可以用來檢測某物種在環境中，分佈之顯著性（即某物種之分佈是否與環境有所關聯），上述的情形中，卡方分析之虛無假設表示此二物種之分佈屬於：

A. is nonrandom.非隨機分佈

B. is independent of each other.兩物種間為獨立者即互不影響

C. shows a mutually negative influence.顯示二物種間有此消彼長的負面影響

D. shows a mutually positive influence.顯示二物種間有正向之相互影響

E. is influenced by a third species.二物種間受到第三種物種之影響

Put a checkmark (√) in the appropriate box in the answer sheet.

請於答案卷中勾選(√)正確答案

Q11. (4 points) To perform the χ^2 test, first determine the expected counts for each observational class. For example, the expected counts of quadrats where both species are present is calculated by multiplying the number of quadrats where one species is present with the number of quadrats where the other species is present divided by the total number of quadrats. Compute the other expected counts similarly to the nearest tenths (one decimal place) and fill the table in the answer sheet.

（4 分）執行卡方分析時，首先需計算每一觀察組別之期望（預測）值。例如，兩個物種皆出現之方格數的期望值即可藉由一物種所出現的方格數乘另一物種所出現之方格數後除以所有的方格數而得出。計算本題之期望值至小數點後 1 位，填入答案卷中。

Q12. (2 points) Using the function below, calculate the χ^2 value for this data set. Record your value to the nearest hundredth (two decimal places) in the answer sheet.

（2 分）用下列公式，計算此資料（上題之期望值）之卡方值至小數點後 2 位，並填入答案卷中。

$$\chi 2 = \sum \frac{(\text{observed count} - \text{expected count})^2}{\text{expected count}}$$

Q13. (1 point) In order to evaluate the Chi-square value (χ^2), the degree of freedom for the data set must be determined (*df*). What is the degree of freedom for this data set? Record the value in the answer sheet.

（1 分）為檢測卡方值，資料的自由度(*df*)必須確認。本資料的自由度為何？請將數值填入答案卷中。

Q14. (2 points) Decide whether to reject or not reject the null hypothesis using the significance level (probability, p) of 0.05. In the given χ^2 table, locate the degree of freedom in the appropriate column. Compare your calculated χ^2 test statistic to the tabular χ^2 value to make your decision. Put a checkmark (√) in the appropriate box in the answer sheet.

（2 分）將顯著水準設在 0.05（即或然率 p 為 5%），決定是否拒絕或不拒絕虛無假設。在所提供之卡方值分佈表中，選取出最適切的自由度並比較你所得之卡方值與表中所列之卡方值，來做出你對虛無假設的決定，並在答案卷中勾選(√)正確答案。

Q15. (1 point) Considering the spatial pattern of the distribution, what kind of interactionis likely to be taking place between the two species? Choose **all** possible options and put a checkmark (√) in the appropriate box in the answer sheet.

（1 分）考量上述二物種之空間分佈型態，試問此二物種間的交互作用可能為何？請選出所有可能的答案，並勾選 (√)於答案卷中

A. No interaction 無交互作用存在

B. Commensalism 片利共生

C. Competition 競爭

D. Parasitism 寄生關係

E. Exclusion 互相排斥

Chi-square Table 卡方值分佈表

Degree of freedom 自由度	Probability, p 或然率（機率 p）				
	0.99	0.95	0.05	0.01	0.001
1	0.000	0.004	3.84	6.64	10.83
2	0.020	0.103	5.99	9.21	13.82
3	0.115	0.352	7.82	11.35	16.27
4	0.297	0.711	9.49	13.28	18.47
5	0.554	1.145	11.07	15.09	20.52
6	0.872	1.635	12.59	16.81	22.46
7	1.239	2.167	14.07	18.48	24.32
8	1.646	2.733	15.51	20.09	26.13
9	2.088	3.325	16.92	21.67	27.88
10	2.558	3.940	18.31	23.21	29.59
11	3.05	4.58	19.68	24.73	31.26
12	3.57	5.23	21.03	26.22	32.91
13	4.11	5.89	22.36	27.69	34.53
14	4.66	6.57	23.69	29.14	36.12
15	5.23	7.26	25.00	30.58	37.70
16	5.81	7.96	26.30	32.00	39.25
17	6.41	8.67	27.59	33.41	40.79
18	7.02	9.39	28.87	34.81	42.31
19	7.63	10.12	30.14	36.19	43.82
20	8.26	10.85	31.41	37.57	45.32
21	8.90	11.59	32.67	38.93	46.80
22	9.54	12.34	33.92	40.29	48.27
23	10.20	13.09	35.17	41.64	49.73
24	10.86	13.85	36.42	42.98	51.18
25	11.52	14.61	37.65	44.31	52.62
26	12.20	15.38	38.89	45.64	54.05
27	12.88	16.15	40.11	46.96	55.48
28	13.57	16.93	41.34	48.28	56.89
29	14.26	17.71	42.56	49.59	58.30
30	14.95	18.49	43.77	50.89	59.70

TASK IV. (13 points) Prey choice model

項目 **IV**（13 分）對獵物選擇之模式

Materials	Quantity
1. Prey model board (22 × 24 cm) 獵物模式圖版	2
2. Electronic calculator 計算機	1

Introduction 前言

A foraging animal encounters various types of prey items. Each type of prey can be characterized by its energy content (E), the time required to search for that prey (searching time, Ts), and the time required to capture and consume it (handling time, Th). Therefore, we can measure prey profitability by the function E/(Ts+Th). In this situation, according to optimality theory, natural selection would favor behaviors that maximize an animal's net energy intake per amount of foraging time.

動物覓食時會遇到不同型態的獵物。每一種型態的獵物可藉由其所含有之能量(E)，尋找該獵物所花費的時間（尋找時間，Ts），以及捕捉及進食該獵物的時間（捕食時間，Th）等來區分。故我們可藉 E/(Ts+Th)來測量獵物之適合性或有利程度。在此種情形下，根據最適覓食理論，天擇將有利於動物所採取之覓食行為，使其能在單位覓食時間內獲取最大的淨能量（即扣除覓食過程中所消耗的能量後所得之淨收入）。

The behavioral options for a forager are whether to accept or to reject an item of a given prey type when it is encountered. Assume that there are two kinds of prey item, Type 1 and Type 2. Let the profitability be higher for Type 1 — that is, $E_1/(Ts_1+Th_1) > E_2/(Ts_2+Th_2)$. Thus, Type 1 items should always be accepted. Prey profitability is density-dependant. That is, profitability of a prey species changes if the prey species becomes less abundant.

對覓食者而言，覓食行為的選擇取決於其接受或拒絕牠所遭遇的獵物。假設有 2 種不同型態的獵物存在，第一型及第二型，倘若第一型獵物之有利程度較高—即 $E_1/(Ts_1+Th_1) > E_2/(Ts_2+Th_2)$，如此情況，則第一型獵物應永遠被接受。獵物之有利程度係與其密度有關，也就是此有利程度會因該種獵物變少而降低其有利程度。

On the boards for Site I and Site II, there are three prey items for gulls:

在圖版地點 I 及 II 區，有三種海鷗所會捕食的獵物：

Prey A: Spiral shellfish

獵物 A:旋螺

Prey B: Clam

獵物 B:蛤

Prey C: Razor clam

獵物 C:刀蛤

Q16. (2 points) For Site I, record the density of each of the prey species A, B, C (number of individuals per m^2, assuming that each quadrat is 1m x 1m). Calculate searching time (Ts) for each of the prey species, where the species-specific searching time at density = 1 has been provided. Ts= (1/density)·*a* (sec). The value '*a*' is a species-specific constant. Calculate the values to nearest hundredth (two decimal places).

（2 分）在第一區，紀錄 ABC 三種獵物的密度（每平方米之每種個體數，假設每一方格係 1 平方米），根據下表所提供之資訊（在每一物種密度為 1 隻時，所需的尋找時間）來計算對每種獵物的尋找時間(Ts)。Ts= (1/density)·*a* (sec)。'*a*'值為一物種之常數，請將數值計算至小數點後 2 位。

Prey species	Ts (sec) when the prey density is 1 當獵物密度為 1 時，所需之尋找時間
Prey A	**10**
Prey B	**15**
Prey C	**5**

Q17. (2 points) After capturing a prey item, gulls fly high and drop the item to break its shell. The forager repeats the behavior if the shell does not break. The table below indicates the drop height and the average number of drops required at that height to break the prey's shell. For each prey

type, indicate with a checkmark (√), in the answer sheet, the optimal drop height that gulls should choose, if they are optimal foragers.

（2 分）海鷗在捕到一隻獵物後，會高飛並將其丟下以打破其殼，若殼未破，海鷗會重複此行為。下表顯示其投擲獵物的高度及打破獵物殼所需的平均投擲數。根據下表中所提供各種不同獵物被投擲的高度及所需打破之平均次數來看，海鷗若為最適覓食者時，所應採行之最佳投擲高度為何？將答案勾選(√)於答案卷上。

	Height of drop (m) 投擲高度	Average number of drops required to break shell 打破殼所需之平均投擲次數
Prey A 獵物 A	2	60
	3	40
	5	20
	10	8
	15	7

	Height of drop (m)	Average number of drops required to break shell
Prey B	2	60
	3	20
	5	7
	10	5
	15	4

	Height of drop (m)	Average number of drops required to break shell
Prey C	2	30
	3	10
	5	8
	10	5
	15	4

Q18. (2 points) Gulls fly one meter up or down in 0.5 seconds. Given the optimal drop height for each prey species, calculate the handling time (Th) for each prey item. Record the number in the box in the answer sheet.

（2 分）海鷗在 0.5 秒可升高或降低 1 米，請根據上題你所選取之最佳獵物投擲高度，計算每種獵物之捕食時間(Th)，將答案填於答案卷上。

Q19. (3 points) The table below lists the average energy gain from eating an individual of each prey species (kilojoules (KJ) per prey). Calculate the profitability of each prey species at Site I to the nearest hundredth (two decimal places), and record the number in the box in the answer sheet.

（3 分）下表列出從每種獵物身上所能獲得之平均能量（仟焦耳(KJ)）。請計算在 I 區中每一獵物的有利程度至小數點後 2 位，並將答案填於答案卷上。

Prey species	Energy (KJ per prey) 能量（仟焦耳每一獵物）
Prey A	7
Prey B	25
Prey C	5

Q20. (2 points) Of the following choices, what would be the optimal decision for the gulls at site I? Put a checkmark (√) in the most appropriate box in the answer sheet.

（2 分）在下列的選項中，對 I 區活動的海鷗而言，何者為最適的決定？勾選最可能之答案於答案卷上。

A. Eat all of prey A. 將所有的獵物 A 皆吃光

B. Eat all of prey B. 將所有的獵物 B 皆吃光

C. Eat all of prey C. 將所有的獵物 C 皆吃光

D. Eat prey A at first and then switch to prey B. 先吃獵物 A 而後改吃獵物 B

E. Eat prey B at first and then switch to prey C. 先吃獵物 B 而後改吃獵物 C

Q21. (2 points) A gull finds an item of prey C in Site II. The gull can, however, decide not to take this item and fly to Site I where it can search for prey B. Given that Site I requires 50 seconds of flying time from Site II, what should the gull do in order to maximize the profitability of the next prey item, if it is an optimal forager? Distribution of the prey items in Site II has been provided to you. Put a checkmark (√) in the most appropriate box in the answer sheet.

（2 分）假設有一隻海鷗在 II 區發現一隻獵物 C，牠可選擇不吃此獵物，而飛到第 I 區去尋找獵物 B。若由 II 區飛到 I 區須耗時 50 秒，則海鷗若要達到對下一獵物的最大有利程度時，其該作何決定？參考所提供之第 II 區獵物分佈圖版，於答案卷上勾選最適當的答案。

A. The gull will eat the prey C in Site II.海鷗將吃第 II 區之獵物 C

B. The gull will move to Site I to search for prey B.海鷗將移到 I 區去尋找獵物 B

C. The gull will search for prey B in Site II.海鷗將在第 II 區尋找獵物 B

D. The gull will move to site I to search for prey C. 海鷗將移到第 I 區去尋找獵物 C

E. The gull will search for prey A in Site II. 海鷗將在第 II 區尋找獵物 A