內政部營建署陽明山國家公園管理處 84 年度研究報告

陽明山國家公園台灣梅花鹿野放計畫（三）
——台灣地區梅花鹿野放評估研究

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中 華 民 國 八 十 五 年 十 二 月

序

本報告共分四章，第一章重點總結介紹了本計畫之背景、研究方法與內容、及主要結論。第二章是對台灣梅花鹿保育計畫的整體觀及建議，第三章是陽明山國家公園梅花鹿野放計畫分析，包括了野放計畫之目的、環境評估、墾丁計畫可提供的參考、及綠島梅花鹿可提供的參考等層面。第四章是對經營現有三個梅花鹿亞族群的建議。

本研究之完成，得到許多人的協助，筆者要特別感激美國柏克萊大學的鹿類專家麥可樂博士，同意來台一個月，協助分析梅花鹿現狀與需求，擬定梅花鹿保育與復育整體觀，研擬對未來工作的建議等，對本計畫之成果有決定性的貢獻。中央研究院調查工作室的齊力教授，於百忙當中，同意爲問卷設計與調查分析之顧問；指導墾丁國家公園梅花鹿復育計畫多年的師範大學王穎教授，更親自由台北來到墾丁，協助工作人員了解狀況，建議調查地點等。此外，陽明山國家公園管理處各處室同仁，均多次不吝提供建議與指導，承辦人黃光瀛先生更提供多方協助與支持，使本計畫之進行十分順利；墾丁國家公園的劉新明課長，馬協群先生，及潘民雄先生不但提供資料，詳加解說，並且帶領現場參觀以加強了解；綠島鄉公所的陳進文鄉長、林再貴課長、陳頂福課長、及李威仁先生，屢次花費長時間接受訪問，提供書面資料，陳鄉長除派員於日間領路調查外，並親自於夜間帶領尋找梅花鹿；觀光局東部海岸國家風景區管理處綠島管理站主任陳崇賢先生，熱心協助安排工作人員的起居交通。若無上述眾人之協助，本計畫定然無法順利完成。研究進行及報告撰寫過程中，方韻如小姐，許育誠、及簡哲仲兩位先生提供大量行政、翻譯、電腦、繪圖等方面的協助；報告之初稿，得師範大學王穎及呂光洋教授，台灣大學林曜松、李玲玲、及蘇鴻傑教授，屏東技術學院裴家騏教授過目審定，方得以把錯誤降至最低。

謹在此對前列諸位先生、女士、及各單位致上最誠摯的謝意。

目錄

第一章 重點總結

一、背景

自從台灣梅花鹿在野外絕種，國外學者即建議進行其復育工作（McCullough 1974）。1984以來，內政部營建署在墾丁國家公園積極進行梅花鹿人工繁殖，並於1994年開始把繁殖出的鹿隻野放於墾丁國家公園內，十二年來此計畫一直是國內重要保育行動，更是政府重視野生動物保育工作最重要的代表。近年來墾丁以外的其他國家公園也開始考量是否應參與復育工作以共襄盛舉，陽明山國家公園更熱心期望對此種動物之復育有直接的貢獻；但因任何的復育計畫均需長期的努力與大量的經費，同時野生動物的復育需求應從生態系保育的角度來思考，而在中華民國不論天然環境、保育資金和人力資源均相當有限，故陽明山國家公園決定在採取行動之前，委託筆者進行梅花鹿野放計畫之政策評估。

雖然梅花鹿在野外已經消失了許多年，但在民間人爲飼養的情形非常普遍。目前梅花鹿在臺灣的法定地位是家畜，但又被政府當作野生動物來加以復育；墾丁國家公園已花了十二年的時間進行梅花鹿的飼養、繁殖和野放工作，但是在綠島，卻因野外的梅花鹿族群，對作物及植被造成傷害，而被當地人視爲有害動物。顯然梅花鹿當今之法定地位，復育所需之整體規劃，社會對此計畫的認定等，均與墾丁計畫開始之時有所不同，也顯示未來梅花鹿的保育工作，有整體規劃與進一步評估的必要。

二、研究內容及方法

爲妥善評估陽明山國家公園應否進行梅花鹿野放計畫，筆者乃針對台灣地區梅花鹿復育、野放工作已有之成就，可資借鏡之經驗，及擴大梅花鹿野放的必要性從事分析，不但參考墾丁國家公園十餘年復育的成果和利弊得失，也蒐集了綠島梅花鹿野放的經驗及現狀資料，以供陽明山國家公園做政策性判斷的依據。計畫所用的資料由兩方面獲得：(1) 已完成的報告及(2) 現場訪談與現況勘查。計畫考慮的角度包括：

1、陽明山國家公園擬進行野放的目的爲何？和墾丁計畫之關係如何？其適當性、可實現性、實用性、及必需性如何？

2、分析在陽明山國家公園野放梅花鹿應做的環境影響評估，尤其注重此舉對自然環境和生物族群可能造成之立即效應和長期效應。

3、墾丁國家公園梅花鹿復育計畫可提供那些參考？

4、綠島民間長期飼育梅花鹿，及野放經驗可提供那些參考？

有關墾丁復育、野放工作，本計畫分析了下列幾個層面：

1、最初建立之復育種群之遺傳組成、性別比例是如何選擇的？

2、如何進行飼育計畫，如何管理飼養種群，現有族群和當初種群相比，其族群基因組成和性別比例如何？

3、人工復育繁殖出的鹿隻，野放前經過那些準備以使之能生存於野外？

4、如何選擇野放的地點？

5、野放鹿隻的監測情形如何？是否能提供梅花鹿族群變動的資料？是否已有鹿群對當地棲地和生物群聚之生態影響報告？墾丁國家公園如何決定其梅花鹿承載量？

6、墾丁國家公園是否會繼續或擴大復育計畫？

7、若陽明山國家公園進行梅花鹿野放計畫，是否會對墾丁的復育計畫有所助益？抑或對梅花鹿在臺灣的整體保育有所幫助？

8、根據墾丁經驗，復育計畫能有那些附加的貢獻？會有那些間接的成本或損失？

有關綠島的梅花鹿野放經驗，本計畫整理了地方政府及民間飼養梅花鹿的背景、野放結果、野放後之經營管理經驗，未來擬採取之行動等相關資料。

三、總結

（一）在梅花鹿保育整體需求方面：

本報告之內容以評估陽明山國家公園野放計畫爲主，但因評估的依據有時是以台灣梅花鹿整體生存需求爲著眼點，故筆者在麥可樂博士協助下，撰寫了台灣梅花鹿保育計畫整體觀，介紹梅花鹿保育的基本觀念，包括集合族群觀念，基因管理的重要，梅花鹿的棲地、分布、和生態環境需求，族

群及棲地管理方法，並對梅花鹿的保育，提出下列建議：

1 、梅花鹿未來經營管理首先要解決其法定地位的問題。

2 、立即擬定一個整體性的梅花鹿保育與管理計劃。

3 、進行任何經營管理之前，應先分析梅花鹿的 DNA ，以確定現有亞族群之種源及基因多樣性。

4 、爲保育梅花鹿免於絕種，應建立四個亞族群。目前已有三個亞族群，若可能，應在西海岸平原或花東縱谷，建立第四個亞族群；四個亞族群應儘量互相間隔開，以免被同一天災影響，但四個亞族群之經營管理則應互相配合，而非各自獨立。

5 、因梅花鹿沒有立即絕種的危機，保育工作應謹慎地循序漸進。

（二）有關陽明山國家公園野放計畫：

1 、依據集合族群原則，因爲陽明山和台北市立動物園位置非常接近，並不適合作爲建立第四個亞族群的地點。

2 、陽明山國家公園能提供梅花鹿族群未來擴張的潛力極少，因爲梅花鹿喜愛的棲地在此範圍內僅侷限於幾個小地區，故並非最佳野放地區。

3 、評估是否應進行梅花鹿野放計畫時，在梅花鹿生存方面，還應考慮氣候與棲地、天敵與族群控制、可利用之食物量，及進行飢餓實驗以判斷環境惡劣時梅花鹿之食性與食量，及可能產生之生態衝擊。在野放地點方面，應考慮所選地點之便利性、適當性（對生態保護區可能有那些影響）、面積是否夠大、及遊客管理之難易等。在生態影響方面，則應考慮天然植群受危害之可接受性。

4 、建議以綠島經驗爲參考，包括野放的後果，經營管理的經驗，及鄉公所對陽明山國家公園的建議等。

5 、在陽明山國家公園決定進行野放前，應事先考慮如何處理傳染性疾病、進行族群經營管理、及獲得經費需求等層面。

6、如果陽明山國家公園決定進行野放計畫，應在開始進行前審慎規劃。管理處應有永久妥善經營此亞族群的準備與決心，以確保它在整個集合族群管理計畫中，能確實發揮功能。

7 、野放計畫開始時即應建立明確的棲地監測制度，以追蹤梅花鹿對棲地的影響，包括在草地及樹林中設置標準拍照點來覺察樹種組成的改變，用穿越線法記錄被剝皮之樹種、樹的年齡或大小，不同種的樹被剝皮或環剝的頻度及分布等。

8、野放後應定期追蹤鹿隻，以掌握其生存狀況及活動範圍。

9、因爲陽明山國家公園的環境現狀並非最適合梅花鹿生存的地點，適合之棲地面積均很小，且無發展之潛力，故判斷較適合圈養梅花鹿而非野放。

（三）在鹿群經營管理方面：

1、陽明山國家公園若野放梅花鹿，鹿隻應該來自經過驗證的純台灣梅花鹿群；另外若墾丁鹿群的基因多樣性已大幅減少，鹿隻即不應來自墾丁鹿群。

2、鹿群的飼養與經營管理、及野放前的準備工作，均可以墾丁復育計畫爲參考，但應積極進行繁殖管理，使每隻雄鹿均能參與繁殖，並完整地記錄每隻鹿的繁殖史。

3、本報告提出對在鹿崛坪建立圈養梅花鹿的圍籬及其他設施的初步建議。

4、台灣梅花鹿的棲地需求，判斷是 70%樹林，30%草生地的組合；一個地區中應有幾隻鹿，應以樹林之承載量爲判斷依據。

5、鹿崛坪的梅花鹿承載量，估計約爲 50 隻。建議用水牛爲「第二種草食性動物」來協助維持草生地的開闊度。因鹿崛坪能容納之梅花鹿隻數有限，在經營管理上必須考慮族群管理，並需克服地區偏遠，管理昂貴，及可能有的遊客及野狗干擾問題。

（四）對現有亞族群管理的建議：

1、對墾丁梅花鹿族群，建議分析基因以判定鹿隻的純度，在不知純度前暫停野放，若分析結果證明種源不純，則應停止野放。此外應分析是否有需要繼續進行人工繁殖，還是應開始採取節育措施。未來可考慮停止人工繁殖，將復育重點放在追蹤及管理野放族群上。

2、對綠島梅花鹿族群，建議分析基因以判定鹿隻的純度。因爲鄉公所的經費不足，建議農委會或觀光局東海岸風景特定區，未來在此族群的經營管理上扮演較積極的角色。對鹿隻危害農作物的管理方法，筆者提出初步的建議，同時認爲從生態旅遊的角度，應可尋得梅花鹿保育與地方福利兩全的解決辦法。

第二章　台灣梅花鹿保育計畫整體觀

一、總論

現今的保育趨勢是要保護生物多樣性，但因爲生物多樣性涵蓋的範圍很廣，而一般大眾對它的了解也更少，所以若能用一個成功的保育案例作爲推動其他保育工作的參考，對整體保育工作應是有利的。對保育人員來說，所有的物種都具有生物或生態的重要性，但某些物種在社會上另外還有經濟價值或文化意義。若能證明我們可以成功地保護這些具有文化或經濟價值的物種，再談拯救整體生物多樣性的行動，可能更容易讓一般大眾接受；何況保護這些物種的過程中，也經常保護了許多其他棲息於同一地點，但較不受人們重視的物種。

保存台灣梅花鹿(*Cervus nippon taiwanus*)是重要的，因爲牠在台灣原有動物相中佔有顯著地位，又因爲在台灣被歐洲人佔領的初期鹿皮曾被用作抵稅的財物，牠也具有重要歷史價值。政府的努力與投入，已使梅花鹿和陸封性的櫻花鉤吻鮭，成爲台灣野生動物保育努力的旗艦物種。

台灣梅花鹿的復育工作自1984年展開至今已十二年。有人質疑政府是否應在梅花鹿和櫻花鉤吻鮭兩個物種上投入如此鉅額的保育經費，卻忽視或犧牲了許多其他物種的保育需求。這種批判基本上是正確的，不過我們也應思考若這些經費不被用來保育這兩個物種，是否真的會被用來推動其他的保育工作，或是根本不會被用在自然保育的領域裡。在世界上大多數的社會中，至少在保育觀念興起的初期，雖然可以爲少數有名、受大眾喜愛的物種之保育工作籌得所需的經費，但對價值不明顯、較難引起注意、不易產生情感上共鳴的物種，要讓保育觀念不強的社會大眾願意支持牠們的保育，是有實質困難的。

基於以上考慮，這些得來不易的保育經費，應該被非常謹慎而科學地用在梅花鹿保育上。因此我們研擬了台灣梅花鹿保育計畫書，對未來所需的整體保育策略提出建議。我們認爲梅花鹿保育計劃應包括三個特定目標：

1、維持足夠的族群數量，以避免外在環境的變動導致台灣梅花鹿滅絕。

2、將台灣梅花鹿族群維持在至少四個互相遠離的地區上。此乃因台灣環境現狀已無法提供一個夠大的單一保留區，來容納一個大到可長久存活下去的有效族群；故惟有靠數個分散的亞族群，來減少因疾病或環境上的逢機變動（environmental stochasticity），如火災、颱風等，給族群生存帶來的風險。

3、鑑定原生台灣梅花鹿的基因特色，選用具有這個特色的種群，來進行所有梅花鹿復育的工作。爲能保持這個種群內的基因多樣性，必須使用小族群遺傳學中的集合族群(metapopulation)觀念，來經營管理。

二、保育背景及理論考量

1 、 族群模式

因爲有關族群衰減和滅絕的實際資料不足，學者只好用數學模式來模擬導致族群滅絕的狀況及風險，以增加了解並協助判斷。脊椎動物的絕滅常是在族群數量已降到相當低，或通常是已無法挽回減少的趨勢，甚至已絕滅後才被發現，所以通常無法及時蒐集資料以供分析；因此研究人員長利用可以變動出生率、死亡率、遷入或遷出率、性別比例、及其他族群參數的數學模式，進行「族群可存活率分析」（ PVA, population viability analysis ），來判斷一個族群能繼續存活的機率。

前述各種族群參數的值，在大部分生存於野外的族群中都會有些變動，變動的大小受環境的穩定性和可預測性的影響。當一個物種的數量夠多且分布夠廣時，這類的變動對一種生物的存活並不會產生太大的影響，因爲一個環境變動不會同時影響這個物種的全部亞族群，並且有影響時各亞族群受影響的程度也會互不相同，不會因各亞族群同時減少而絕滅；但當這個物種的數量少，族群又被孤立在一個或少數幾個棲地時，環境變動影響的嚴重性也相對地提高，因而必須被納入於「族群可存活率分析」的族群參數中。

「族群可存活率分析」模式中的逢機變化通常有兩種：一種與環境相關，例如因植物生長狀況、降水、氣溫、捕食壓力等之變異所導致的；另一種與族群動態相關，例如由族群中之性別比例不平衡、意外死亡事件、無法找到配偶等因素導致的。族群愈小時，族群動態導致的變異對物種存亡之重要性

也愈高，不像在大族群中，各種變異會被互相抵消。

2 、 族群大小

要防止大型脊椎動物絕滅，一種動物至少需要有多少隻？早年的「族群可存活率分析模式」（ Gavin 1978 ； McCullough 1978 ； Shaffer 1981 ）估算得較爲樂觀，答案均在數百隻的範圍內，再加上可能的誤差，一般便以 500 隻作爲基本值。然而近年發展出的模式則較悲觀，認爲至少要有 1000 隻才能達到目的（ Lande 1993 ）。雖然因爲各個模式的結構不同而無法直接互相比較，但一般而言，對「最小可存活族群數量」的估算值不同的主要原因有：（ 1 ）近年的模式多用體型小、繁殖快速、生命週期短、族群內個體的替換速率（ turnover rate ）快的小型動物（ r-selected species ）爲研究對象，早年的模式則主要考慮壽命長、繁殖較慢、個體替換速率慢的大型動物（ K-selected species ）；（ 2 ）族群中個體的密度對小型動物較不重要，對大型動物則較重要；（ 3 ）近年的模式比較強調毀滅性天災的影響，如火災、洪水、旱災、酷熱或酷寒、傳染性疾病的大流行等，這些不常發生的天災多是劇烈的環境變動，對動物的生存和繁殖有巨大的影響；（ 4 ）近年的模式對族群存活所定義的時間較長，指從數百到數千年。

早年的模式所選用的物種側重於引人注意的大型動物，這些物種較爲一般大眾所熟知，也常被稱爲「有魅力的大動物」。當年的模式建立者常常也是野生動物經營者，他們採取的角度是所謂的「族群減少模式」（ Caughley 1994 ），也就是藉著修正會導致物種減少的因素，來停止滅絕的趨勢。由於相信野生動物的經營會是持續性的，因此他們認爲只要能確保物種仍可存活 30 ～ 50 年即已足夠，因爲未來可以再決定新的經營措施或修正經營方法，何況社經條件的改變也會形成不同的保育需求，所以加長對族群存活所考慮的年限，被認爲是不切實際的。

近年的模式建立者常是保育生物學者，採用的觀點被 Caughley （ 1994 ）稱爲「小族群模式」，他們是主張「單次干涉」的人，希望尋得一個可以長期解決問題的方法。他們問：「要保留多大的棲地才可以保護足夠大的族群，使這個物種能長久維持生存，未來不再需要採取新的干涉措施？」

台灣環境的大幅度改變，使我們無法再以後者的觀點來進行台灣梅花鹿

的保育。持續的經營管理行動，能使一個較小的族群得以維持與大保護區中之大族群相同的可存活率；台灣梅花鹿是屬於 K 選擇型的大型物種，因此在諸多層面上可能與早期的模式較相符，所以當年推估的至少 500 隻個體可能已足夠。不過雖然持續的經營管理行動將是必須的，經營計畫仍應儘量減低未來保育工作所需付出的代價，並且儘量借重於自然的機制。

3 、 亞族群互相遠離

降低「最小可存活族群」所需個體數的方法之一，就是把亞族群維持在互相遠離的地區，使每一個地點只有整個族群的一部份，這也就是「不把所有的雞蛋放在同一個籃子裡」的策略。偶發的毀滅性災變是近年來多數「族群可存活率分析」模式中的重要因子，當一個物種的亞族群分散在相隔夠遠的地區，便可以避免讓同一個災變衝擊到整個分布區，因而得以降低這類災害的影響力。若亞族群間的距離大於動物自然移動的距離，分散分布也有防止接觸性傳染病擴散的功能；分布區相隔夠遠，才不會被同一次火災、旱災等影響。換言之，各亞族群分布區的環境必須是互相不相關的；理想的狀況是使用數個互相完全獨立的地點，但實際上在台灣很難滿足這樣嚴苛的條件。無論如何，各地點必須能不被同一天災導致同樣程度的影響，這樣即使有一個亞族群因天災而滅絕，其他亞族群依然存在，一旦災區的環境恢復，其他亞族群便可作爲再引入（ reintroduction ）的種源。這樣即使某個亞族群暫時滅絕，整個物種仍可避免滅種的危機，這種管理方法使得一個數量較小的族群有長期存活的機會。

集合族群（ metapopulation ）的觀念應是思考此種分散分布系統的最好依據。 Gilpinh 和 Hanski （ 1991 ）曾將集合族群的理論加以整理， McCullough （ 1996 ）也曾對它的實際應用作過探討。集合族群的基本觀念是：生物族群分布在適合生存的棲地塊集（ patches ）上，而這些塊集則是鑲嵌於不適生存的棲地基質（ matrix ）上的；每一個區塊上的亞族群都可能滅絕，但經過一段時間，來自其他塊集的個體會經由播遷過程遷入此區塊再度定殖（ recolonization ）。在任何時間點上，並非所有適合的棲地上均有族群生存，但只要亞族群滅絕的速率低於再拓殖的速率，即使各亞族群會不定期的滅絕，整個集合族群仍可穩定地持續下去。

在人爲經營的集合族群中，如台灣梅花鹿復育計畫的狀況，族群中個體的播遷、再拓殖、那些個體要移入那些塊集等，都是經營者的決定與選擇（ McCullough *et al.* 1996 ）。在野生的集合族群中，「機率」與「偶然」扮演著關鍵性的角色；在人爲經營的集合族群中，經營者會刻意地減少亞族群滅絕的機率，一旦滅絕發生也會儘快安排再拓殖，或使用其他合宜的方法來增加物種的可存活率。自然族群因需要克服自然界不可預知的變動所帶來的生存壓力，需要較多的區塊來維持族群數量，復育用的族群在人爲的經營下，則可在數量較少的區塊中維持物種的存活。

不過將一個大族群分散成數個亞族群，也會衍生一些小族群的問題，例如基因多樣性在小族群中降低的機率就遠較在大族群中高。因此在管理亞族群間的播遷時，必須仔細選擇播遷個體的來源、數量、移出移入的地點等，來儘量維持物種的基因多樣性。要達此目標，經營單位必須對亞族群的長期經營有足夠的認知和投入，各個亞族群的經營管理也必須能相互配合，亦即應將各亞族群之管理視爲整體族群管理計畫的一部份，而非各自獨立的小計畫。

4 、 遺傳方面的考量

要研擬台灣梅花鹿經營計畫的細節，必須要有兩個問題的答案。第一、是否能找到遺傳標記（ genetic marker ）來鑑定鹿隻是不是純種的台灣梅花鹿；第二、現存純種台灣梅花鹿族群的基因多樣性如何。顯然必須先回答第一個問題，才能回答第二個問題，雖然可以進行 DNA 分析來同時回答兩個問題，但仍必須先確定那些是純種的台灣梅花鹿，才能確定現存族群還維持著多少基因多樣性。

維持夠大的族群數量和基因多樣性的保存，則是這個計畫中兩個並重的目標。因台灣梅花鹿已在 1960 年代末期自野外絕跡（ McCullough 1974 ），而復育計畫必須考慮遺傳的瓶頸問題（ genetic bottleneck ）、拓殖者效應（ founder effects ）、及與外來種源雜交的可能，故遺傳學的考量必須是台灣梅花鹿復育和保育計畫的基礎。

（ 1 ）基因管理

參與保育復育計畫的人員，應充分了解經營管理梅花鹿基因層面的理

由，才能正確地執行復育工作，而不只是選擇最容易的方法而已。妥善的基因經營管理包括了防止某些個體進行繁殖，這種做法需要謹慎與耐心，常與只追求梅花鹿隻數快速增加的目的互相抵觸，因此管理者對基因經營管理的目標和需求應有清楚的認知。

只考慮用純種台灣梅花鹿來進行復育的理由，一個是本地演化出來的物種對本地的適應力較高，另一個是本地演化出的物種反映了本地演化的歷史。現詳述如下：

A. 自台灣變成孤立的島嶼，這一萬年來長期的天擇壓力，使只有最適應台灣環境的梅花鹿之遺傳特質才能留存下來；因此我們相信本地的梅花鹿，經過大自然如此的雕琢，已形成了一個特殊的、優良的基因庫。

世界上共有 13 個梅花鹿亞種（王 1985 ），其中有 7 個分布於日本和台灣地區一些原有陸橋相連的小島上；梅花鹿也因爲有許多分布於海島上的族群，使牠在鹿科中相當特殊。台灣是一個在更新世仍與亞洲大陸相連的大陸性島嶼；當時梅花鹿的地理分布也應是連續性的，直到海平面上升、陸橋消失後，台灣的梅花鹿才成爲一個獨立的族群，因此台灣的梅花鹿亞種可能從來沒有面臨過族群過小、基因漂變（ genetic drift ）的問題。在十五世紀歐洲人第一次來到台灣時，梅花鹿在島上分布廣泛且數量豐富，應已對台灣的環境產生獨特的適應，所以復育計畫選用原生的種源，顯然有其生態及演化上的優點。

這並不表示其他種源的梅花鹿不能在台灣生存，實際上牠們也可能在此生存得很好。但所謂「適應」，包括了能承擔不定期出現的偶發事件所造成的生存壓力，而能適應短期內的生存壓力，並不表示能通過長時期的考驗。本地原生物種對可能在台灣發生的天然事件，必定會展現較佳的適應能力，而保育工作正是長期的工作。

B. 只用純種台灣梅花鹿進行復育的第二個理由，主要反應了我們的生物哲學。生物的亞種，是一個地區獨特自然史的果實，這份自然史是不能重演的，所以一個亞種一旦消失，便永遠不能再被創造出來。台灣梅花鹿是台灣史的一部份，就像是一只稀有的古董花瓶，是獨一無二的。我們或可以就原

形複製一件古董，但這個贗品的價值永遠比不上原來的真品。就像珍貴的藝術品一樣，一個遺傳種源的價值特殊就是因爲它是無法取代的；人工製造出的遺傳種源，因爲可以重複製造所以價值較低，它的消失通常不會導致人類的遺憾。因此，保護台灣特有的梅花鹿亞種才是主要的保育目標，唯有在原生梅花鹿已消失的情況下，才應考慮使用不純的個體。

（２） 基因多樣性

如何維持基因多樣性是梅花鹿復育計畫的第二個主要考量。在現存或爲復育而組成的台灣梅花鹿小族群中，基因多樣性很容易快速消失；一個族群變小以後的時間長短，也會影響其中基因多樣性流失的程度。過去族群數量曾減到很低的「瓶頸」效應，和少數個體移出去建立新族群的拓殖者效應，對基因多樣性的影響都只是單次的事件，它們的發生都是機緣，但只要一個族群停留在小族群的狀況下，其中的基因多樣性便會不斷地的流失（Denniston 1978）。

要維持基因多樣性的主要理由，是我們無法預知多樣性消失的全部後果，因爲人類才剛開始對遺傳資源的保育有初步的了解。根據現有的知識，多樣性消失後短期內最嚴重的後果就是近親交配會導致遺傳衰退（inbreeding depression），也就是因爲隱性不良基因的表現，使得個體的適應力降低（Ralls *et al.* 1979； 1988）。在 tule elk及其他與梅花鹿同屬的鹿科動物中，近親交配易導致兔唇的發生，這是由一組隱性對偶基因造成的先天性遺傳疾病。在墾丁的復育計畫中曾經出現過兩個這樣的案例（吳等 1992），但這是自墾丁復育計畫開始以來僅有的兩個例子（潘明雄，個人通訊），因此問題應該還不嚴重。

第二個維持基因多樣性的長遠理由，是要確保梅花鹿的特殊遺傳性狀，使牠應付台灣不定期天災（如傳染疾病）的能力不致減少。舉例來說，澳洲的歐洲野兔（*Oryctolagus cuniculus*）產生出一種抵抗病毒的基因，因而使兔子沒有被病毒全面消滅；非洲的牛羚（*Connochaetes* spp.）也有抵抗牛瘟病毒的基因。不過澳洲的野兔有上百萬隻， 非洲的牛羚也有數十萬隻，所以有較多機會產生這些有利的基因。台灣梅花鹿的數量少很多，所以自然產生此類有利基因的機會也很低。

從事野生動物經營管理的鼻祖Aldo Leopold (1949) 指出，想要有智慧地干預自然，最重要的原則便是保留自然的每一部份。基於這種精神，我們不僅需要保存純台灣梅花鹿的基因組，還應保存儘量多的基因組，所以遺傳方面的考量必須被包含在復育計畫中。我們不知台灣梅花鹿族群還保有多少基因多樣性，或許過去的瓶頸效應和拓殖者效應已導致基因多樣性的大量流失。若基因多樣性已消失，復育計畫即不須爲其維持多花心力，但由北美洲一種與梅花鹿同屬、且有類似興衰史的 Tule elk（*Cervus elaphus nannodes*；McCullough *et al.* 1996）的情形來判斷，台灣梅花鹿應還保有相當程度的基因多樣性，因此，除非現有梅花鹿的基因多樣性已幾乎消失，否則經營決策就應以保育遺傳資源的考量爲依歸。物種的基因多樣性可以藉由分子生物的技術來探知，例如做DNA的 microsatellites分析，這些技術在 Roy *et al.* (1994) 中均有介紹。

三、梅花鹿在台灣的歷史

梅花鹿至少在更新世即已通過陸橋來到台灣（Patel *et al.* 1989），大約在一萬年前變成一個孤立的族群。台灣梅花鹿是在低海拔活動的動物，過去的記錄主要集中於海拔300公尺以下的地區（Kano 1940；McCullough 1974）。早年梅花鹿在台灣西南平原的數量非常的龐大，但在全島其他地區的低海拔谷地也普遍分布（蘇 1985）。

由於數量龐大，梅花鹿過去曾承受巨大的獵捕壓力，在歐洲佔有台灣的早期還曾被當作一種主要的貨幣，每年不但有上千張鹿皮被用作貢品或稅款，甚至大量輸出到海外市場（ 江 1987；Petal *et al.* 1989）。在捕獵和棲地被大量變更爲耕地的雙重壓力之下，梅花鹿的數量和分布都急速地減少。梅花鹿早年的主要棲地，恰是甘蔗、水稻和其他高經濟作物的最佳耕地，事實上過去梅花鹿棲地的分布 （蘇 1985, 圖二），和後來的稻米產地的分布（Severinghaus 1989, Fig. 1.4）幾乎完全重疊。

從梅花鹿早年被大量捕獲到幾十年前的銳減，這期間文獻資料非常少，推測其族群的變化，可能是先從人口稠密、棲地日漸被佔據的西部平原區消

失，其後隨著北部地區的開發，也慢慢從北台灣的山谷中消失。鹿野忠雄曾報導在1930年代末期，雪山地區仍可發現梅花鹿，但那是當時已屬相當偏遠的地區（Kano 1940）；在1960年代，Ruhle（1966）的報告指出在東部海岸山脈仍有梅花鹿活動，但McCullough在1973年做全島調查時，並沒有在野外發現任何梅花鹿的蹤跡，而已知的最後一筆獵捕記錄是在1969年，因此他的結論是台灣梅花鹿已在野外絕跡（McCullough 1974）。所幸販賣鹿茸的利潤使民間廣泛飼養梅花鹿，故仍有相當的種源存在於圈養環境中，且台北市立動物園也還維持者一個小族群。McCullough在1974年即建議在墾丁地區進行台灣梅花鹿的復育；這個建議由墾丁國家公園自1984年付諸執行，至今仍在進行中。

四、以生態相似種爲參考

有關北美洲白尾鹿（*Odocoileus virginianus*）的研究很多。這種鹿，尤其美國東南部的族群，大部分的覓食生態、行爲、與棲地的關係都與梅花鹿很相似，因此在對梅花鹿有較徹底的研究前，有關白尾鹿的知識可以被用爲重要的參考，本保育計畫在許多地方即以對白尾鹿的了解爲判斷依據。

早先McCullough 即已發現這兩種鹿的相似性，最近在墾丁國家公園和綠島對梅花鹿所做的觀察，更近一步印證了這種看法。台灣梅花鹿和白尾鹿一樣神經質而易受驚嚇，牠們在受到追趕時會驚慌失措並設法跳越圍籬逃走，所以很容易弄傷自己。今年四月墾丁國家公園在復育區的一個圍籬中，利用一排人並肩前進的趕鹿行動，曾造成兩隻懷孕的母鹿流產（潘明雄，個人通訊）；在我們拜訪墾丁國家公園時，正逢德國電視台在圈養區拍攝鹿群，也曾目睹因趕鹿而導致鹿隻相當驚慌的表現。

不過當我們以有關白尾鹿的知識做爲管理梅花鹿之參考時，須特別留意這兩種鹿仍有許多不同之處。根據梅花鹿臼齒磨損的情形判斷，梅花鹿較偏好以草本爲食，且也會像其他 *Cervus* 屬的鹿一樣啃食樹皮，但這習性在 *Odocoileus* 屬則很少見；此外這兩種鹿在繁殖生物學上有極大的不同，*Odocoileus* 屬是新世界的物種，繁殖時一胎可生多隻小鹿，而 *Cervus* 屬的鹿一次通常只生一隻，少有雙胞胎的情形，所以白尾鹿的族群模式並不適用於

梅花鹿上，否則會過度高估牠族群增長的潛力。

五、梅花鹿與棲地

一般來說，梅花鹿會利用森林或其它能提供遮蔽的植被中之被干擾地區，所以梅花鹿可算是亞極盛相物種（subclimax adapted species）。在極盛相植被中，牠也可以生存，但只能維持較低的密度。墾丁的梅花鹿被自圈養區放出後，主要在干擾地區的邊緣活動，這些地區是過去的農耕地，或是現在水牛和山羊的放牧地；梅花鹿利用夜間在這類的空曠地覓食，白天則在周圍的樹林中休息。綠島的野生梅花鹿，也是夜晚大量聚集在水牛放牧區及農耕地覓食，白天回到鄰近的樹林中休息。綠島全島皆可發現梅花鹿留下的痕跡，但在島中央的森林地區則痕跡較少，顯然島中央因爲干擾地區少，對梅花鹿較缺乏吸引力。梅花鹿通常成五隻或五隻以下的小群，偏好在森林邊緣50公尺的範圍內活動，如果牠們走到這個範圍之外的開闊地覓食，通常會結合幾個小群而形成較大的臨時性覓食集團。

梅花鹿的食性很廣，會食用許多種類的禾本、雙子葉草本、及木本植物的小苗、嫩芽等（夏 1990）；顯然只要是能提供足夠的營養，且不含太多禦敵化學成分的植物，都可能是它的取食對象。

根據我們對其他鹿科種類的了解，梅花鹿應會優先攝取當時品質最好的食物；牠們是選擇性的覓食者，一邊移動一邊覓食，東吃一口西吃一口，因此是藉混合多種食物來獲得平衡的營養。在雨量及溫度適宜、植物生長快速時，梅花鹿通常會優先以草本植物爲食，因爲此時這些植物含有較高的營養及較低的纖維成分；而在旱季或其他草本植物休眠及生長緩慢的季節，牠們會轉而攝取較大量的木本植物的嫩枝和嫩芽，因爲木本植物較能在不同季節維持穩定的營養成分（Sampson and Jepersen 1963； McCullough and Ullrey 1985）。在食物有限，通常是鹿的數量過多競爭壓力大時，梅花鹿也會用門齒刮取小樹的表皮爲食；仍在墾丁圈養中的鹿隻，因爲沒有足夠的草地和干擾後的植被可供覓食，已經對當地的森林造成嚴重的衝擊。鹿隻啃樹皮時，多選表層較薄、韌皮部較厚的樹種，這些樹種通常生長較快，也常是受干擾地區的先驅樹種，它們會逐漸被生長緩慢的較陰性樹種取代，進而形成較成

熟的森林；所以當梅花鹿的數量合宜時，牠啃食先驅性小樹的行爲，應會加速森林演替到較成熟的階段，促使一個地區的植物相改變成較不適和牠生存的環境。因此除非梅花鹿數量過高，這種取食方式應不致給棲地造成太大的生態災害（另見本章八、棲地的經營），不過有時雖然鹿群密度不高也有刮取樹皮的現象，這是因爲梅花鹿會試吃各種食物，但刮取樹皮主要還是發生在食物稀少或缺乏時。

梅花鹿應是適存於森林邊緣的物種（edge species），在因干擾而具有不同演替階段植相的地區，族群可以達到最大的數量；這種受干擾的環境中之草本植物，常能提供梅花鹿品質最好且最多的食物。次生林中有多量的木本植物幼苗，且能提供良好的遮蔽以供躲避天敵；成熟林鬱閉的樹冠層提供遮蔭的場所，較爲稀疏的林下植被也使梅花鹿容易由其中察覺掠食者的入侵，這是牠們在休息時最常利用的棲地，尤其在白天較熱或正在反芻的時候。王（1985）的觀察顯示，梅花鹿一般的日活動模式是早晨和傍晚在空曠地區覓食，其他時間則在森林裡休息。

在原有梅花鹿分布的海岸平原上，牠們休息時極可能是利用濃密的五節芒草原和矮灌叢爲遮蔽，實際上梅花鹿並不一定需要森林，而可以利用其他植被做爲休息、遮蔭和遮蔽的場所。在草本植物終年生長良好的環境，例如四季雨量豐富的地區、或在溪岸及湖岸的環境，梅花鹿對樹木小苗的需求程度也較低。

六、分布與生態環境

從梅花鹿的生態習性，我們可對其分布和生態環境作一些有關的推測。根據歷史的記載，過去梅花鹿在台灣的西南平原密度最高（蘇 1985），顯然梅花鹿很適應此區平緩的地勢，但可能更重要的因素是此區的雨量集中於夏季，冬季則氣候乾旱。此區發生旱災的頻度是平均每兩年一次（Severinghaus 1989），在乾旱的季節很容易發生火災，火災又是干擾植群演替的主要因素；西南平原一向以多閃電著稱，故常有天然引發的火災，再加上原住民在四千年前抵達之後，也會放火製造有利於主要獵物生存的環境。

由此可知，梅花鹿數量最大的地區，也是具有合適的地形、氣候條件、並特別是常有干擾發生的環境。若據此來評估台灣北部的棲地條件，雖然北部仍有適當的地形和氣候，但因終年雨量分布均勻，使植群演替趨勢受氣候干擾的程度減少，因此梅花鹿的分布雖然仍然普遍，但各地的密度應顯著地較少。

梅花鹿的海拔分布也受到地形、氣候、干擾頻度及強度的綜合影響。雖然梅花鹿在中國東北和日本的北海道可適應當地嚴寒的氣候，但台灣亞種的皮毛較薄，顯然是屬於亞熱帶到熱帶的動物，低溫和強風應會限制牠們海拔分布的上限。梅花鹿也會利用較破碎的地形，例如墾丁國家公園的高位珊瑚礁地帶，但地形陡峭的程度會限制梅花鹿的分布，中央山脈典型的陡坡顯然並不適合牠們生存。最後，較高海拔的森林溼度較高而較不易燃燒，也限制了梅花鹿適存棲地的分布。當然，高海拔地區仍有火災發生，尤其在南部乾燥的冬季，若火勢延燒到樹冠層就會引發規模較大的火災，玉山國家公園內大面積的箭竹草原和由火災適存樹種組成的松樹林便是例證（McCullough 1974），山區稜線上方也常可看到由閃電引發的火災所形成的塊集；不過這些火災發生的海拔，對梅花鹿分布而言大部分都太高了。

在低海拔山區，尤其對位於颱風主要路徑上的東部和南部地區，颱風可能是對森林形成干擾的主要事件。颱風會將老樹和衰弱的樹木吹倒而使冠層疏開，但很少會像火災一樣將整個林地上的植物清除，所以對森林演替的影響程度較小；下層小樹的生長也很快會使森林的孔隙再度鬱閉，因此由颱風所形成的梅花鹿適存棲地，存在的時間將比由火災形成的短許多。

地形陡峭、因干擾形成的開闊地存在的時間較短、干擾頻度較低等因素的組合，使山區適於梅花鹿生存的棲地面積較小且分布較孤立。所以雖然梅花鹿的分布廣泛，但在山地出現的密度卻很不規律。不過花東縱谷有較為合適的氣候、地形、和干擾規模，對梅花鹿而言應該是僅次於西南平原的重要棲地。

七、族群和經營管理

適應受干擾棲地的梅花鹿，極可能就像白尾鹿一樣，族群數量常常會出現暴增暴跌的現象；在棲地的植群被干擾之後，梅花鹿的族群數量會上升；當植群逐漸恢復到演替的成熟階段時，梅花鹿族群便會隨之逐漸減少。我們不應預期一個地區的鹿群數量會達到穩定，或當地的生態系會維持在平衡的狀態，因爲生物及物理狀況會使受干擾地區的環境不斷改變，加上植物社會、草食動物、肉食動物等各方的反應均會有時間上的延宕，因此要在這種地區達到狹義的生態平衡不太可能。在自然的情況下，這類系統的穩定只有在我們將觀察尺度擴大到地景尺度時才可能看到；在地景尺度下，干擾形成的適宜塊集與因演替而消失的塊集間，可能有平衡關係的存在，各種動物的數量也可能在這大範圍內呈現穩定的狀態。草食與肉食動物的分布，會因被干擾塊集的鑲嵌結構隨時間改變而變動，但因爲干擾的性質和出現頻度並非固定，而是隨著氣候現象變動，所以即使考慮大範圍的面積，這樣的系統也很難達到嚴格的平衡。

對爲復育梅花鹿而經營的系統，族群的穩定必須透過規劃來獲得。首先，這種系統中通常已經沒有掠食性天敵的存在，所以人類必須扮演天敵的角色來控制草食性動物的族群，如增加死亡率（射殺或捕捉後宰殺）、降低繁殖率（控制性別比例、年齡結構、或使之避孕）、或移出部分個體（藉捕捉後移至他地）等。經營者須評估實際執行每一種措施的可行性、執行的成本、及大眾可接受的程度，再決定應採用那一種方法來控制族群量。不論採用那一種方法，族群控制對這類會急遽增減的物種都是必要的；在管理者不能進行族群數量控制之前，或梅花鹿的棲地利用會和其他土地利用產生強烈衝突時，不該貿然建立復育族群。

其次，在人爲經營的系統中，人類可以控制被干擾環境的面積，間接影響草食動物族群數量波動的程度，把族群維持在較穩定的狀態。管理者可藉人工修枝及割草來維持受干擾地區的草地形態，或利用「第二種草食性動物」來平衡被經營的對象對環境帶來的影響（見本章之九、第二種草食動物）。對台灣梅花鹿而言，農家飼養的水牛便可作爲「第二種草食動物」。這種方式在經濟上的效益較高，對植被的衝擊也較自然，在後面會有進一步的說明。

八、棲地的經營

要滿足梅花鹿的需求，棲地中草生地與樹林的比例應該是甚麼？由於缺少相關的研究和經營管理的經驗，目前很難提供精確的答案。但根據墾丁國家公園已做過的研究、我們在綠島的觀察結果、以及對白尾鹿的了解，我們判斷草生地應佔約30% 樹林應佔70% 的面積。這種面積比例與梅花鹿的食物中草本植物約佔70% ，木本植物約佔30% 的比例恰好相反，這是因為就鹿的食物而言，單位面積的草生地之生產力比單位面積的森林高。因此在冬季乾旱的南台灣，若要把梅花鹿維持在與北台灣相同的密度，就須保留較大比例的森林，而北台灣因雨量豐沛且四季降雨較平均，棲地中森林所必須佔的比例或許可以較低。

另外，森林對鹿群過度啃食的壓力會比草原敏感，不但因為林地所提供的食物資源較分散，其再生也因林冠的遮蔽而較緩慢，同時各種植物的適口性（palatability）不同也會造成植群中物種組成的改變，可食性低的種類會逐漸擴張，佔用了被大量啃食的植種的生存空間；梅花鹿剝食樹皮的習性也會產生相同的結果。

草類植物固有的生長方式使之有較高的再生力和食物生產力，因此草生地對草食動物的啃食有較高的承受力；草生地的創造及控制也比森林容易。基於上述理由，若要在草地面積固定的情況下建立梅花鹿群，當地森林對鹿隻的最高承載力（carrying capacity）應比草原的最高承載力更是考慮的重點。鹿隻的數量不應導致對森林的破壞，雖然鹿隻對森林造成少量衝擊是正常並可以預期的，但應該謹慎地監測森林植群的變化趨勢，以避免不良改變的發生。

知道森林的承載力後，經營者便可以調整草原和森林的面積比例，以防止森林被過度啃食。若森林中的跡象反映它還能承受更多的梅花鹿利用，就可以擴張草原面積來供養較多的鹿隻生存，但若森林顯然已承受過大的壓力，就應將草地面積縮小，當然鹿的隻數也需要調整到適當的數量。經營者可以透過試驗與修正，為一塊棲地中林地與草原的比例找到正確的平衡點，當然也可藉擴大復育用棲地的面積，來達到增加草地或森林的目的。最後，

如果利用「第二種草食動物」爲經營管理的工具，也可藉增減這種動物的數量來獲得森林草地面積的正確比例。

九、第二種草食動物

在台灣，水牛應是最接近理想的「第二種草食動物」。牠很適應台灣的氣候及棲習環境，且幾乎是完全以草爲食的，所以對森林植物的衝擊非常小；在森林易受過度利用的狀況下，這正是理想的條件。水牛的性情溫和，且歷經數世紀的馴養後，牠們可以是易於操作的管理工具，何況水牛肉的市場價值也可增加收益，不過水牛的糞便可能帶來水源的污染，水牛製造泥坑在其中打滾的習性，會帶來地表的破壞，使得水牛數量應被維持在最低。雖然水牛不是台灣的原生種，但數世紀以來牠早已馴化成爲本地常見的景觀之一，在自然環境中添加水牛，對一般人而言應不致太突兀，而實際上水牛在中國的景觀中一直被賦予正面的價值。

綠島農人放牧水牛的廢棄稻田似乎是梅花鹿最喜歡的覓食場所；陽明山國家公園預定用來復育梅花鹿的鹿堀坪，目前也有水牛在荒廢的耕地上活動。如果沒有水牛把廢耕地維持在草地的狀態，這些地點很快就會被木本植物入侵而逐漸演替成樹林，墾丁梅花鹿復育區的棲地，有一部份就是這樣消失的。草地消失後若要重建，將會需要大量經費，在經營者還在以試誤實驗決定森林對梅花鹿承載量的過程中，水牛是維持草地開闊的有效工具；在引入梅花鹿族群的初期，梅花鹿的數量還不足以維持整區草原的開闊度，此時水牛也可以發揮維持草地面積的功能。

梅花鹿保育計劃的長遠目標，應是重建一個儘量自然的生態系。如果可能，復育區內最好沒有水牛這類的外來種，所以經營的目標應是把水牛的數量減到最低，而使梅花鹿及其他原生物種的數量達到最多，但是因爲能提供梅花鹿復育的地點有限，又缺乏足夠的知識來做精確的規劃，水牛便成爲有效甚至不可缺的經營工具。

隨著經驗的累積，將來必可以不需借助於水牛即能直接維持梅花鹿的棲地，但在目前，「第二種草食動物」可以協助復育計畫步上成功之路。真正的穩定在自然界很少存在，但藉由對干擾和草食動物數量的控制，整個系統應可維持相當程度的穩定性，也希望這種系統能逐漸轉成只靠梅花鹿一種草食動物即可維持的狀況；根據美國的經驗，單靠白尾鹿來阻止演替的前進很難成功，若梅花鹿與白尾鹿相似，可能必須靠水牛或其他人爲措施來管理草原。

十、對梅花鹿保育的建議

根據前述的背景資料與各種理由，我們對梅花鹿的保育有下列幾點建議：

（一）法定地位

首先，應設法解決梅花鹿現有法定地位帶來的困擾。過去政府爲了方便處理有結核病的梅花鹿而將之定位爲家畜，但卻因此使其無法受到野生動物保育法的管理與保護，也使保育單位投注大量精力及經費來進行牠的復育，變成不易辯解的行動。

（二）擬定保育方案

目前迫切需要擬定一個整體性的梅花鹿保育與管理計劃，以使各亞族群的經營能互相協調，使各亞族群均成爲整體的一部份，而非各自孤立的小族群，如此方能發揮集合族群的功能。

（三）行動方案

我們強烈建議有關單位立即進行下列研究或行動：

1、 確定原生台灣梅花鹿的種群。

向早年曾來台灣採集收藏動物的博物館，例如大英博物館（the British Museum of Natural History in London）、芝加哥博物館（Field Museum in Chicago）、美國自然史博物館（American Museum of Natural History in New York）、及史密蘇尼亞研究中心（the Smithsonian Institution）等均可能有純台

灣梅花鹿的標本。應向這些單位索取確定是原生梅花鹿的標本，以供進行粒線體去氧核糖核酸（mtDNA）分析；

分析此類標本所得之mtDNA序列，可以用來判斷現存綠島、墾丁、或其他公有及私有台灣梅花鹿個體的純度。谷及王（1992）已對墾丁的梅花鹿族群進行過小樣本的分析；如果墾丁的梅花鹿確定是純種的族群，將來在其他地區進行復育時便可考慮使用墾丁的鹿隻，但若墾丁族群的純度已受其他種源的污染，就應避免使用。如果綠島的梅花鹿被證明是現存唯一的純種梅花鹿族群，未來的復育種源皆應來自綠島，墾丁與台北市立動物園內的族群則應被侷限於現有範圍內不能野放，且最好能逐漸以綠島的梅花鹿來取代；但如今大概只能完全取代台北市立動物園的族群，墾丁已被野放的個體並無法一一捕回，只能靠引入綠島的個體將被污染的種源逐漸稀釋。

在台灣還有其他私人飼養的梅花鹿群，但這些鹿的來源不明，其血緣很可能已與其他種源混雜過。復育計劃應儘量避免利用這些私有梅花鹿作為種源，以免使問題更加複雜，只有對確知族群來源，並經mtDNA分析能確定純度的特例，才可考慮用於復育計劃中。

2、 遺傳多樣性分析。

一旦可以辨別那些是純種台灣梅花鹿，就可以進行基因多樣性的評估。若結果顯示所有或大多數的對偶基因都已經固定，未來就不需為基因的經營花太多功夫；但若現存個體中仍有相當程度的基因變異，就應該特別設計人工繁殖計畫來儘量維持各亞族群中的基因多樣性，以便集合族群能保有最高的整體多樣性。綠島的梅花鹿現在還很多，所以應還維持著相當程度的基因多樣性，但若進行遷地繁殖時，應留意使所有被選定的個體都有繁殖的機會（尤其要注意年輕的公鹿常會被較年長者排擠而無法繁殖）；對一直很小的亞族群，則可考慮將一些個體移入以增加其族群量及生物多樣性。

3、 經營四個亞族群。

目前台灣有三個公家擁有的梅花鹿群，分別在墾丁、綠島、及台北市立動物園。根據前述集合族群的觀念，由於台灣梅花鹿的總數很少，經營分隔的亞族群是避免牠滅絕的主要方法，尤其是因天災導致的滅絕。

就集合族群的觀點來看，現有三個亞族群仍嫌太少，因爲台北市立動物園的族群非常小，目前只有17隻，且長期緊鄰其他圈養動物，一直都面臨傳染疾病的威脅；過去動物園曾因梅花鹿感染了肺結核而必須將之全部消滅，便說明了這個族群潛在的危機，所以實有需要建立第四個亞族群。當然，管理者仍須評估其他梅花鹿族群的健康情形，以避免傳染性疾病透過復育計畫的圈養繁殖過程被擴散。隨著管理經驗的累積，現存問題的解決，未來也許可能或有需要建立四個以外的亞族群，所以四個亞族群只是目前應建立的，而非最理想的亞族群數。

我們無法確定最理想的亞族群數，因爲在超過四個亞族群之後，再增加一個亞族群的好處必須與其所在的地點及當地棲地的品質一併衡量。屆時分析可利用的棲地、經費、與其他保育需求的相對優先順序、社會教育及遊憩的需求、及社會大眾關心的程度等，可協助決定最後要建立的亞族群數。

4、 亞族群的隔離。

集合族群觀念中所謂各亞族群所在地點的環境因子間應沒有相關性，通常是指牠們所在地理位置互相分隔較遠；但直線的距離只是一個很粗略的指標，因爲各點之間氣候差異的改變幅度、山脈、水體或其他類似的環境屏障，都可能使亞族群間的環境條件互無關連。在現有三個亞族群中，台北市立動物園位於台灣北部，距其他兩個在南部的亞族群較遠，因此在環境條件上與另兩個亞族群較不相同。墾丁與綠島相距 100 公里，且有海域相隔，因此對大部分天災而言，兩地也應沒有相關性；颱風是台灣最常發生的天災，也可能同時對這兩地造成影響，但颱風對梅花鹿群應不具有毀滅性，因爲梅花鹿可以在岩石間或山谷地區尋得庇護。另外，雖然颱風可能使梅花鹿在短期內有食物缺乏的問題，但就長期而言，所帶來的干擾應有利於梅花鹿棲地品質的改善。

現存三個亞族群所處地點的環境因子大致並無相關性，同一個天災對牠們的影響也應各不相同，但陽明山國家公園的環境條件至少與台北市立動物園有部份相關。若要建立第四個亞族群，選擇距台北市較遠，承受同一個災害的可能較小的地區，會較爲理想。

5、 最小可存活族群。

我們建議至少應維持 500 隻梅花鹿的存活，或應進行「族群及棲地可存活性評估」（ Population and Habitat Viability Analysis ），來決定應在台灣維持多少隻梅花鹿。

要維持 500 隻梅花鹿應是短期內即可達成的目標。目前綠島已有約 250 隻，墾丁有近 200 隻，台北市立動物園有 17 隻，因此在第四個亞族群建立之後， 梅花鹿的總數應很快即可提高到 500 隻以上。

長久以往，當農地面積隨經濟成長而減少、民眾對保育的關心增加、鹿隻數量能被控制、危害農作的問題能獲得妥善處理，則可考慮讓梅花鹿回復野外自由的生存，屆時應將之視爲野生動物來經營管理，圈養繁殖和復育計畫也應中止。

6 、 循序漸進。

梅花鹿復育計畫之進行應謹慎地循序漸進以避免昂貴的錯誤，因爲梅花鹿目前並非面臨即將滅絕的危機，也已有三個相當安全的亞族群存在，所以現在應仔細研擬整體保育措施，依序進行，不必急切地做決定。

十一、結論

梅花鹿復育計畫首應完成之要務，是確定純種台灣梅花鹿的現狀，其後才是考慮下一個亞族群的建立，而且是否繼續野放墾丁族群繁殖出的個體，也應在基因問題獲得解答後才能決定。此項基因分析工作應可在兩年之內完成。如果基因問題無法獲得解決，未來再引入的種源則可視方便性和可行性而定。

其次，第四個亞族群建立的地點，應在調查及評估全島有潛力的地點之後再決定。陽明山國家公園的鹿崛坪固然應可以成功地維持第四個亞族群，但此地點在很多條件上都會受到限制，在此建立梅花鹿族群的成本也會非常高。所以我們認爲應可以在西部海岸平原或花東縱谷找到更合適的地點，這

些地區的天然條件也與梅花鹿原來的棲地條件更爲接近。

台灣農地所佔面積，自 1977 年到 1995 年，已減少 324,200 公頃（ 11.65 %）（台灣省農林廳林務局 1995 ）。若廢耕地區在農業區的邊緣地帶，當會形成適合梅花鹿的新棲地，應考慮將之設立爲梅花鹿復育區的可能。

建立第四個亞族群對梅花鹿的保育是有利的。目前只有陽明山國家公園有意願參與此計畫，但陽明山地區的條件帶給梅花鹿復育工作很大的限制，未來族群發展的潛力也很有限，加上復育需求也與國家公園其他土地利用現狀及目標有潛在的衝突。所以站在梅花鹿復育整體要求的立場，我們認爲應先評估其他有潛力的地點，或許在陽明山國家公園範圍之外，還可以找到更好的復育地點。

台灣西部平原有些地區應具潛力作爲復育的地點；台灣中西部是過去台灣梅花鹿分布區的中心，且與現有三個亞族群所在地距離較遠，環境因子差別也大，若能在此區建立一個亞族群，應會對整個保育計畫有更大的貢獻。無論如何，第四個地點的選擇必會牽涉到很複雜的取捨問題，必須考慮地理位置、現存自然狀態、面積大小、設置圍籬的需要、是否會有土地利用的衝突等等。最適地點的決定必須是整合這些因素後的折衷方案，因爲保育經費有限，最後的決定必須是最妥善的選擇。

第三章　陽明山國家公園梅花鹿野放計畫分析

一、野放梅花鹿之目的

如果資源有限，只允許再建立一個而不是多個梅花鹿亞族群，依據第二章所述亞族群建立原則，陽明山並不適合作爲第四個地點，因爲陽明山的位置和台北市立動物園位置非常接近。

另外，陽明山國家公園能提供梅花鹿族群未來擴張的潛力極少，因爲梅花鹿喜愛的棲地在此範圍內僅侷限於幾個小地區，而這些地區彼此的距離都很遠，沒有任何一處大到可以容納夠多的鹿隻，例如超過 100 隻。雖然各棲地間的森林或許可以供養少數四處移動的鹿隻，但是陽明山國家公園內複雜的土地所有權及管理單位，和極高的遊客壓力，使得整個問題更加複雜。

不過，在陽明山國家公園內重新建立梅花鹿族群的構想數年前即已被提出，並已經有兩篇研究報告發表對其可行性及其中可用地點之評估（王及蘇 1994 ；王等 1995 ），因此筆者仍然針對此計畫之可行性進行進一步評估。

陽明山國家公園野放梅花鹿之目的，依據王及蘇（ 1994 ），是爲了增加梅花鹿種群及分佈，在現有之墾丁國家公園鹿群外，建立北部地區梅花鹿族群復育的基地，不但使牠重現於陽明山國家公園境內，並可進而擴展到北部各地山區。而據墾丁國家公園梅花鹿復育計畫七十三年度的報告，梅花鹿復育之長期計畫目的，應是保存台灣固有梅花鹿之品系，使梅花鹿回歸原有之野性生活，並喚起國人對生態保育之重視，及對梅花鹿與傳統歷史之淵源的認知。

分析民國七十三年至民國八十一年的各項梅花鹿復育研究報告，並未在其中找到要建立北部梅花鹿族群復育基地的構想，故在陽明山國家公園內建立族群應不是原定統籌計畫的一部分，而是近年發展出的新方向。而有關梅花鹿復育的長遠目標，筆者閱覽過的文獻中均未明確指出理想的終極隻數，也未說明要在台灣現存自然環境中建立幾個族群，還是將設法使梅花鹿回歸全島；顯然對這類目標的適當性、及可實現性，尚未進行妥善評估。當然這

可能是因爲復育工作進行初期無法預期未來之成敗的緣故。但今天要在陽明山國家公園建立梅花鹿族群，實應事先確定長期目標。

若陽明山國家公園之長期目標，是以圈養方式建立梅花鹿族群，不論圈養範圍是 20 或 100 公頃，都是可實現的。但若目標是任由梅花鹿在國家公園中或其他特定地區自由活動，或希望全島都能回復到有野生梅花鹿的狀況，則必須考慮：

1 、現有適當棲地之分布、面積、及其目前土地利用種類等。

2 、野外自由放養所可能導致的問題，例如：（ 1 ）必須化解梅花鹿現有法定地位的困擾；政府爲處理梅花鹿罹患傳染疾病而將之指定爲家畜，但國家公園將之認定爲需要復育的野生動物，其間的矛盾已在社會上引發某種程度的疑惑。（ 2 ）現有梅花鹿種源之基因組成是否允許長期在野外健康地生存繁衍。（ 3 ）梅花鹿會感染肺結核等人畜共通的疾病；野放於陽明山國家公園之個體若被疾病傳染，其後之善後工作將如何進行。（ 4 ）梅花鹿在台灣已無大型掠食動物爲天敵；在缺少天敵制衡的情況下，大量野生梅花鹿對國家公園內或特定地區之生態平衡的影響，將如何處理。（ 5 ）草食性動物繁殖快速，梅花鹿數量大量增加後，若需控制梅花鹿數量以減少對國家公園內環境、或其他地區之農作或林木的破壞，應如何進行，其代價將如何負擔等。

3 、 野放梅花鹿對人文社會的正面或負面影響，如野放梅花鹿之社會教育價值，未來梅花鹿被民眾干擾、或濫獵等社會問題，其他野生動物被濫獵的機率是否會隨著提高，及梅花鹿危害農作的處理等。

4 、經費之長期可獲得性，應是陽明山國家公園決定是否進行此計畫之重要考量。以台灣現狀，要再使梅花鹿完全回歸到百年前的自然、不必依靠人類做任何經營管理的狀態，應已不可能，所以陽明山國家公園應預期並規劃從事野放各階段所需的經費，包括立即的需要、其後永久性經營管理、族群數量控制、棲地維護、甚至未來補償農民損失所需的經費。陽明山國家公園應向墾丁詢問歷年累積經費需求，以爲參考。

二、野放梅花鹿之環境影響評估

已完成之環境影響評估，考慮了陽明山國家公園是否能提供梅花鹿足夠的食物，民眾對梅花鹿野放的態度，並對可能的野放地點加以評比選擇。至於野放梅花鹿對陽明山自然環境和生物族群可能導致的影響，則尚未完成評估。筆者建議評估項目也應包括：

（一）梅花鹿的生存

1 、氣候與棲地方面

梅花鹿原來的分布，以本省西部近海平原的族群數量最大。依據蘇（ 1985 ），此區的氣候特徵是雨量集中於夏季（五至九月），低海拔地區冬天會有乾旱現象，而其中最乾燥之地區是中西部近海區，也是梅花鹿最多之地區；最適宜梅花鹿生存之環境應是夏雨冬乾之氣候，經年重濕多雨之雨林氣候則非所宜。他判斷因台灣梅花鹿在光復前曾被引進日本並且繁殖成功，同時台灣民間野常在山區飼養梅花鹿，故山地的低溫應不是限制梅花鹿分布的因子。

蘇（ 1985 ）指出，雖然缺乏有關梅花鹿食性的歷史資料，但根據在其天然生育地進行的植群調查及飼養所用的野生植物種類，可推測其食物所屬之植群類型，他認為夏雨型氣候區中之半落葉闊葉林中及草原上，曾有許多梅花鹿喜食之植種，而相思樹林則可能是梅花鹿尋求遮蔽的處所。半落葉林及草原是梅花鹿生存所需之兩大植群型，而這兩種植群型在雨量少且有乾旱季節的氣候區，亦即本省西部及南部之平原或山麓，較盛行。在終年多雨之東北區，除了多風面海的山坡及海崖外，天然草原及大面積的落葉林極為罕見，而台灣內陸被常綠闊葉林連綿不斷地覆蓋著，這種屬於亞熱帶雨林形態的植群型，料非最適合梅花鹿生存的環境。因梅花鹿生存於森林及草原邊緣，而臺灣的主要植物社會是森林，所以梅花鹿主要分布在草原大量出現的地點。

陽明山國家公園之氣候與植群型是否最適合梅花鹿生存，應進一步分析。

2 、天敵與族群控制機制

野狗可以是梅花鹿的天敵（江 1984 ，王等 1995 ）。台灣島上之原生大

型掠食者於今若非絕種即已十分稀有，野狗應是梅花鹿現存之最重要天敵。除非欲完全移除野狗，否則陽明山國家公園內野狗族群之數量、活動範圍與食性，可能帶給梅花鹿的生存壓力，應事先加以瞭解；當然也應分析在復育之中、後期，利用野狗爲族群控制機制之可能。但未來若欲在無野狗地區引進野狗以控制梅花鹿族群量，所可能產生之生態後遺症及社會輿論壓力亦絕不容忽視。

3 、食性分析

梅花鹿之食性與陽明山植被的關係，尚有待深入研究。已完成之分析只證明陽明山地區有可供梅花鹿取食的植種（王 1995 ），但不能用來做爲判斷當地最高容納量的依據，更不能判斷食物稀少時，梅花鹿會給當地原生植被帶來何種影響。王等（ 1994 ）在墾丁復育區內的研究顯示，梅花鹿會利用 151 種植物，食物匱乏時更會轉而食用平時不吃的植種。若欲仔細評估梅花鹿之食性與陽明山植被的關係，除需量化可供利用之植種外，還應進行飢餓實驗，以判斷環境惡劣時梅花鹿之食性與食量，及可能產生之生態衝擊。

（二）野放地點的選擇方面

陽明山國家公園台灣梅花鹿野放研究（一）（王 1994 ）中對復育地點之選擇，考慮了各地區之面積、土地使用現況、生態保護區、道路等條件，又將特稀有植物保護區及生態保護區分爲可利用及不可利用兩組，但可惜對判斷何者爲可利用或不可利用之依據未詳細說明，故無法確實了解已考慮那些角度。陽明山國家公園或應進一步整理當時選用之評估原則，作爲未來執行工作之依據；此點十分重要，因爲優先地點是否真正適合梅花鹿復育或野放，要看所考慮條件之完整性及妥當性而定。

墾丁國家公園選擇梅花鹿野放地點時，考慮了溫度、雨量、棲地需求與食性、及其他環境因子，如野放地點之位置、交通可及度、地形、在當地生存之其他動物種類、及目前土地利用情形等，除評估該地點之生育環境對梅花鹿之適合程度外，亦考慮了鹿與其他動物（競爭者及掠食者）之可能衝突。

目前鹿崛坪被選定爲陽明山國家公園內最適合重新引入梅花鹿的地點（王與蘇 1994 ；王等 1995 ）。另外也被列入優先考慮之磺嘴山點（第四區）則似乎並未出現在評估表中。筆者建議在選用鹿崛坪爲野放區前，應考慮以

下的角度：

1 、區位之便利性

筆者曾與麥博士前往鹿崛坪現場考察，發現必須從可通小型車輛的硬路面盡頭，沿著一條土徑步行約 45 分鐘（約 1.5 公里）方能到達，顯然若在此進行復育，其可達性應是重要考慮角度。梅花鹿亞族群應能在鹿崛坪生存，但是所需的費用會很高，因爲圍籬和其他建設所必須的建材都需要靠人或其他動物搬入，所有鹿隻也需要被裝箱運入（或運出）；由重型直升機運送建築材料及鹿隻或許較有效率，但未來圈養或管理時所需之物品，仍必須從道路盡頭以人力搬運進入，未來對該地區的巡邏管理也將非常困難，可能給管理者帶來相當程度的困擾。

當然地區偏遠也是它的優點，因爲民眾對此地利用的程度也相對的會較低；不過，梅花鹿的出現可能會吸引遠比目前更多的人到此野餐、露營與健行（見下面第 4 點）。

2 、區位之適當性

目前所選梅花鹿野放地點（鹿崛坪）緊臨生態保護區，若計畫在野放區邊緣建圍籬，則應考慮若圍籬破損可能導致的影響；若計畫不用圍籬而將鹿隻自由野放，則必須考慮對生態保護區之可能衝擊，及此地點是否恰當。

3 、面積

鹿崛坪「復育區」之面積僅 20 公頃。由王等（ 1994 ）之圖 17 推估一隻鹿二個月內會利用 6 公頃活動空間，每公頃之最高容納量是 3 隻。若考慮族群基因組成， 20 公頃之族群可能會太小。若此地對梅花鹿之最高容納量與墾丁相同，即使開始時每公頃僅野放 1-2 隻，野放 5 年內族群密度應已達飽和；但陽明山地區之棲地若更不適合梅花鹿之生存，對梅花鹿之最高容納量可能較墾丁更低，野放族群到達飽和之速度可能更快。

4 、遊客管理

因遊客會對梅花鹿造成干擾與壓力，梅花鹿圈養區附近的遊客人數、遊憩類型、及遊憩地點均必須加以管理。若圈養梅花鹿吸引更多人前來遊憩，必會給梅花鹿帶來干擾，也會對當地水源及生態環境造成壓力與破壞，均應

有計畫地預先防範。

遊客被吸引前來參觀梅花鹿復育工作，提供了良好的社會大眾保育教育的機會，把握此等機會提升社會大眾對自然環境及野生動物的愛護，應是進行此類計畫的重要附帶收穫。

（三）生態影響方面

鹿隻野放對鹿崛坪或陽明山地區會有那些確實的生態影響，尚有待研究，但鹿隻野放對墾丁地區已有某些生態影響，或可用爲參考。蘇及楊（ 1988 ）曾在墾丁國家公園的社頂梅花鹿復育區內，以 80 個植群樣區及 13 項環境因子進行植群演替研究，發現放牧區中動物不吃的植種會大量衍生，故判斷梅花鹿的密度及放牧壓力，會對當地樹林、高草原、和低草原的面積有所影響。

墾丁的旱季是 11 月至 4 月。旱季時鹿隻會把可吃的植物吃光，剩下枯黃的部分，有些樹會被剝皮，但並非每棵被剝皮的樹都會死亡；不同的樹種對梅花鹿啃食壓力的反應，有待進一步研究（馬協群，個人通訊）。因爲野放區第一區中的鹿隻太多，導致該區的植物受到超過可接受限度的損害，故 1996 年 4 月墾丁國家公園動員人力，把 25 隻鹿由復育區第一區趕到圈養區，只有約 10 隻鹿仍留在野放區第一區中，趕鹿的目的是要舒緩對第一區的壓力。其他幾區的梅花鹿數量也都很高，明年將另擇一區來趕鹿（馬協群，個人通訊）。

王等（ 1994 ）發現梅花鹿在墾丁會食用 12 種台灣地區稀有植物，雖然野放梅花鹿多年以後，尤其鹿隻增加後，會對墾丁地區植物之天然族群造成何種危害及其影響程度，仍有待定量調查，但陽明山國家公園應事先評估此等威脅之可接受性。

另墾丁國家公園的梅花鹿被野放後，現有約 30 頭生存在野外，曾有三戶居民口頭抱怨鹿隻損害了作物，但不曾正式要求處理（馬協群，個人通訊），顯然至今影響並不嚴重；綠島的狀況則已惡化到鄉公所悔不當初的地步（見下一節）。

若陽明山國家公園決定進行梅花鹿野放計畫，筆者以爲要減低鹿群對公園環境的生態撞擊，野放目標應只是圈養，而不是野放使之自由生存。

三、綠島的梅花鹿經驗

此節有關綠島民間飼養梅花鹿及鄉公所野放梅花鹿的歷史及現狀報告，乃根據筆者於 1996 年 5 月及 6 月兩次訪問綠島鄉公所陳進文鄉長、林再貴課長、陳頂福課長、李威仁先生及其他人士，現場夜間觀察，鄉公所提供的書面資料，及參與「台東縣綠島鄉利用野放梅花鹿闢建『觀光梅花鹿園』研討會」的記錄。

1 、民間養鹿史

梅花鹿是在約一百年前自台東被引入綠島的，其後的 20 到 25 年間陸續又引進了數次，之後便不曾再有引進。綠島民間養鹿，早年是公共造產， 1969 年鹿茸價格起飛，把養鹿事業在 1975 到 1976 年帶到高峰，當時養了約 2000 隻梅花鹿。

養鹿盛行時，鄉公所飼養了197隻鹿，另由民間代養約50隻，其中包括40隻自北美洲進口的歐洲鹿。即所謂的「美國梅花鹿」。根據描述（平直的鹿角和白色的毛皮），這些鹿應該是與梅花鹿十分不同的 fallow deer（*Dama dama*）。鄉公所引進外國鹿是為了改良品種，以增加鹿茸的產量，但這兩種鹿不能雜交，且美國梅花鹿多因不適應綠島的氣候而死亡。

自從鹿茸市場不利，養鹿者大量減少，現僅有 160 戶養鹿，共養 550 隻梅花鹿。依現有鹿茸市場價格，一頭雄鹿一年僅可賺 15000 元；現在的飼養者並非單純為賺錢而養鹿，也有些是年長農民為找些事情做的結果。

2 、野放的後果

鹿茸市場低迷後，鄉公所於1986年將公有的197隻梅花鹿全數野放。劉和義（1992）接受東海岸風景特定區管理處的委託所進行的調查發現，全島各地之取樣地點皆有梅花鹿活動的痕跡；調查估計1992年約有200至250隻梅花鹿生存於島上。根據陳鄉長的個人估計，綠島野生梅花鹿的隻數應在穩定增加中，顯然梅花鹿在綠島生存沒有任何問題。陳鄉長認為島上的樹林高度夠高，不會受梅花鹿破壞，同時梅花鹿不喜歡密林，所以樹林中鹿的數量應不多；他晚上出去巡邏時常可見梅花鹿成群在開闊地中覓食，有時可見20到30隻的大群。麥博士我的觀察顯示，梅花鹿大多數集中在植被受干擾的地區，

也就是有水牛放牧的廢耕水田、有山羊放牧的山坡地、及鄰近的農耕地；夜間很容易藉著燈光看見梅花鹿在這些地區覓食。我們也在內陸及島上其他地區見到梅花鹿的痕跡，只是在內陸森林區內鹿的密度都很低。

因為鄉公所野放了鹿群，故須對所導致的為害負責。鄉公所於 1986 年野放梅花鹿後，即開始賠償農作物的損失，其後每年賠償量均增加，直到 1992 年進行圍網後才略見改善。筆者未能獲得早年之賠償資料，近 5 年之賠償量見表一。梅花鹿損害農作物之補償標準是縣政府決定的，農民報告損失後，由鄉公所派員估計損失，再依損失額加倍賠償。受損之作物多是為飼養鹿所種的植種，如蘭嶼鐵莧草等，農民用補償金購買肥料，再種植同樣的作物，作物成長後再被野鹿啃食，形成惡性循環。雖受害面積不大，補償金額也不多，但鄉公所有不堪其擾的苦衷。

根據農民申請賠償的狀況，野鹿對作物的損害有季節性的不同，夏天全島均有，冬天則多在背風的南寮一帶，可能鹿的活動受氣候及風向的影響；但總受損面積變化不大。梅花鹿最喜愛的作物包括蘭嶼鐵莧草，花生，及地瓜葉等。

鹿害的逐年增加，使鄉公所於 1992 年開始利用圍網的方式，設法將鹿群侷限在島的中央，防止梅花鹿進入邊緣的農耕地。林再貴課長說，若會受損的作物區是獨立的，顯然可在其四周建立圍籬，但梅花鹿的食性似乎非常廣，結果與其圍起眾多零散田地，不如圍起整個山坡較易進行（圖一）。第一年圍網所用的材料是塑膠網，材質易碎，圍籬易倒，故於第二年全面改用魚網（網目 15x15 公分），每張網 100 公尺長，約 2 公尺高，單價 5000 元，安裝後的長度約 70 公尺。每年圍籬的長度不斷增加，現全長約達 18 公里。圍網使農害情況有所改善，但網的損耗速度很快，必須經常更新，同時一段圍籬與另一段之間還有空隙，鹿隻可由此進出圍籬地區，所以至今無法杜絕鹿害。

梅花鹿發情期雄鹿會被纏死在網上，網也很容易受損。鄉民報告的梅花鹿纏網及被狗咬死總隻數，一年約 50 隻，但未報的隻數應是有報告的兩倍。鄉公所聘請專職巡邏員及臨時工，每天不斷巡視圍籬，一方面要把纏在網上的鹿隻解下，也在見到網有損害時可以立即修補；不少地區的圍籬上現已有 5 層魚網。此等圍網及巡邏的經費（表一），對鄉公所是很大的負擔。

3 、綠島問題可提供的參考

若陽明山國家公園復育梅花鹿的目標是野放，綠島的梅花鹿問題，在切實評估政策之可行性時，應是十分重要的參考。

鄉公所對野放梅花鹿後悔不已，自鄉長至承辦人都說若今天能從新來過，將不飼養也不野放。現在鄉公所希望能尋得長遠的解決辦法，例如將野生個體全部捕回關在欄內飼養，但因梅花鹿在島上的分布廣泛，又有許多躲藏在內陸林中，故也知這是不易實現的理想。曾有民間某俱樂部向鄉公所申請，以每年給鄉公所兩三百萬元的代價，租用梅花鹿管理權，鄉公所雖然願意，但可惜礙於無法令可循而未能進行。鄉公所原也曾考慮靠全面捕殺梅花鹿來解決問題，但時機不巧正逢犀牛角事件而只好擱置此計畫。目前鄉公所正在研擬如何利用梅花

表一：綠島鄉八十年度至八十四年度梅花鹿損害農作物處理情形統計表

台東縣綠島鄉八十年度至八十四年度野放梅花鹿損害農作物處理情形統計表					
年度	損害面積（平方公尺）	損害次數	賠償金額（元）	用人費（元）	圍網費（萬）
80	136,400	106	127,000	189,000	0
81	109,600	89	96,200	201,758	90
82	117,730	81	97,800	215,380	142
83	95,750	73	87,600	277,017	70
84	81,200	44	64,800	322,611	151
合計	540,680	393	473,400	1,205,766	453
備註					

資料來源：綠島鄉公所

圖一：綠島鄉梅花鹿圈籬分布示意圖

鹿的觀光價值賺取外資，例如建立觀光鹿園等，期望可以將梅花鹿由禍害改為財源，而不再是鄉公所永遠的負擔。

鄉公所各級人士均一再表示，墾丁國家公園以鉅額經費復育梅花鹿，歷時十數年，所得成果並不比綠島未花中央政府任何經費來得好，綠島養了這麼多梅花鹿，不但未得到中央政府的經費補助，還要額外負擔損害的賠償，現中央政府又在考慮撥款於陽明山進行復育，何不用少量經費補助綠島鄉公所，進行已十分成功的梅花鹿復育野放工作；陳鄉長保證不須十年，綠島必可以成為鹿島。

4 、綠島鄉公所對陽明山國家公園的建議

陽明山國家公園若進行梅花鹿復育工作，應儘量考慮於圍籬中飼養，雖然較像動物園，較不自然，但會節省許多麻煩。圍籬的材料應使用鍍鋅的網較好，雖然較貴，但可使用較多年，不必每年更新修補。除非沒有破壞環境的顧慮，或沒有對當地人提供賠償的隱憂，否則一定要在圍籬完成後再引進鹿隻。

四、陽明山鹿隻之來源

為求維持台灣梅花鹿的純度，並增加各梅花鹿復育群中的總基因變異度，陽明山國家公園若決定進行野放，未來引進野放鹿隻的種源應經過仔細選擇。

1 、野放種群之選擇

墾丁國家公園梅花鹿復育種群的基因組成至今尚無確實資料，部分原因顯然是從事此方面研究所需的技術，於墾丁復育計畫開始時尚未發展成熟。王及詹（ 1985 ）的報告提到復育初期以台北市立動物園的梅花鹿群為選定對象，希望未來能由他處引進純種且較具適應性及野性的鹿隻。但除在 1988 年有 6 隻年青的雌鹿來自左營鹿場， 1989 年有 8 雄 9 雌原來屬於台北市立動物園的個體，由東海鹿群再被引入外，並無其他種源。台北市立動物園及左營鹿場的梅花鹿是否為純種台灣梅花鹿尚有待求證。陽明山國家公園未來引進繁殖種源之前，應先進行粒線體去氧核醣核酸（ mitochondrial DNA; mtDNA ）

分析以求確定。

2 、基因多樣性之管理

爲維持或增加各亞族群中之基因多樣性，應盡量避免各亞族群具有相同的基因組成。在不知各亞族群的基因組成前，要達此目的有一個簡單的原則，即建立復育族群時儘量避免選用來自同一小族群的個體。以墾丁鹿群爲例，雖然此族群之基因組成並沒有資料，但原來先後引進的 45 隻鹿，至 1996 年已繁殖成 185 頭（馬協群，個人通訊）；因爲並無資料呈現所育出的現存 140 隻子代之親代是誰及個體間之親緣關係，故無法判定族群之基因組成是否更趨簡化。但王（ 1990 ）提到當年 13 隻仔鹿極可能多係來自同一隻雄鹿。若鹿群中各年之繁殖狀況均呈現最優勢的雄鹿獨霸繁殖機會的現象，墾丁鹿群中之族群遺傳變異性很可能是在減少中；當然確實狀況有待求證。

若此顧慮被證明是事實，陽明山國家公園應避免自墾丁鹿群引進繁殖種源，以便增加各復育群中之總基因變異度。

五、 鹿崛坪的圍籬設計

如果要在鹿崛坪引入梅花鹿，必須架設圍籬以利鹿群的適當管理，並防止鹿隻對鄰近的生態保護區造成棲地破壞，圍籬的設計也應以儘量減少遊客對養鹿設施的干擾爲目標。以下是麥可樂博士有關圍籬的建議。

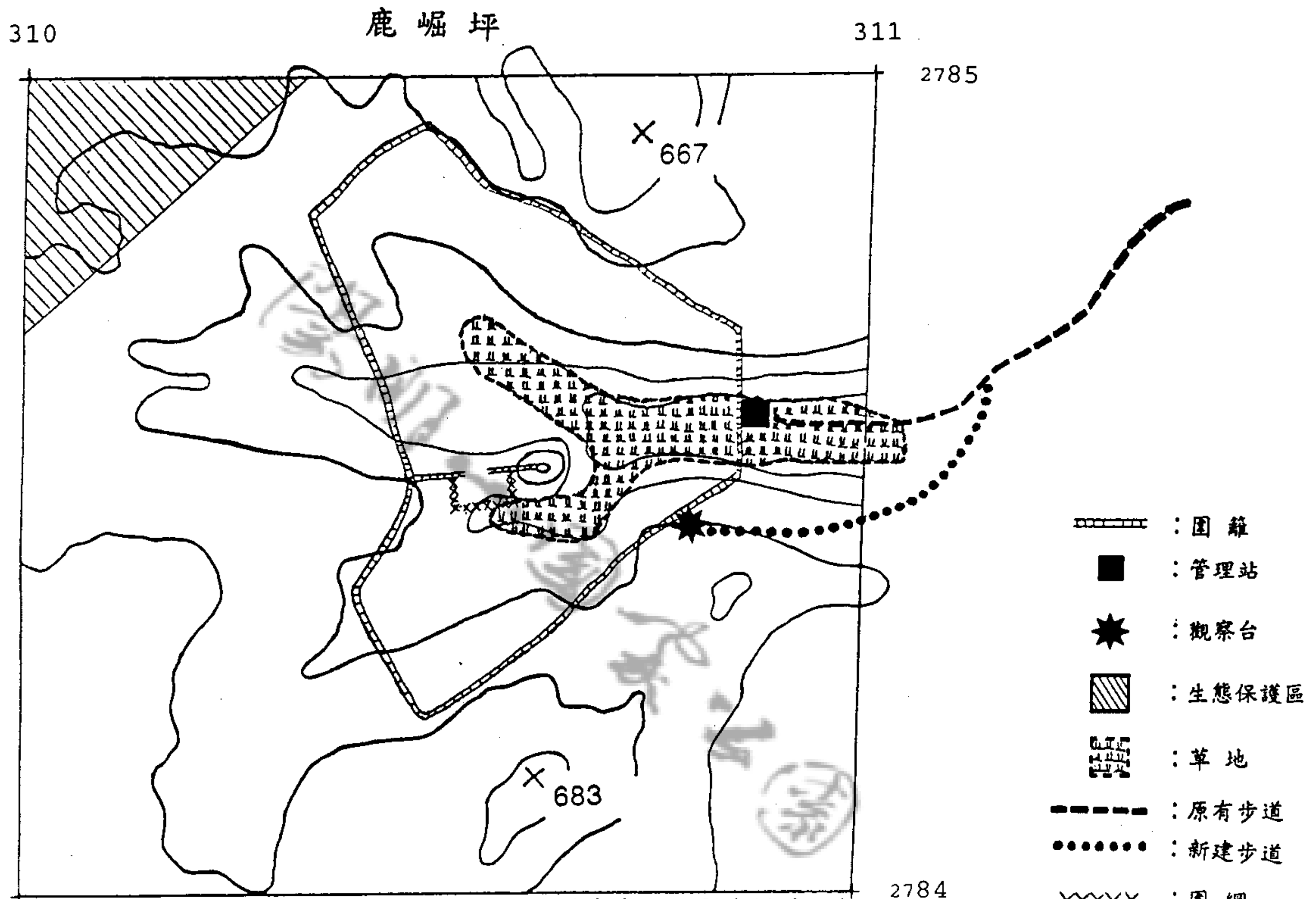
圍籬的確實設計，需要先詳細研究該區的航測照片，再做實地徹底調查；圍籬的範圍大小取決於所需費用與架設的難易性，並受到鹿崛坪西北方的生態保護區邊界的限制。

爲滿足遊憩需求，可能必須把鹿崛坪區內一片地勢較低的草生地保留給遊客使用，而僅把鹿圈養在地勢較高的草地上。靠近遊客區的鹿籬應架設於草生地最狹窄的位置，山谷兩邊則讓濃密的植物覆蓋著，來防止遊客接近鹿籬，圖二呈現了此處所要介紹的觀念；此圖並非可用於現場施工的設計圖，而是說明應如何融入某些重要考慮的示意圖。此種設計的目的，在儘量減少可能引誘人們攀爬跨越的圍籬區段長度，而對曝露在外的圍籬，則可在上面

架設刺絲網等來加強隔離保護。

將圍籬設置在草地最窄處，配合兩邊陡峭的地形，加上山坡上濃密的植被，會減少人們沿著圍籬走動的意願。另外，原有步道會穿過養鹿用的草地，除了應將此段步道改道外，修建一條支路讓它通往一個對養鹿區展望良好的地點（見圖二），應能進一步吸引人們利用新步道而不會直接穿過養鹿的草原。

把圍籬的形狀設計成近似三角形，有助於提升捕鹿時的效率。圖二所示的圍籬中有一座小山頭，若自此山頭向西另建一道永久性或尼龍的臨時圍籬，在籬中間地勢最低處設有一個缺口，梅花鹿會逐漸習慣這道圍籬並由缺口通過；捕捉梅花鹿時，將缺口以圈網封住，只要請六位到十位工作人員在圍籬內自缺口的一邊並肩繞著小山頭移動，就可容易地把鹿趕向圈網中。如果此道圍籬及圈網使用的是尼龍網，網目不能太大以免梅花鹿的頭鑽入網中被纏住，設置時網也應拉緊以免鹿隻在跳過時被纏到而受傷。墾丁復育計畫中有經驗的工作人員，應可協助陽明山國家公園訓練捕捉及處理鹿隻的技術。



圖二：鹿崛坪園籬設計示意圖(方格座標：橫麥卡脱投影座標系統)

六、梅花鹿群的經營管理

梅花鹿的復育與野放，及事後的經營管理與追蹤，均需要專業知識。墾丁國家公園梅花鹿復育計畫已進行十二年，在此方面已有相當多的經驗，可供陽明山國家公園參考。

1 、種群之飼養管理

墾丁國家公園梅花鹿復育計畫已成功地飼養及繁殖出相當隻數的子代。若陽明山國家公園決定進行梅花鹿復育工作，在飼養方法上，應以墾丁國家公園梅花鹿復育計畫研究管理人員的飼養心得爲重要參考。例如自 1994 年，主管此計畫之馬協群先生，將圈養區以圍籬隔成數小區，大的面積約 1 公頃，小的數百平方公尺，區中種植盤固拉草給鹿吃。區隔的原因是若採全區開放式，鹿隻踐踏會導致很多草的損耗浪費，以小區隔開時，則可把鹿群先趕到某區中，等草吃光再趕到下一區去放牧，如此可提高草料的利用效率。未採此法之前，墾丁國家公園每月要爲鹿隻提供 20 包飼料（苜蓿粒料），如今 20 包飼料可供鹿隻 2 至 3 個月的需要（馬協群，個人通訊）。

2 、鹿群之繁殖管理

陽明山國家公園之經營管理者，必須小心安排提供鹿群中各成年雄鹿繁殖機會，以儘量維持種群中之遺傳變異性。

墾丁鹿群在組成之時，王（ 1984 ）有鑑於鹿多用一雄多雌的方式繁殖，雖然在 20 頭鹿中有 1 雄與 19 雌相配即可，他選用了 5 頭雄鹿配 17 頭雌鹿的比例，以免 1 雄可能因意外而導致繁衍中斷，及 1 雄交配可能導致族群遺傳變異性減少等問題。墾丁種群起始之雄雌性別比是 1 ： 3.4 ；在繁殖後之總性別比於各研究報告中均未確切說明，但研判各區鹿隻數量，在 1988 年似共有 23 隻雄及 50 隻雌鹿，雄雌性別比是 1 ： 2.2 ；到 1992 年，報告中共提到 102 隻的性別（王 1991 ； 1992 ； 1993 ； 1994 ），至少在這些小群中之雄雌性別比是 1 ： 1.8 。性別比逐漸趨向於 1 ： 1 應是正常趨勢，但不論墾丁之經營管理者是否曾追蹤各隻鹿的繁殖史，陽明山應儘量努力維持鹿群中之遺傳變異性，積極進行繁殖管理。

有關繁殖管理，還應考慮鹿群之年齡結構、個體成熟率、繁殖年齡、死

亡率、壽命等層面，王（ 1985 ）曾表示鹿群年齡組成以年幼者較年長者多的型態較佳，但在族群成長之初期，可能不論何種組成鹿群的繁殖都很快速。墾丁國家公園之梅花鹿隻數成長十分快速，且以植生區中的鹿群爲例，此群 5 年內由 6 隻成鹿增加至 15 頭成鹿及 4 頭幼鹿，亦即 5 年中成長爲原來的三倍多；此等高增加率會使鹿崛坪之鹿隻兩三年內即達飽和，故陽明山管理計畫應預先擬定理想的成長率，及對過多鹿隻之處置方法，以避免鹿隻過多可能導致的管理問題。前列各種資料，相信存在於墾丁國家公園梅花鹿管理者處，故建議陽明山國家公園於野放計畫起始之初，即蒐集完整繁殖資料，以爲擬定復育計畫，及未來鹿群管理之重要參考依據。

3 、野放前的準備

墾丁國家公園歷次野放的梅花鹿仍有相當數量存活於野外，顯示野放前之準備工作相當完整，應是陽明山國家公園的重要參考依據；原則上應逐步減少待野放之個體與人的接觸，並加強鹿隻對野放區植物性食物的適應性。野放前逐步提供鹿隻當地可食的植物，培養其胃中所需特有微生物相的建立，有助於其食性的轉換及野外存活（王 1990 ）。

（ 1 ）族群組成

王（ 1990 ）認爲族群中達到生殖年齡或已具有成功繁殖經驗者愈多，族群的增長愈快，故野放應選擇雌多雄少，幼體多成體少的配合，避免族群在短期內激增；此外，年輕的個體對野外的適應性應較高，可能有助於及早建立完全野性的族群。

王（ 1990 ）指出，野放時必須顧及被放出的個體間及其與野外鹿群的關係，否則可能導致被野放的鹿隻被野外鹿群排斥而落單，因而遭受較高的被掠食機率，而有較高的死亡率；故野放時應選擇原已共同生活且有既存關係及地位的鹿隻。

（ 2 ）時間考量

王（ 1990 ； 1994 ）指出野放的時間會影響動物生存所面臨的壓力，所以最好在野外食物來源供應好轉，並且雌鹿並非懷孕或待產的時節釋放，讓新進入野外生活的鹿隻有漸進適應新環境的機會。

（3）建立適應區

根據王（1990）的報告，釋放方式有可能影響動物對空間利用的偏好，如果在特定的地點提供食物，可能會養成動物對該處的偏好，故在野放區內建立適應區，或許能將鹿群侷限在某一範圍內，使之及時在新環境建立起個體間的關係；同時在該區提供草料與鹽塊，不但能協助動物渡過野放初期的適應階段，亦能養成個體對該處的偏好，有助於日後對野放族群的經營管理。陽明山國家公園是否採用此建議，或採用到什麼程度，應看未來的長期目標是否與此相符。

野放前先在野放區建築圍籬，移除圍籬內的競爭者，也是墾丁國家公園採用的步驟。王（1990）說明野放的成功，與環境的狀況及競爭者的存在與否有相當的關係，故在設立社頂復育區時，已先移除在當地放牧的牛、羊，來減少鹿群與外來種的競爭壓力。陽明山國家公園應仔細分析那些草食性動物是梅花鹿的競爭者，那些是共存者，再視情況考慮是否移除某些動物（參考本報告第二章）。

4、鹿崛坪的梅花鹿承載量

鹿崛坪最多可以容納多少隻鹿，目前只能推測。若以墾丁地區的研究結果（王等 1993；1994）為依據，此區大約可供養 50 隻鹿（約每公頃 2 隻）。為供養 50 頭鹿的需要，鹿崛坪的草地面積與森林相比可能過大，森林會被過度啃食；因為附近有生態保護區，建造及維護圍籬所需的費用也相當高，所以不能圍入更多的森林來減少梅花鹿對森林的危害，因此圍籬內能承載的鹿隻數量應受森林面積的限制，而不是單看草地的面積能供養多少隻來決定。由於鹿崛坪地區的樹種多屬普遍分布的種類（蘇鴻傑，個人通訊），因此梅花鹿對森林產生某個程度的衝擊或許可以被接受，某些樹的樹皮會被啃食，林下植物也會較為稀疏。但無論如何，鹿對森林的影響應受到控制，至少森林應保留其視覺屏障的功能，樹皮被啃食導致小樹死亡的速率，也不可超過林下小樹自我疏伐的速率，更不能讓鹿隻的覓食改變森林冠層的樹種組成。

5、棲地管理

就麥可樂博士判斷，現有森林植被所能承載的梅花鹿數量，不足以維持草生地的開闊度，木本植物的入侵是可預期的結果，因此需要在梅花鹿之外，另靠水牛協助嚼食，才能把足夠的面積維持在草生地的階段。

在復育計畫之初引入維持草生地所需的最小水牛量，可協助棲地管理，同時也把水牛糞便污染及破壞地表的負面效果減到最低。爲了經營上的彈性，這些水牛最好是屬於國家公園的（參見第二章）。隨著梅花鹿隻數的逐漸增加，水牛的數量便可相對地被裁減；最佳的梅花鹿與水牛比例，可以透過一面仔細監測植被狀況，一面嘗試與修正水牛數量來獲得。欲得到適當的水牛與鹿之比例，並不需要高深的學術研究，但野放計畫開始時即應建立明確的監測制度，包括在草地及樹林中設置標準拍照點，利用照片及樹林中的樣區估算樹幹被啃食的比例，以便及時覺察樹種組成的改變。

陽明山國家公園野放梅花鹿後，應定期進行棲地狀況調查，以掌握梅花鹿與棲地中植被的互動關係，若發現有樹木被剝皮的現象，應注意被剝皮之樹種、樹的年齡或大小，不同種的樹被剝皮或環剝的頻度及分布等。要判斷鹿隻對生態環境的壓力時，也可以用固定穿越線上每五百公尺有幾棵樹被剝皮的方法，收集簡單的數據，作爲鹿群管理時的行動依據。

6 、野放後之追蹤監測

對被野放後的梅花鹿進行追蹤，攸關野放計畫的成功與否，是不可或缺的部分。因爲即使事先妥善規劃，野放後仍可能會有未曾預期的問題出現，需要管理者調整修正飼養、繁殖、或野放方法等。

墾丁國家公園的野放及追蹤經驗，應可作爲陽明山的參考。目前在墾丁國家公園裡，不同的圈養及野放區內共有約 165 隻鹿，另有 20 隻已野放至區外（馬協群，個人通訊）。1994 年 1 月 23 日野放的 10 隻梅花鹿（ 3 雄 7 雌）中，有兩隻雄鹿死在通道中，故又補放了 2 隻雄鹿，其中有八隻帶有無線電追蹤器； 1995 年 4 月 23 日放出的 5 雄 5 雌，全帶有追蹤器。現共有 16 隻備有追蹤器，但有 3 個追蹤器之電池已耗盡，還有 13 隻有人進行追蹤記錄。野放之鹿隻，多在復育區附近活動，最遠有到 1 公里（潘明雄，個人通訊），或 2 公里外的記錄（馬協群，個人通訊）；多數鹿隻皆在欄舍的東南方活動，只有兩隻在北邊（潘明雄，個人通訊）。墾丁國家公園估計，野外的族群數量至今可能已有約 30 隻。

進行無線電追蹤是專門但易學的技術，陽明山國家公園未來可向墾丁復育計畫之管理人員，求取心得與經驗。

7、對梅花鹿復育之社會反應

因為復育計畫實也是一種大型公共政策，故了解民意乃是事業主管當局應該進行的重要工作，墾丁國家公園的梅花鹿復育計畫即曾進行過遊客及當地居民意見調查（王等 1994），陽明山國家公園於復育計畫進行之初，亦曾完成初步民意調查（王 1995），兩個國家公園此舉均應受到肯定。陽明山國家公園未來進一步執行復育野放計畫前，亦當進一步從事民意調查。

根據齊力博士的書面意見，調查民意時，不論以書面問卷或訪談方式，若要調查之結果具有可信度，務必要使問卷的文字保持中性的語法，以避免有引導受訪者做出特定答案的嫌疑；訪談者亦必須用固定的、中性的方式與每一位受訪者對談，以免導致被訪者回答上的偏差，答案選擇的設計也應避免引導受訪者做出特定的答案。另外，要使民意調查具有代表性，樣本數及抽樣方法也是重要考量，一般調查通常會尋求性別、年齡、學歷、或收入級層上的平衡。

有關梅花鹿數量過多後的處置方法，王穎（1994）說明，有三分之二的遊客反對開放狩獵梅花鹿；墾丁居民中也有六成反對用狩獵來控制梅花鹿數量，甚至由國家公園工作人員進行獵殺均不被接受（王等，1996）。陽明山國家公園須將此等社會反應，納入整體復育及經營管理政策考量。

七、梅花鹿復育計畫之附加貢獻、成本或損失

進行瀕臨絕種物種的復育工作，最重要的動機自然是物種的保育，但計畫進行時很可能為社會帶來附加的收穫，但也可能有未曾預期的代價。分析此等收穫與代價，可作為陽明山國家公園進行政策性評估時的參考。此部份之分析以墾丁的狀況為依據，但陽明山國家公園必須體認兩單位進行此一計畫在時空上的差異，不應預期會獲得相同的收穫，亦不會面臨完全相同的代價。

墾丁梅花鹿復育計畫進行至今已十二年，每年參與此計畫的研究人員自 3 人（1993 年）至 23 人（1988 年）不等，其中許多研究生或研究助理因此獲得保育研究方面的訓練，並已培植出 2 位現已在相關領域中服務的教授，及數位碩士研究生。陽明山國家公園若進行梅花鹿野放工作，相信可預期類

似的成果。

在研究成果方面，墾丁梅花鹿復育計畫是國內針對單一物種生存需求最大規模的長期研究，故已累積了大量的觀察及研究資料。陽明山國家公園進行梅花鹿野放工作，已不須再收集許多墾丁既有的資料，而需針對尚無資料的部分來努力。

在保育宣導方面，墾丁之計畫與櫻花鉤吻鮭之復育，是政府爲挽救瀕臨絕種動物所採取的行動中最主要的努力，也是政府向國際社會證明中華民國重視野生動物保育的實例，更是墾丁國家公園宣導野生動物保育的最佳案例。陽明山國家公園當然也可獲得此方面的殊榮。

在附加成本及損失方面，墾丁國家公園若對梅花鹿未來帶來的生態或農作影響加以評估，或可以具體分析此計畫是否有某些開始時未曾預期的環境影響，及間接的經費開銷，另外或許因爲此計畫的進行，使某些保育工作因爲經費不足而被擱置，導致某些損失等，這方面的資料均可作爲陽明山國家公園梅花鹿計畫的參考。

八、陽明山國家公園是否應進行梅花鹿野放

陽明山國家公園是否要進行梅花鹿野放是政策性的決定。筆者認爲就梅花鹿整體保育需求來考量，並不需要在陽明山國家公園進行野放計畫。根據前述眾多理由，建議應在台灣尋找潛力更大的地點，作爲建立第四個梅花鹿亞族群的基地；當然決定選用任何地點前，都應進行徹底的調查評估。顯然陽明山國家公園對島上其它地區並沒有管轄權，此部份工作也不在陽明山國家公園的業務範圍內，而須待梅花鹿之野生動物身分確定後，由主管機關來負責進行此種調查。

依據對陽明山國家公園內種種狀況的評估，筆者認爲陽明山的自然資源及經費來源，可能都會給野放計畫相當大的限制，既然梅花鹿目前並無立即絕種的危機，建議陽明山國家公園從長考慮公園內的各種保育工作的優先順序，再做決定。王（ 1993 ）建議在野放前應先建立野放區動植物資料庫以爲評估依據，亦是應及早完成的工作。

如果陽明山國家公園決定進行野放計畫，則應在開始進行前審慎規劃，管理處應該有永久妥善經營此亞族群的準備與決心，以確保它在整個集合族群管理計畫中，能確實發揮功能。

第四章 對經營管理現有梅花鹿亞族群的建議

考慮了梅花鹿整體需求後，筆者及麥可樂博士對現有的三個亞族群之經營管理，提出以下的建議。

一、 墾丁國家公園亞族群

自從梅花鹿人工繁殖計畫於 1984 年在社頂展開，墾丁的族群就一直是梅花鹿保育工作的焦點。管理處馬協群先生曾口頭說明，墾丁國家公園進行梅花鹿復育工作，固然希望能讓梅花鹿回復到兩、三百年前的狀況，在野外自由生存，但近年台灣開發的狀況顯然使此目標無法達成；現在希望各國家公園均有梅花鹿生存，而今陽明山國家公園已進行評估，其他國家公園則尚未表示意願。墾丁國家公園管理處計畫在 10 月生產期結束後，把 1996 年 4 月趕鹿時所聚集於圈養區中的 25 隻鹿野放。未來墾丁國家公園將繼續進行人工繁殖，預期會將繁殖出之鹿隻野放到墾丁國家公園區外，並希望野放之鹿群能逐漸擴散到鄰近地區或大武山區。

因墾丁的鹿群來自兩個以上的基因庫：台北市立動物園，及左營鹿場，進行基因分析以確定種源乃迫切需要的工作。若墾丁的梅花鹿是純種的，被野放出去的個體便具有第二個亞族群的功能；如果發現血統不純，就應努力將這些個體侷限於特定地區，並逐漸以純種的個體取代。

在未能確定血統之前，建議暫停野放計畫，以免加添未來處理上的困難度。另外，復育設施中已生產了足夠的鹿隻允許野放的進行，可以說已達到原先設立的主要目標。野放在外的族群應不需太多人工繁殖出的鹿隻來補強，故在基因問題未解決之前，墾丁復育中心應將所產出的多餘鹿隻都留在欄舍中。未來復育中心是否繼續、或應如何繁殖梅花鹿，應視整體保育經營計畫是否需要以墾丁族群爲遷地繁殖的種源；若不再需要以現有方式增加墾丁梅花鹿的數量，就必須效仿台北市立動物園，設法控制梅花鹿的出生率。如果爲了保存族群之基因多樣性而必須讓特定的個體繁殖，則可以利用墾丁復育區中的小型欄舍。如果綠島的族群要被用爲未來復育的種源，又不須做特定譜系的繁殖，墾丁繁殖中心的設施可以說功德圓滿，圈養繁殖的工作也

應逐步結束。

社頂當年因有山羊和水牛的放牧而被選爲復育計畫的地點（McCullough 1974），但不幸大部分草生地已因植被演替而消失，現存被鹿用來覓食的草生地，只剩下圍籬邊緣的狹窄條狀地帶；這些草地受到鹿隻重度利用，但鹿在這兒的覓食壓力仍不足以維持合宜的、可滿足鹿隻食物需求的草地與森林面積比例。是若圈養工作未來要持續進行，目前種植牧草的方法，或採用其他的棲地管理方法，應能減少必須爲鹿提供之食物量。

墾丁的梅花鹿計畫經過多年的努力，已完成了許多研究論文與報告，獲得了許多的資料。建議未來積極追蹤已野放個體之生存、移動、及繁殖狀況，以累積重要的族群動態資料。另外，未來所有亞族群均會面臨鹿隻密度過高的問題，墾丁可領先研究高密度情況下鹿隻對棲地的衝擊，作爲未來訂定經營管理策略的參考。

二、 台北市立動物園亞族群

台北市立動物園的梅花鹿，或來自墾丁，或是由墾丁的鹿隻在動物園繁殖產生的，因此與墾丁的鹿一樣面臨血統是否純正的問題。目前台北市立動物園只將一隻雌鹿放在飼養著三隻雄鹿的欄舍裡，其他雌鹿全部被隔離在另一間欄舍中，靠這種隔離的方式來控制這個小族群的成長；動物園中的鹿隻定期接受結核病的檢驗，任何可能帶原者都必須由欄舍中移除。

因爲有感染結核病的歷史，基因組成又與墾丁的鹿群相似，動物園飼養出的個體不應被用爲遷地繁殖的種源。除此之外，在保育上，台北動物園鹿群的最大價值就是作爲梅花鹿保育計畫中的一個亞族群，這個角色與在園區內展示、社會教育、提供民眾娛樂休閒等目的並不相違背。就長期的需求來看，若要使此小族群成爲台灣梅花鹿的第四個亞族群，基因的經營管理是不可或缺的，以避免一般小族群常見的健康和基因的問題。

三、 綠島的亞族群

1、未來研究

雖然據綠島地方人士的傳述，當地鹿群應是純種台灣梅花鹿，其的遺傳特質、基因純度及多樣性依然應被分析檢定。綠島梅花鹿族群是現存最自然的族群，研究此族群之生存模式，可對未來各亞族群之經營管理有直接且重要的貢獻。

2、梅花鹿帶來的難題

綠島不經意地建立了一個理想的梅花鹿繁殖中心；在現有的亞族群中，包括計畫中的陽明山國家公園亞族群，綠島的族群最具保育潛力，即使另覓地點建立第四個亞族群也不可能找到像綠島一樣好的條件。但是綠島鄉公所並沒有經費、人力、對梅花鹿也沒有足夠的專業知識來做妥善的經營，故鄉公所希望國家公園不必另覓復育地點，可直接補助綠島來養鹿；鄉公所的觀點並沒有錯，但可惜權責單位的不同，不允許經費的直接流通。

農委會是野生動物的中央主管機關，未來應在綠島經營梅花鹿的行動中扮演更積極的角色；不然，觀光局的東部海岸國家風景區管理處，或可以成爲這項工作的經費來源和管理單位。不論如何，顯然必須要有一些經費的調整，才能全面發揮綠島的潛力。

3、觀光和生態旅遊

漁業、農業、和觀光是綠島經濟的基礎，其中漁業佔80% 。綠島是東部海岸國家風景區的一部份，觀光局在此設有管理站及遊客中心。綠島的農業發展受限於宜農地的缺乏，所有的農產收穫每年約只有八百萬元；漁業是最重要的經濟命脈，但現在正逐漸衰退中，有些地方人士認爲這種衰退是反應大自然的正常波動，但也有人認爲應歸咎於過渡漁撈。一般咸信觀光業是當地唯一有發展潛力的事業，鄉公所也寄望能擴展此方面的經濟收益，鄉公所和當地的意見領袖正在認真地研究將梅花鹿變作生態旅遊賣點的方法，並希望可以藉此解決農作遭鹿危害的問題；這正符合觀光局將綠島變爲重要生態觀光據點的目標。

有鑑於日本奈良一些寺廟的鹿場會吸引觀光客，鄉公所提出的方案是將

500隻梅花鹿關在一個大型圍籬中來吸引遊客，認爲把所有的鹿隻自野外捕回是可實現的目標，如此不但可解決鹿隻造成農業損害的問題，同時可吸引遊客前來賞鹿讓地方賺取觀光收入。（麥可樂博士認爲要捕捉一些鹿放入圍籬中是可能的，但要將已變成野生的鹿隻全部抓回應是不可能實現的目標。）

此方案與觀光局提倡的欣賞大自然的生態旅遊理念有所抵觸。綠島人口稀少，目前開發的程度也不高，最吸引人的特色大都是自然或半自然的環境：綠意盎然的人工林、美麗的海灘、綿延的珊瑚礁、海底溫泉等等，人文特色相較之下並不顯眼。鄉公所的鹿園構想，在建築及日後的運作上均會十分昂貴，未來是否能有足夠的回收來平衡所需的投資，實際還存在著很大的風險，也有可能會導致很大的虧損。利用在自然狀態下的野生梅花鹿作爲觀光的賣點，將會更切實際且使風險大幅減低。

（1）生態旅遊的發展

綠島若將梅花鹿宣傳爲當地的觀光特色，應會成爲引人注目的觀光焦點，可以擴展遊客在島上的遊憩形態；綠島可以因擁有野生梅花鹿自由活動在美麗的半自然景緻中而聞名。遊客很容易在夜間藉手電筒的光觀察鹿群；筆者與麥可樂博士進行夜間觀察時便吸引了一些路過的遊客，他們看到了梅花鹿，也對這些鹿的歷史及保育現況展現了高度的興趣。綠島有潛力發展夜間的生態導覽，由解說員打光引導遊客觀看梅花鹿，解說有關牠的生態、行爲、及現況。

到綠島享受海灘、浮潛、和天然景緻的人們，在夜晚常駕車環島尋找遊憩機會（島上幾乎沒有夜生活），在旅遊旺季安排夜間的賞鹿之旅應很受歡迎，或許還可以收費來支付開銷。不過我們認爲舉辦賞鹿之旅的最主要利益，不是能直接賺多少錢，而是有良好規劃及宣傳的旅遊機會，會吸引更多的遊客前來；增加的遊客量反應於旅館業、餐飲業、運輸業、潛水業等事業上，會增加民間的收入。賞鹿之旅的困難是對遊客的管理；梅花鹿活動區的可及性很高，遊客可以自行組隊前往，當地居民也可以自行招攬生意，以不顧鹿的需求的方式安排賞鹿活動，這樣無限制的觀賞可能對鹿群造成過度的干擾，鹿群可能會因此躲藏起來。這種狀況會破壞原先推動生態觀光的目的；所以無疑鄉公所及當地居民必須針對如何管理賞鹿活動及分享利潤達到共識。

隨著與人類接近而不曾發生危險的次數的增加，綠島的鹿隻應會比現在不怕人，那時在白天看到鹿的機會也會隨著增加。要讓梅花鹿可以自由使用綠島大部分的面積，主要的阻力應是鹿對農作的危害。

（2）農作危害的管理

目前鄉公所處理農作物受損的方式只是應急。圍網的設置缺乏效率又需昂貴的維護費用，最多也只能獲得部份成效；損害賠償對農民和鄉公所而言都很煩瑣。若鄉公所能與曾受鹿害的農民期約，每年在給與適度經費補償的情況下進行限耕，僅在農民願意完全自行承當鹿害風險時才允許耕作，另外極力遏阻在公有地上非法濫墾，對濫墾地政府不負責賠償損失等，應可改變鄉公所和農民均不滿意的現存現狀，減少雙方的困擾。對在山坡上耕作來打發時間的年長農民，或許可以僱用他們來作梅花鹿的觀察員之類的工作，而不須繼續耕作。排除農作問題後，將梅花鹿併入自然觀光計畫的阻礙便可被移除。

（3）家畜的放牧

水牛的放牧與梅花鹿計畫卻是相容的，且是可以維護草地開闊度成本最低最有效的方式；開闊的草地是梅花鹿最好的棲地，也是夜間最容易觀察梅花鹿的環境。如果鹿群隻數增加，這也是白天最有可能看到牠們的地方。鹿群增加之後，畜養的水牛數量便可以減少，但在綠島要只靠梅花鹿，不靠家畜來維持開闊草地似乎不太可能。

綠島的面積不大，梅花鹿的數量早晚會到達環境承載量，因此未來的管理需求除了要減少梅花鹿對農作物的危害，也要考慮如何控制鹿的數量過多的問題。綠島的環境變異度相當大，其中高品質的梅花鹿棲地面積均很小，目前多靠放牧維持其開闊度；如果未來有控制數量的必要，在草地附近射殺或誘捕是較易進行的作法。如果梅花鹿的法定地位仍是家畜，販賣被捉的活體或被獵殺鹿隻的產製品，或可以補貼數量控制計畫所需的部分經費。將來能採用哪種族群控制的方法，得視當時的自然及社會環境狀況而定。

參考文獻

王穎，1985。台灣梅花鹿之行爲研究。台灣梅花鹿復育之研究----七十三年度報告，pp102-179。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

王穎，1987。台灣梅花鹿復育之研究----七十四年度報告。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

王穎、陳順其、詹世琛、黃正龍、吳幸如，1995。陽明山國家公園台灣梅花鹿野放研究（二）。陽明山國家公園84年度研究報告。內政部營建署陽明山國家公園管理處。

王穎、陳順其、孫元勳、林政田、廖秀芬，1996。墾丁國家公園台灣梅花鹿野放後之生態學研究。墾丁國家公園保育研究報告。內政部營建署陽明山國家公園管理處。

王穎、陳輝勝、吳幸如、蘇銘言，1992。台灣梅花鹿行爲及棲地利用之研究。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

王穎、郭國偉、胡正恆、陳美汀，1994。台灣地區梅花鹿野放追蹤之研究。墾丁國家公園研究報告。內政部營建署墾丁國家公園管理處。

王穎、郭國偉、楊美玉，1993。台灣地區梅花鹿原野棲地調查及野放可行性之評估。墾丁國家公園研究報告。內政部營建署墾丁國家公園管理處。

王穎、蘇庭輝，1994。陽明山國家公園台灣梅花鹿野放研究（一）。陽明山國家公園83年度研究報告。內政部營建署陽明山國家公園管理處。

江樹生，1985。梅花鹿與台灣早期歷史關係之研究。台灣梅花鹿復育之研究----七十三年度報告，pp3-62。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

江樹生，1987。梅花鹿與台灣早期歷史關係之研究。台灣梅花鹿復育之研究----七十四年度報告，pp2-24。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

谷喬、王穎，1992。台灣梅花鹿品系之分析。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

吳永惠、劉世賢、黃和靖、張聰洲、蔡專福、蔡信雄，1992。墾丁國家公園野生動物的醫療保健。墾丁國家公園保育研究報告，pp32-42。內政部營建署墾丁國家公園管理處。

夏良宙、王穎、程中江、陳寶忠，1990。台灣梅花鹿攝食喜好性試驗。台灣梅花鹿復育之研究----七十八年度報告，pp49-73。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

劉和義，1992。綠島野放梅花鹿生態之調查研究。交通部觀光局東部海岸風景特定區管理處。

蘇鴻傑，1985。台灣梅花鹿天然生育地之植群分析及其在墾丁國家公園內復育地點之勘選。台灣梅花鹿復育之研究----七十三年度報告，pp63-101。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

蘇鴻傑，陳雲倩，1990。台灣梅花鹿對社頂地區植群影響之研究。台灣梅花鹿復育之研究----七十八年度報告，pp18-48。墾丁國家公園保育研究報告。 內政部營建署墾丁國家公園管理處。

蘇鴻傑、楊勝任、陳雲倩，1989。台灣梅花鹿對社頂地區植群影響效應之研究----社頂地區之植群生態與演替。台灣梅花鹿復育之研究----七十七年度報告，pp42-69。墾丁國家公園保育研究報告。內政部營建署墾丁國家公園管理處。

台灣省農林廳林務局，1995，第三次台灣森林資源及土地利用調查。

Alverson, W. S., Waller, D. M. and Solheim, S. L. 1988. Forests to deer: Edge effects in northern Wisconsin. Conserv. Biol. 2:348-358.

Caughley, G. 1994. Directions in conservation biology. J. Anim. Ecol. 63:215-244.

Denniston, C. 1978. Small population size and genetic diversity implications for endangered species. Pages 281-289 in Endangered birds: management techniques for preserving threatened species, (S. A. Temple, ed.), University of Wisconsin, Madison, WI.

Gavin, T. 1978. Status of Columbian white-tailed deer *Odocoileus virginianus leucurus*: some quantitative uses of biogeographic data. Pages 185-202 in Threatened deer, IUCN, Morges, Switzerland.

Gilpin, M. E. and I. Hanski. 1991. Metapopulation dynamics: empirical and theoretical investigations. Academic Press, New York, NY.

Kano, T. 1940. Zoogeographical studies of the Tsugitaka Mountains of Taiwan. Shibusawa Institute of Ethnographic Research. 145pp.

Lande, R. 1993. Risks of population extinction from demographic and environmental stochastic and random catastrophes. American Naturalist 142:911-927.

Leopold, A. 1949. A Sand County Almanac. Oxford University Press, New York, NY.

McCullough, D. R. 1969. The tule elk: its history, behavior. and ecology. University of California. Publications in Zoology 88:1-209.

McCullough, D. R. 1974. Status of larger mammals in Taiwan. Tourism Bureau, Taipei, Taiwan. 36pp.

McCullough, D. R. 1978. Essential data required on population structure and dynamics in field studies of threatened herbivores. Pages 302-317 in Threatened deer, IUCN, Morges, Switzerland.

McCullough, D. R. 1985. Chemical composition and gross energy of deer forage plants on the George Reserve, Michigan. Michigan Agricultural Experiment Station Research Report 465, East Lansing, MI. 19pp.

McCullough, D. R. 1996. Metapopulations and wildlife conservation. Island Press, Covelo, CA.

McCullough, D. R., J. K. Fischer, and J. Ballou. 1996. From bottleneck to metapopulation: recovery of the tule elk in California. Pages 375-403 in Metapopulations and wildlife conservation, (D. R. McCullough, ed.), Island Press, Covelo, CA.

McCullough, D. R. and D. E. Ullrey. 1985. Chemical composition and gross energy of deer forage plants on the George Reserve, Michigan. Michigan State University Agricultural Experiment Station Research Rept, 465, East Lansing, Michigan.

Patel, A. D., Y-S. Lin, and H-Y. Wu. 1989. History of wildlife conservation in Taiwan. Ecology Lab, National Taiwan University,Taipei, Taiwan. 115pp.

Ralls, K., J. Ballou, and A. R. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conserv. Biol. 2:185-193.

Ralls, K., K. Brugger, and J. Ballou. 1979. Inbreeding and juvenile mortality in small populations of ungulates. Science 206:1101-1103.

Roy, M. S., E. Geffen, D. Smith, E. A. Ostrauder, and R. K. Wayne. 1994. Patterns of differentiation and hybridization in North American wolflike canids revealed by microsatellite loci. Mol. Biol. Evol. 11:553-571.

Ruhle, G. C. 1966. National parks and reserves for Taiwan. American Committee on International Wild Life Protection Special Publication No. 19, Bronx, NY. 77pp.

Sampson, A. W., and B. S. Jepersen. 1963. California range and brushlands and browse plants. California Agricultural Experiment Station, Berkeley, CA. 162pp.

Severinghaus, L. L. 1989. Natural resources. Pages 49-127 in Taiwan 2000, The Steering Committee for Taiwan 2000 Study, Institute of Ethnology, Academia Sinica, Taipei, Taiwan.

Shaffer, M. L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.

Shaffer, M. L. 1983. Determining minimum viable population sizes for grizzly bears. International Conference of Bear Research and Management 5:135-141.

A COMPREHENSIVE REVIEW OF THE SIKA DEER RESTORATION PROGRAM IN TAIWAN

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CONTENT

SUMMARY OF CONCLUSIONS

A. On sika deer conservation needs

This report is mainly an evaluation of the sika deer reintroduction plan of Yangmingshan National Park. Because some of the evaluations are based on an overall sika deer conservation needs. We drafted a recovery program, introducing the basic concepts of sika deer conservation, the key considerations of metapopulation concept, the significance of genetic management, discussed the habitat, distribution, ecology of sika deer, the management of its populations and habitat, and proposed the following recommendations for its conservation:

1. The problem of the sika deer's legal status must be properly solved.
2. An overall conservation and management plan should be drafted urgently.
3. It is necessary to analyze mtDNA to establish the original Taiwan stock, and its genetic diversity.
4. Maintain at least 4 spearate subpopulations to be managed by metapopulation methods.
5. Maintain a population of at least 500 individuals. 6.
6. Pursue the restoration program cautiously and incre mentally.

B. Concerning sika deer reintroduction of Yangmingshan National Park:

1. Based on metapopulation principles, Yangmingshan National Park is not the best location for establish ing a fourth subpopulation, because of its proximity to the Taipei Zoo.
2. Because suitable habitat is limited, Yangmingshan National Park has very little potential for the future expansion of sika deer population. Thus it is not the best location for reintroduction of sika deer.
3. When evaluating whether to reintroduce sika deer into the park, one should examine the suitability of the climate and habitat, the presence of wild dogs as predator and a population control mechanism, the quantity of available food, the potential ecological impact including whether it is acceptable if the plant community is altered. When selecting a release site, the accessibility and suitability of the site, its size, and the ease of tourist management in this location should be considered.
4. The sika deer release experience of Green Island should be used as a reference.
5. Before reintroduction, Yangmingshan National Park should have plans for contagious diseases management, deer population management, and a commitment to fund

this program as long as it is necessary.

6. If Yangmingshan National Park decides to proceed with the reintroduction program, it should plan carefully and be commitment to the proper management of this subpopulation, so it is a functional part of the metapopulation program.
7. Proper habitat monitoring schemes should be established at the onset of reintroduction program.
8. Wild released deer should be tracked carefully to monitor their movement patterns and survival.
9. Because the environmental conditions of Yangmingshan National Park is not the most suitable for sika deer, deer should be kept in pens instead of released into the wild.

C. Concerning deer population management:

1. If Yangmingshan National Park decided to reintroduce sika deer into the park, it should obtain deer from stock proven to be the original Taiwan subspecies. If the genetic diversity of the Kenting deer herd is proven to be decreasing, Yangmingshan National Park should obtain deer from other sources.
2. Yangmingshan National Park can learn deer keeping and breeding techniques from managers of the Kenting herd. However, active breeding management should be conduct ed to ensure every adult male breeds. Detailed

breeding records should be kept for every deer.

3. Design suggestions for the enclosure at Lu-chueh-ping is provided.
4. The habitat needs of sika deer is estimated to be 70% forest with 30% grassland. The carrying capacity of the forest should be followed when determining the carrying capacity of a site for sika deer.
5. The carrying capacity of Lu-chueh-ping for sika deer is estimated to be 50 deer. Water buffalo is recommended as the second herbivore which can assist in keeping the grassland open. Because the number of deer Lu-chueh-ping can support is limited, population management will be necessary in the future. The remoteness of the site, the high cost necessary to establish a deer herd there, and potential tourist interferences should all be planned for.

D. Recommendations for the management of existing subpopulations:

1. DNA analysis should be conducted on the Kenting deer herd to determine its purity. Before the purity is known, release of captive bred individuals should be halted. If this deer herd is found to be not pure, future release should be prevented. Analysis should be made to determine whether captive breeding should be continued or whether birth control methods should be

practiced. Monitoring of wild populations and the reactions of the plant community should be emphasized in the future.

2. Green Island deer population should also be anlyzed to determine its purity. Because the Hsiang Office is short of funds, perhaps the Council of Agriculture or the East Coast Scenic Area Office should play a more active role in sika deer management here. Recommendations are made on the management of deer damage to crops. Ecotourism may be the most promising way to accomplish the dual goal of deer conservation and increasing local welfare.

PART I: SIKA DEER CONSERVATION NEEDS

Overview

Successful conservation efforts are needed to serve as models for continuing conservation efforts, particularly those for all biodiversity, which is much broader, and less well understood. All species are of conservational importance and interest, but the realities of economic and cultural symbolism of some species cannot be ignored. If one can conserve a few, high-profile species, saving all biodiversity should be more convincing to the public. Furthermore, the process of saving a few high-profile spe-cies frequently ensures the safety of numerous other less noticable sympatric species.

The main reasons for preserving the Taiwan sika deer (Cervus nippon taiouanus) are its original importance in the Island's fauna, and its historic significance as a currency (for the payment of taxes) during the early settlement of Taiwan. It and the landlocked salmon have been flagship species in the efforts to conserve wildlife in Taiwan. The Taiwan sika deer is an endemic subspecies which evolved in isolation for about 10,000 years since the closing of the last landbridge between the island and mainland China which separated it from other sika deer stocks.

The Taiwan sika deer should be preserved by establishment of a population of deer of sufficient numbers and distribution to prevent extinction. Efforts to conserve this species have been on-going since 1984. The criticism that too much money has been spent on the conservation of two species (sika deer and salmon) at the expense of the broader conservation of Taiwan's biodiversity is valid as far as it goes. But it begs the question of whether the funds would have been made available for other general conservation efforts; most human societies around the world have found that whereas funds can be generated for conservation of a few well known, popular species, it often is difficult, at least in the early stages of conservation, to generate funds to conserve a diversity of wildlife of dubious value to an unsensitized public.

Given these considerations, it is paramount that the hard obtained public funds be spent properly and the sika deer restoration project be conducted in the most scientifically sound way. Thus, this project, as initiated by Yangmingshan National Park, aims to evaluate the accomplishments of the past ten years and to suggest future strategies for sika deer conservation as a whole, and to Yangmingshan National Park in particular.

In our view, the Taiwan sika deer conservation program should have three specific goals:

1. Maintain sufficient population size to avoid extinction in a fluctuating environment.

2. Maintain the population in at least 4 geographically separated areas. This goal is necessary because one single reserve large enough to contain a long term viable population of sika deer in no longer available in Taiwan; it is desirable because separation of subpopulations reduces the likelihood of catastrophic loss to disease, or environmental stochasticity (fire, typhoon, etc.).

3. Identify original genetic stock of Taiwan sika deer and base conservation efforts on this stock. Within the original stock, manage to retain genetic diversity. This will require metapopulation management approaches using small population genetic ideas.

BACKGROUND AND THEORETICAL CONSIDERATIONS

1. Population Models

The assessment of risk of extinction has been explored through mathematical modeling because we do not have enough cases of documented decline and extinction of populations to depend on empirical evidence. Usually, extinction of vertebrate species has been discovered after it has occurred, or when the population is already extremely low (often with no chance of recovery).

Therefore, we need to rely on models that can vary birth, death, immigration, emigration, sex ratio, and other parameters to do a population viability analysis (PVA).

Most species in nature show variation in these population parameters of greater or lesser amount depending upon the predictability and stability of the environment. Such variation is of less concern when a species is widespread and abundant. Not all parts of such a range are equally affected by environmental stochasity and, consequently, some areas do well at the same time that others decline. However, as numbers decline, and as the population is isolated to one of a few areas, variation becomes increasingly important; thus, variation (stochasticity) must be assigned to mean population parameters in the PVA model.

In PVA models, stochasticity is usually of two kinds: environmental, i.e. that due to variation in plant growth, rainfall, temperature, predation, etc., and demographic, i.e. that due to unbalanced sex ratio, accidental mortality, failure to find a mate, etc. Demographic stochasticity becomes increasingly important as the population becomes small because chance plays a bigger role, not being averaged out over large numbers.

2. Maintain a Sufficient Population Size

Early models of population viability gave relatively optimistic estimates of numbers of large vertebrates necessary for survival (Gavin 1978, McCullough 1978, Shaffer 1981, 1983). These values fell in the range of several hundred, and with a margin of error, 500 was commonly cited as a rule of thumb. However, more recent models are much more pessimistic in their predictions, calling for numbers in excess of 1,000 (Lande 1993). Why are estimates of numbers necessary for viability increasing? The models vary in structure, so direct isolation of the reasons are complex. But more generally, the causes are: (1) greater emphasis on small, rapidly-reproducing organisms with short life expectancies and rapid population turnover ("r-selected species") whereas early models involved long lived, slowly reproducing species with slow population turnover ("K-selected species"); (2) down playing or ignoring density dependence which is unimportant in r-selected species but much more important in K-selected species; (3) greater emphasis on catastrophic events (infrequent, severe environmental variation of extreme consequence to reproduction and survival) such as fires, floods, droughts, extremes of heat or cold, outbreaks of epizootic diseases, etc.; and (4) simulations over long time scales in hundreds or thousands of years.

The choice of species for early modeling reflected the emphasis first placed on the large, evocative species with which people could identify, sometimes referred to as "charismatic megafauna". The view of these modelers was that of wildlife managers, what Caughley (1994) referred to as the "declining population paradigm", in which correction of factors causing the species to decline was the approach taken. Because management was viewed as an ongoing activity, saving a species over 30 to 50 years was seen as satisfactory, because further management measures or adjustments were assumed to be possible in the future, and economic and societal changes would result in different circumstance in any event. Planning on a longer time frame was presumed to be unrealistic.

The recent view of modelers (usually conservation biologists), referred to as the "small population paradigm" by Caughley (1994), is a single interventionist approach which seeks one solution that will apply over the long term. Thus, this approach asks, "what size of reserve will protect sufficient habitat to maintain a minimum viable population of the species with no new interventions necessary for an infinite time?"

History has proceeded to the point where the latter approach is no longer feasible for the Taiwan sika deer. Thus, continuing management will be required, although planning should attempt to minimize such costs in future, and use natural processes to the maximum extent possible. Through continuing management, fewer numbers can be maintained and still have the same population viability as the creation of large reserves that afford total protection but no other management. And, the sika deer is a K-selected species, so in most regards the earlier, more conservative estimates of 500 individuals is probably sufficient.

3. Maintain Separate Areas

One means of substantially reducing the minimum numbers of a population to achieve viability is to have separate areas, each containing a part of the total population. This is the strategy of not putting all of your eggs in one basket. Because infrequent catastrophic events are a major contributor to the high numbers predicted by recent PVA models, these problems can be lessened by having separate areas sufficiently distant from each other to prevent a catastrophe from affecting all areas equally. For contagious diseases spread by contact, the areas have to be far enough apart to prevent animal dispersal between the areas, thus preventing transmission. For climatic variables, the areas need to be separated far enough that the same fire, drought, or whatever will not affect all of the areas equally; in other words, the environments between the several areas are not correlated. Ideally, each of the areas would be completely independent, but this demanding criterion is hard to meet in practice. Nevertheless, to be useful, the separate areas need to be differentially affected by the catastrophe so that even if some areas are devastated, and the subpopulations in those areas go to extinction, subpopulations in other areas will survive, and can furnish seed for reintroduction once the environment in the extinct areas has recovered sufficiently to support the species. Thus, a species maintained in a number of separate areas will be immune to total extinction even if some subpopulations go to extinction periodically. This approach allows a substantially smaller number of individuals in order for the population to be viable over the long term.

The "metapopulation" is the best paradigm about which to think about and plan such a system of separate areas. The theory of metapopulations was summarized by Gilpin and Hanski (1991) and the practical applications explored by McCullough (1996a). The basic idea of a metapopulation is that the population occurs in patches of favorable habitat in a matrix of unfavorable habitat: subpopulations in given patches may go to extinction, but over time, will be recolonized by dispersers from other patches. Not all patches will be occupied at any point in time, but if the rate of extinction is low relative to the rate of recolonization, the metapopulation will persist and be relatively stable even though any given patch of habitat will suffer extinction periodically, and thus be unstable.

In managed metapopulations, as in the recovery of species such as the Taiwan sika deer, dispersal and recolonization, selection of number and placement of patches, etc. are performed by the manager (McCullough 1996b). In contrast to natural metapopulations in which random chance plays a large role, the manager purposefully reduces the probability of patch extinction, recolonizes quickly if extinctions occur, and otherwise intelligently increases the viability of the species. Thus, much simplified systems can be maintained by management. Viability can be maintained in fewer patches than required for natural metapopulations subject to the vagaries of nature.

On the other hand, dividing the population into subpopulations results in many small populations instead of one large one, and this has consequences for loss of genetic diversity, the risk of which is much greater in small populations. It is important, therefore, in managing "dispersal" between subpopulations by relocation that genetic diversity be addressed in selection of stock, and deciding numbers and locations of animals to be moved. This of course means conservation agencies must make permanant commitments to the proper management of the metapopulations for the long term good of the species, and the management programs of the various subpopulations must be coordinated as parts of a whole, instead of being independent of each other.

4. Genetic Considerations

There are two basic questions about the genetics of sika deer in Taiwan. First, are there genetic markers that can be used to identify pure, original Taiwan sika deer, and second, what is the genetic diversity in the remaining pure stock? It is intuitively obvious that the first question must be answered before the second question can be addressed. Therefore, although DNA studies can proceed simultaneously on both questions, the results on which stocks are pure Taiwan deer are needed before it can be determined how much genetic diversity that stock has retained.

Answers to both questions are necessary to the development of a detailed management plan for Taiwan sika deer. Because the subspecies has been extinct in the wild since the late 1960s (McCullough 1974) the sika deer program is a recovery program. As such it has many concerns with genetic bottleneck, founder effects, and possible interbreeding with stock from outside of Taiwan. Consequently, genetics must be part of the basis upon which conservation and recovery of the subspecies is based. Numerical recovery of the subspecies and genetic conservation must proceed hand in hand.

A. Rationale for Genetic Management

It is important that the reasons for genetic management of sika deer be understood so that recovery plans and money spent can be directed along sound lines, and not follow simple expediency. Often the quest for rapid numerical increase in numbers comes into conflict with sound genetic management, which may require caution, patience, and the exclusion of some individuals from the program for genetic reasons. The goals and requirements of genetic management, therefore, must be clearly recognized.

Why be concerned about using only pure Taiwan stock in the recovery program? One reason is that that stock should be best adapted to the local environment. The second one is it is a piece of the evolutionary history of the island.

1) Over eons, generations of sika deer have been subjected to natural selection, and those individuals best fit to survive in the Taiwan environment were selected. These

fitness trials were continued over some 10,000 years at minimum (the closure of the latest landbridge, and perhaps longer since fossil sika deer have been found from the Pliocene)(Patel et al. 1989). It seems reasonable that such refinement and fine-tuning of the local sika deer stock to the local environment has produced a unique, superior genetic deme.

Over its range the sika deer has evolved into 13 subspecies (Wang 1985), including 7 on former landbridge islands in Japan and Taiwan. The sika deer is unusual among deer in the high number of different island subspecies it contains. The subspecies on Taiwan probably never occurred in a small population size that could result in genetic drift, because Taiwan is a continental island which was connected to the Asian mainland in the Pleistocene, and the sika deer was continuously distributed across the range of the species. The closing of the landbridge by the gradual rise in sea level, therefore, isolated a substantial population of sika deer on the island. When the first Europeans arrived in Taiwan in the 1500s the sika deer was widespread and abundant--so much so that their hides were a major form of currency, being used to pay taxes, and were an important export product. Given this history of origin, Taiwan sika deer should be uniquely adapted through natural selection to the ecological conditions of Taiwan. Basing the recovery program on the original stock, therefore, has ecological and evolutionary advantages.

This does not mean that other stocks of sika deer would not be able to survive in Taiwan. Indeed, they well may thrive here. But adaptation includes response to periodic challenge by irregular events, and an apparently successful stock in the short term may fail under long term conditions that include the periodic challenges. In any event, the original Taiwan stock will be best adapted over the long term, and conservation, by definition, is a long-term activity.

2) A second reason for using pure stock is largely philosophical. The evolution of a subspecies is the unique outcome of a particular history. It will never be repeated. Once a certain lineage is lost it can never be recreated. The Taiwan sika deer is a piece of Taiwan history much like a rare antique vase. There is only one. We may be able to make a copy of the original, but a fake vase has no value as an antique. Like precious art objects, genetic stocks have value especially because they are original. Protecting the sika deer that is unique to Taiwan should be the proper conservation goal. Only if pure stock is no longer available should unpure stock be considered.

B. Maintaining Genetic Diversity

How to maintain genetic diversity is the second genetic issue to consider. Diversity is rapidly lost in small populations, and in the selection of stocks for reintroduction, which applies to sika deer in Taiwan. Also, the length of time a population is low influences genetic loss. Bottlenecks (i.e. a low in population numbers in the past) and founder effects (genes retained by translocated subsamples of a population) are one-time events. They result from the luck of the draw. But gradual gene loss continues so long as the population remains small (Denniston 1978).

The major reason for trying to retain diversity is the unknown consequences of failure to do so. We are still in the early stages of understanding conservation genetics, and there is much we do not know. What are the consequences of loss of genetic diversity? The major short term concern is inbreeding depression--the loss of fitness and expression of deleterious genes (Ralls et al. 1979, 1988). In the tule elk and other Cervus species, inbreeding frequently causes the occurrence of "hairlip", which is a genetic birth defect due to a double recessive trait. Two cases of this has been reported in the Kenting Breeding Facility (Wu et al. 1992). However, since there were only two cases among the many births in the Kenting facility (Pan Min-Hsiung personal communication), it has not been much of a problem.

A second, long term concern is the loss of alleles that confer advantage to withstand periodic challenges, such as epizootic diseases. However, the total number of Taiwan sika deer that can be maintained is likely to be too few for the occurrence of rare alleles, by chance, to convey this protection. Natural resistance to (for example) viral diseases occurred in European rabbits (Oryctolagus cuniculus) against myxomatosis in Australia, or wildebeest (Connochaetes taurinus) against rinderpest in Africa. However, rabbits in Australia occurred in the millions, and wildebeest in the hundreds of thousands, so there was a good chance of naturally resistant genes to occur by chance. Such numbers are unrealistic for sika deer in Taiwan, and it is unrealistic to expect this to work for sika deer in Taiwan.

Aldo Leopold (1949) observed that the first rule of intelligent tinkering is to save all of the pieces. In this spirit, not only the original genome, but as much of it as possible should be conserved. Therefore, genetic concerns should be included in restoration efforts. It is not known how much genetic diversity of the original Taiwan sika deer population has been retained by the current stock. Perhaps most diversity already has been lost because of low numbers and founder effects in the past. In this case, genetic diversity can be ignored in management. However, judging from the results on a species in the same genus, the tule elk (Cervus elaphus nannodes, McCullough 1996b), which has a similar history, we would expect some level of genetic diversity still present in sika deer stocks. Management decisions should be guided by genetic considerations unless it is verified that no diversity is present. Diversity needs to be measured by molecular techniques such as DNA microsatallites (Roy et al. 1994).

BRIEF HISTORY OF SIKA DEER IN TAIWAN

Sika deer spread to Taiwan at least as early as the Pliocene across landbridges (Patel et al. 1989), and subsequently were isolated by rising sea levels, perhaps about 10,000 years ago. Sika deer is a lowland species, occurring most commonly below 300 meters (Kano 1940, McCullough 1974). These deer were extremely abundant on the southwestern coastal plains, but occurred commonly throughout the island in the lower valleys (Su 1985).

Because of their abundance, sika deer were heavily hunted, and their hides were a major form of currency in the early period of European occupation; thousands of hides were collected as taxes and tribute, and exported to foreign markets (Patel et al. 1989, Chiang 1987). Between the heavy kill for hides and conversion of its habitat to agriculture, the sika deer abundance and distribution declined rapidly. Its preferred habitat was prime land for culture of rice and other high-value crops. In fact, maps of the original distribution of sika deer habitat (Su 1985, Fig. 1) and those of rice production (Severinghaus 1989, Fig. 1.4) are virtually identical.

Few references to sika deer are available between the time of the early hide trade and recent decades. It seems probable that deer disappeared from the western plains first (because of high human populations and habitat conversion), and subsequently in the mountain valleys in the northern part of the island where development and urban areas were concentrated. Kano (1940) reported sika deer still occurred in the Snow Mountains in the late 1930s, but this area is somewhat remote in those days. By the 1960s, Ruhle (1966) reported that they were confined to some areas of the east coastal mountains. Despite an intensive search in 1973, McCullough (1974) could find no sika deer in the wild. The last known record of a sika deer in the wild was one killed in 1969. He concluded that the deer was extinct in the wild, but fortunately deer had been raised in captivity for the antler market, and a population was being kept in the Taipei Zoo. He recommended that a captive breeding program be established in the Kenting area. This facility was subsequently started in 1984, and served as the major conservation effort for sika deer over the next decade.

HABITAT RELATIONSHIPS OF THE SIKA DEER

Over most of its range, the sika deer is adapted to utilize disturbed areas in forests or other climax vegetation that provides cover to the deer. Thus, it is a subclimax adapted species. Sika deer can survive in climax vegetation, but only at very low density. The sika deer is a mixed feeder, consuming a wide array of grasses, forbs, and woody browse (Hsia 1990). It is not restricted to a given set of plants, but rather can use an enormous ranges of species so long as the nutrient content is reasonable and the defensive compounds not too prevalent.

Based on knowledge of other species of deer, sika deer would seek out the highest quality forages available to them at any time. They are selective feeders, and feed on the move, taking a bite here and there, thereby mixing plants in the diet to achieve a balanced nutrition. During rapid plant growth, when rainfall and temperatures are favorable, deer eat predominately herbaceous vegetation (grasses and forbs). During the green growth phase these plants have relatively high nutrient content and low fiber content. During dry periods, or other times when herbaceous vegetation is slow growing or dormant, deer shift to greater amounts of leaves and twigs from woody species (browse) which retain their nutrients contents better across the seasons (Sampson and Jepersen 1963, McCullough 1969, McCullough and Ullrey 1985). Under food stress, usually due to too many animals, they also scrape bark with their incisors from small forest trees that have thin barks and thick cambium-phloem layers. These tree species are usually the rapidly growing species that are typical of early stages of reestablishment of trees on disturbed sites. They are usually replaced by more slowly growing tree species that constitute the mature forest, and in that sense, unless deer density is too high, this feeding is not so ecologically damaging since it often hastens return of the mature forest. Nevertheless, it does alter vegetation to be less favorable to sika deer. Some bark scraping can occur at low density as well, as the deer sample forages that are available, but prevalent scraping usually occurs when other foods are scarce or unavailable.

Based on our best judgements, sika deer should be predominantly an "edge" species, reaching greatest abundance where disturbance areas are interspersed with various stages of forest vegetation. The herbaceous layer of disturbed areas produce the highest quality and greatest biomass of forage. The secondary forests are rich in woody species with good browse and concealment cover from predators. Mature forests with closed canopies furnish cool shady sites with good vantage points to see predators in the more open understories. Such sites are preferred for bedding during the day to rest and ruminate. The usual daily cycle is to feed during morning and evening (Wang 1985) in open areas, and to bed during the day in the forests.

In the coastal plains of the original distribution, sika deer most likely used dense miscanthus grasslands and shrubby woody vegetation instead of forests for resting cover. Sika deer, in fact, are not dependent upon forests per se, but can use other kinds of vegetation that furnish the requisite shade and concealment. Similarly, where herbaceous vegetation grows year round--for example if rainfall occurs in all seasons, or along ponds and streams--sika deer are less dependent on woody browse.

COMPARISON TO AN ECOLOGICAL COUNTERPART

A well-studied species that is a close ecological counterpart to the sika deer--and thus a useful model--is the white-tailed deer (Odocoileus virginianus) in North America, particularly in the southeastern U.S. Most of the feeding ecology, behavior, and habitat relationships of these two species are quite similar, and until further research is available on sika deer in Taiwan, the white-tailed deer literature will be a useful guide.

The similarities have been apparent from earlier work (McCullough 1974) and from our recent examination of sika deer ecology at Kenting National Park and Green Island. At Kenting Park deer that have been released from the pens are occupying areas on the fringes of disturbed areas, either former agricultural fields or current water buffalo and goat pastures. Deer feed in these openings at night and bed during the day in the surrounding forests. Deer still in the pens are lacking in sufficient grassland or disturbed vegetation, and thus are having a relatively heavy impact on forest vegetation. On Green Island, greatest densities of sika deer are found around water buffalo pastures and crop fields where they feed at night, and retreat to adjacent forests to bed during the day. Sika deer sign occurs throughout the island, but is sparse in the forested areas in the center of the island. These areas are lacking disturbed patches attractive to deer. Deer occur in small social groups (typically 5 or less), and tend to feed on the edge of clearings within 50 meters of the forest cover. It they venture out further, they usually form temporary groups of larger size by the joining of separate social groups into temporary feeding aggregations.

Sika deer in Taiwan are very skittish and high strung, much like white-tailed deer. They become panicked if pressed, and leap against fencing in an attempt to escape. They are prone to injuring themselves. A recent deer drive (line of humans walking abreast) in one pen of the Kenting Breeding Facility resulted in two premature births (and neonatal mortalities). Attempts to direct deer in a holding pen for a TV crew while we were there resulted in general panic among the deer. These are typical responses of white-tailed deer as well.

However, there are some differences between the two species, and caution is in order. The sika deer, judging from the depth of the molariform teeth, is more dependent upon grasses; also, bark stripping, which is characteristic of the genus <u>Cervus</u>, is less commonly observed in <u>Odocoileus</u>. Finally, there are major, phylogenetic differences between the two genera in reproductive rate. <u>Odocoileus</u> is a New World genus characterized by multiple births per litter, whereas <u>Cervus</u> species usually have singletons, with twins being relatively rare. Thus, white-tailed deer should not be used as a demographic model for sika deer: to do so would greatly overestimate the potential for population increase.

DISTRIBUTION AND ECOLOGICAL CONDITIONS

Given the ecological traits, some things can be inferred about the sika deer. Reviews of the historical distribution suggest that highest densities of sika deer were originally found in the southwestern plains of Taiwan (Su 1985). Clearly this deer does well in leveler terrain, so the topography would have been favorable. Probably most important, however, was the fact that this area is characterized by summer rainfall and winter dry season. Severinghaus (1989) has mapped the frequency of drought in Taiwan (see her Fig. 1.4), which occurs every two years on average in the southwestern plains. During dry seasons fires, the major cause of disturbance, could burn more readily. This area is known for its frequent lightening storms, so ignition was common naturally, and aboriginals probably contributed further by purposefully setting fires to favor game once they arrived some 4,000 years ago.

Consequently, sika deer were extremely abundant where favorable topography, climate, and especially, a frequent disturbance regime existed. As one moves north on the western plains, climate and topography were still favorable, but the disturbance regime was less frequent due to the more uniform rainfall across the seasons. This would account for lower abundance, but still a wide-spread distribution.

The upper elevational limit of the distribution was probably set by a combination of topography, climate, and disturbance regime. Clearly the thin-coated sika deer on Taiwan is a subtropical to tropical animal, although sika deer in northeastern China and Hokkaido, Japan are winter adapted. Thus, cold temperatures and winds no doubt set upper elevational limits, although they were probably higher than generally appreciated. Kano (1940) for example, showed sika deer occurring up to 300 meters in the Snow Mountains. Steep topography, also certainly disfavored sika deer. Although they are quite adept at using broken terrain (as evidenced by their use of uplifted reefs in Kenting National Park), they clearly do not do well on the steep slopes characteristic of the Central Mountain Range. Finally, the forest characteristics of the higher elevations are better at retaining moisture, and thus, are more difficult to ignite. Fires do occur in the high mountains, particularly in the southern parts where winter dry seasons occur. These burns tend to be relatively large when conditions are such to allow the fires to reach the canopy. Large areas of Yu Shan National Park are kept in bamboo grasslands, and a fire-adapted pine (McCullough 1974). Fire patches are common on ridge tops where lightening strikes are common. Most of these burns, however, occur too high in elevation for the sika deer.

In low elevation mountains, typhoons are probably a more important source of forest disturbance, particularly in southern and eastern areas of Taiwan, because typhoons usually come from the southeast. Typhoons open up the canopy in patches, where old or weakened trees break down. Typhoons seldom clear the site in the manner of fires, so they do not set back succession as much, and the understory stems of small trees close these gaps more rapidly. Consequently, the time during which these disturbed areas are favorable to sika deer is relatively short compared to burned areas.

The combination of steep topography, less frequent disturbance, and shorter duration of disturbed areas remaining open result in a smaller scale and more isolated distribution of good sika deer habitat in the mountains. Thus, sika deer were wide-spread, but irregular in abundance in these areas. However, conditions were more favorable in climate, topography, and disturbance regime in the Hua-Tung Valley, and this was a secondary stronghold for sika deer after the western coastal plain.

POPULATION AND MANAGEMENT

As a disturbance adapted species, the sika deer, like the white-tailed deer, most likely tends to follow a boom-bust population response. Following disturbance the population builds up, but as the disturbed area recovers, the population declines. It is unrealistic to expect local population stability, or an equilibrium in an ecosystem sense. A balance between vegetation, herbivores, and carnivores is unlikely because of time lags as the site changes constantly in response to the disturbance regime. Under natural conditions such systems were stable only over a broad landscape scale as disturbance patches being created balanced those being lost through succession. The distribution of herbivores and carnivores shifts over time to track the shifting mosaic of disturbance. Even over broad areas, such systems were unlikely to be strictly in balance, because the disturbance regime is not constant, but instead related to climatic phenomena that are oscillatory over time.

For managed systems, such as are necessary in a recovery program for sika deer, population stability has to be imposed by human design. First of all, predators are usually not still present in such systems. Humans have to assume the role of predators in controlling the herbivore population. This may be accomplished by increasing the mortality (by shooting, capturing and slaughtering), reducing reproduction (by manipulating the sex ratio, age ratio, or contraception) or emigration (by capture and relocation). The manager will chose the methods depending upon feasibility, cost, and public acceptance. Whatever the means, population control in a boom-bust species is usually required. One should not establish such a population without having the means to control population size, or severe conflicts with other land uses are likely to occur.

Second, in managed systems humans can further stabilize the population by controlling the extent of disturbance areas, and indirectly influence the boom-bust behavior of the herbivore population. Disturbed areas can be maintained by cutting and mowing using human labor, or utilizing a second species of herbivore to balance the impacts of the featured herbivore. With sika deer in Taiwan, the domestic water buffalo can be a second herbivore. Use of a second herbivore often has cost advantages, and a more natural impact on vegetation. This topic will be addressed further below.

HABITAT MANAGEMENT

What mix of disturbed and undisturbed area should be maintained for sika deer? This question cannot be answered at present because of a lack of research and management experience. Based on research done at Kenting National Park, observations on Green Island, and familiarity with white-tailed deer, we judge that the mix should be around 30% disturbed and 70% undisturbed. Ironically this is just about the opposite ratio of sika deer feeding on grass (about 70%) and woody vegetation (about 30%). This is because grasslands are more productive of forage per unit area than forests. Basically, sika deer prefer quality grasses, but balance out nutritional needs with woody vegetation even when grasses are abundant. More importantly, if there is a dry season, the quality of grasses declines to low levels whereas quality remains much more stable in forest vegetation. Thus, deer shift to greater consumption of forest vegetation during dry periods. It follows, therefore, that in the south of Taiwan where winter drought is common, to maintain the same population density as in a more northerly location, a greater proportion of forest is required to support the greater demand at that season by sika deer. In northern Taiwan, rainfall is move evenly spread over the year, and a relatively lower proportion of forest will most likely suffice.

Another consideration is that forests are more sensitive to overbrowsing than grasslands. Damage to population structure and abundance of plant species by overbrowsing white-tailed deer have been well documented (see Alverson et al. 1988, for example). This is because forage is more sparsely distributed in the forest, and regrowth slower because of the shading of the canopy. Also, differential palatability of species often results in shifts in species composition, with unpalatable species expanding at the expense of regrowth of the heavily browsed species. Bark stripping by deer can have the same result.

Grassland are inherently more resistant to grazing than forests due to their growth form, capacity for regrowth, and higher productivity of forage. They are also easier to create and manipulate than forests. For these reasons, (assuming a stable amount of grassland) forest vegetation impacts should be considered more critically than those of grasslands in establishing carrying capacity for sika deer. Population control should be geared to sustainability of the forest vegetation. Some impacts are normal and expected. However, trends in forest vegetation need to be monitored carefully to be sure that undesirable shifts are not occurring.

Once the carrying capacity of the forest is determined, the mix of grassland and forest can be adjusted to the needs of the forest. The grassland can be expanded if the forest can absorb greater pressure, or contracted if the forests are receiving too much pressure. Sika deer numbers need to be adjusted appropriately. The mix of forest and grassland can be adjusted based on trial and error to get the right balance. Or, the size of the area can be changed to add the required component. Finally, if a second herbivore is being used, its numbers can be increased or decreased to achieve the right balance with the featured species.

A SECOND HERBIVORE

The water buffalo is a nearly ideal second species in Taiwan. It does well in the climate and habitat. It feeds almost exclusively on grasses, and thus, has little impact on forest vegetation--just what one wants given the greater sensitivity of the forest. The negative potential of water pollution from buffalo droppings, and the damage to ground surface caused by their digging mud holes to wallow in can be minimized by maintaining the minimal number of water buffalos necessary. Water buffalos are docile. Centuries of management and their tractability have resulted in their being easily manipulated. Furthermore, their meat has market value that may offset costs. Although not native, it has been a prominent feature of the landscape for centuries, so it presence does not cause discord: in fact, it is a positive value in the landscape for most Chinese.

On Green Island, water buffalo pastures on former rice terraces are some of the very best habitats for free-ranging sika deer. Water buffalo are also currently grazing on former rice paddy terraces at Lu-Chueh-Ping, the preferred reintroduction site in Yangmingshan National Park. Without water buffalo, it would be extremely difficult to keep these areas in grassland, for they would readily be invaded by woody species otherwise. Part of the grassland at Kenting Breeding Facility was lost in this way. It is difficult and expensive to reestablish grasslands once lost. Water buffalo can be useful to keep the grasslands open while the process of trial and error proceeds in determining carrying capacity of forests for sika deer. Water buffalo can also be used to maintain grasslands during the time it takes following introduction of sika deer for their population to grow large enough to maintain grasslands.

In the long term, the goal of a sika deer recovery and conservation program is to recreate ecosystems as natural as possible. It would be preferable, if feasible, to eliminate exotics such as the water buffalo from sika deer areas. Therefore, the goal should always be to minimize water buffalo and maximize sika deer (and other native species). However, given the limited areas that are available for sika deer restoration, and the lack of knowledge to plan precisely, the water buffalo is a useful, if not indispensable tool to manage these areas.

With experience perhaps it will prove possible to manage sika deer by controlling only the size of the deer population. In the meantime, however, the availability of a second control is important to keep things on course. True stability is seldom possible, but by using the control of disturbance, and control of herbivore numbers, the system can be kept within reasonable bounds. Hopefully these systems can proceed to a single herbivore, the sika deer. However, experience with white-tailed deer has shown how difficult it is to halt succession with this species. If the same proves true for sika deer, then either water buffalo or artificial means may be required.

RECOMMENDATIONS TO SIKA DEER CONSERVATION PROGRAM

With this background and rationale, we make the following recommendations to the sika deer conservation program. Firstly, the problem of the sika deer's legal staus must be properly solved. It is currently declared a domestic animal in order for relevant government agencies to control potential TB outbreaks in domestic deer herds. Yet, this status removed sika deer from the protection of Wildlife Conservation Law, and also makes investing in its conservation difficult to justify.

Secondly, it is of utmost importance that an overall conservation and management plan for the species is drafted in order to coordinate all the actions concerning the various subpopulations, so the subpopulations can function as parts of a whole, instead of each an isolated small population.

In addition, we recommend immediate action on the following specific research or action steps.

1. Analyze mtDNA to Establish the Original Taiwan Stock.

This research should involve mtDNA studies of samples from museum specimens with unquestionable origin from Taiwan. Samples can be obtained from institutions such as the British Museum of Natural History in London, Field Museum in Chicago, American Museum of National History in New York, the Smithsonian Institution, or other organizations with collections from Taiwan. The DNA sequences from these material will serve as tools for determining the purity of existing major populations of sika deer on Green Island, in Kenting, or in other public or private hands. The Kenting population was already analyzed by Cook (1992), although the sample size was small. If the Kenting population turns out to be pure, future transplants can consider using Kenting deer. If the Kenting animals which Cook analyzed were contaminated with other sika deer stocks, the Green Island population needs to be examined. If the Green Island deer is the only pure stock remaining, future transplants should come from Green Island stock, and the Kenting and Taipei Zoo stocks should be confined to those areas. Preferably these stocks should be replaced with Green Island stock, but complete replacement can only be accomplished at the Taipei Zoo. The free-roaming population at Kenting is beyond recall. The best that could be accomplished at Kenting is to dilute that stock by introduction of Green Island stock.

There are other privately-owned sika deer in deer farms, but their ancestry is unknown, and the possibility of their having interbred with sika deer from elsewhere is high. We recommend that deer from private farms not be used in the restoration of sika deer in Taiwan. Contamination may already be a problem with the Kenting and Taipei Zoo stock. Introducing new blood lines can only further complicate the problem. Only in an exceptional case--where a clear pedigree has been kept, and DNA analysis supports the claim of original Taiwan stock--should private stock be considered in the restoration program.

2. Determine the Genetic Diversity Still Present in the Original Stock.

Obviously the mtDNA work to establish the original stock needs to precede this goal, for the animals to be tested for diversity will vary with the outcome of the first goal. However, the same DNA samples can be used for both. Once the original stock has been identified, genetic studies should be conducted to establish diversity. If all (or virtually all) of the alleles are fixed, no attention needs to be paid to future genetic management. However, if there is still diversity present, breeding programs should be designed to retain as much of the diversity as possible for all the subpopulations, in order to obtain the highest total diversity with metapopulation management. Sufficient numbers of sika deer are present on Green Island to retain diversity. However, in transplants, efforts should be made to be sure that all animals reproduce (a particular problem with young males that often are behaviorally excluded), and some animals may need to be moved to supplement populations that remain small.

3. Maintain at Least 4 Separate Subpopulations to be Managed by Metapopulation Methods.

Currently there are 3 separate populations of sika deer (Kenting, Green Island, and Taipei Zoo) under public control. As explained under metapopulation concepts, this separation of subpopulations is the major hedge against extinction, given the small number of individuals in the total population. It is especially important for the prevention of total extinction due to a catastrophe.

Nevertheless, 3 subpopulations in a metapopulation scheme is quite small. Of particular concern is the fact that one subpopulation (Taipei Zoo) is very small (17 at present), and is subject to epizootics because of confinement close to a number of other species. The fact that the previous Taipei Zoo population had to be eliminated earlier to eradicate TB amply illustrates the hazard. Thus a fourth subpopulation is highly desirable. Of course the health conditions of deer in the other populations need to be determined, to prevent epizootic agents from spreading via captive breeding efforts. It may become possible and desirable to have more than 4 subpopulations as experience with management accumulates, and current problems are solved. Therefore, 4 subpopulations are considered to be a minimum number rather than an ideal number.

An ideal number of subpopulations cannot be stated precisely. Beyond 4 populations, the location and quality of habitat become considerations as important as simply the addition of another subpopulation. Future evaluation of the availability of habitat, funds, competing conservation demands, education and recreation needs, and public interests should assist in determining the eventual number of subpopulations.

4. Spread Out the Subpopulations Geographically to Minimize the Hazard of Catastrophic Events.

As explained in the background on metapopulations, it is important that the environmental stochasticity of the subpopulations not be correlated, and this usually means being separated geographically. However, linear distance alone is only a gross indicator because it is the sharpness of climatic clines, mountain ranges, water bodies, and similar barriers that cause subpopulation environments to be uncorrelated. Of the 3 current subpopulations, Taipei Zoo is in the north of Taiwan, far removed from the other two in southern Taiwan. Thus, the environmental conditions of Taipei Zoo are unlikely to be correlated with that of the other two subpopulations. Kenting National Park and Green Island are separated by about 100 Km, and an intervening stretch of ocean. For most catastrophic events, these two subpopulations would be uncorrelated. Although typhoons, which are common in Taiwan, may strike both areas, typhoons in our judgement are unlikely to cause the extinction of a subpopulation of sika deer. This is because sika deer can take shelter in rocky areas, ravines, and other protected sites. Although food supply may be reduced by a typhoon with adverse effects on sika deer in the short term, in the longer term, the disturbance would favor sika deer habitat quality.

The 3 existing subpopulations are largely uncorrelated, and should be differentially affected by catastrophes. But the environmental conditions of Yangmingshan National Park would be at least partially correlated with Taipei Zoo. Thus, to establish a fourth sika deer subpopulation there for the prevention of extinction would be less desirable than on a more distant site.

5. Attempt to Maintain a Population with Sufficient Number of Deer.

We recommend a population of 500 animals, or a Population and Habitat Viability Analysis (PHVA) be conducted to determine the desired total population of sika deer for Taiwan.

We believe that reaching a total population of 500 deer is a reasonable short term goal. Currently Green Island supports 250, Kenting about 200, and Taipei Zoo 17 individuals. Thus, creation of a fourth subpopulation would almost certainly boost the total to over 500.

In the longer term, as economic conditions reduce the amount of area in field crops, interest in conservation among the public grows, and problems of deer control and prevention of crop damage are solved, it may be possible to let the sika deer reassume the status of a wild, free-roaming animal. At that time efforts can be switched to manage it as a wild species, and captive breeding and restoration programs discontinued.

6. Pursue the Restoration Program Cautiously and Incrementally.

The sika deer restoration program needs to move forward carefully to avoid costly mistakes. There is no crisis of extinction right now, and the 3 existing subpopulations are reasonably secure. Consequently, planning and evaluation should move forward incrementally.

First of all, it is crucial that the questions about genetics of the original stock be resolved before any additional subpopulations are established, and the release of Kenting stock into the wild be curtailed until the genetics studies are done. If the stock from Green Island proves to be the only pure one, all future transplants should be made using this stock. As the new subpopulations become established, the Taipei Zoo stock should be replaced, and the Kenting stock augmented. It should be possible to complete this part of the genetics study within 2 years. If the genetic questions cannot be resolved, the source of stock for reintroduction then becomes a matter of convenience and feasibility.

Secondly, the site of a fourth subpopulation should not be determined until a thorough survey of potential sites is completed. Although we believe that the Lu-Chueh-Ping site in Yangmingshan National Park could be made successful, it has many limitations and would be very costly. We think a more promising site can be found elsewhere in the western coastal plain, or possibly the Hua-Tung Valley, where the habitat more closely approximates sika deer's original prime habitat.

The extent of croplands has been declining in Taiwan. Croplands dropped between 1977 and 1995 by 324 200 ha or 11.65% (Taiwan Provincial Forestry Bureau 1995). If this decline occurs in the more marginal agricultural lands, it is creating new opportunities for sika deer reserves.

It is desirable to establish a fourth subpopulation of sika deer to fill out a metapopulation scheme to conserve the species. Yangmingshan National Park, the only area with a specific proposal for sika deer, has many limitations, limited future potential and many potential conflicts with other goals and uses. Before any additional introductions are approved, a thorough search of potential sites should be conducted. In our estimation, it is highly likely that a more promising site than Yangmingshan can be identified.

Of particular interest are potential sites on the western plains. A subpopulation in this area would reestablish the species in the heart of their original range, and would contribute to the recovery program by being far from existing subpopulations, thus is most likely uncorrelated in the environmental stochasticity encountered. Nevertheless, the selection of a fourth site involves a complicated tradeoff of many factors--location, naturalness, size, requirements for fencing, lack of conflicts with other land uses, etc. Selection of the best site should be made on the integration of all of these factors. Because money for conservation is limited, it is important that the site selected be a sound choice.

PART II

SIKA DEER AND YANGMINGSHAN NATIONAL PARK

1. The Suitability of the Park for Sika Deer Reintroduction

As stated earlier, the close proximity of Yangmingshan and Taipei Zoo makes the geographical location of Yangmingshan less desirable as the fourth site, if limited resources permits the establishment of only one more subpopulation in the sika deer conservation program (instead of several more subpopulations). However, proposals to reestablish sika deer in this National Park have been around for several years, and two research reports have been published on evaluation of various sites (Wang and Su 1994, Wang et al. 1995).

According to these reports, Lu-Chueh-Ping was selected as the preferred reintroduction site within Yangmingshan National Park (Wang and Su 1994, and Wang et al. 1995). We have relied on the site evaluations of these reports and have visited only the preferred site, which is about a 45 minute hike (approximately 1.5 Km) along an unimproved trail from the end of a secondary road. Access to the site is a major problem, and all materials would have to be hauled in from the end of the road. The site consists of a series of terraces that formerly were used to grow rice, but currently are being used as pasturage for domestic water buffalo. Although the national park has purchased the land, the water buffalo, which are privately owned, continue to graze there.

We believe that it would be possible to establish successfully a sika deer subpopulation at this site. However, it would be expensive because all fencing and other necessary construction materials would have to be carried to the site by human or animal labor. Transport by heavy helicopter would be most efficient, but whether this is feasible remains to be determined. All deer stock would have to be carried in (or out) in crates. Furthermore, it would be difficult to police the site, although the remoteness is also an advantage, for there is relatively low human use. Still, the presence of sika deer may attract many more people to the site than presently use it for picnicking, camping, and hiking. If the sika deer project is to go forward, the design of the pen should purposely be such as to minimize problems of humans to the deer facility.

Finally, this site, and Yangmingshan Park in general, has little potential for sika deer expansion in the future. Preferred habitat of sika deer is confined to small patches, which are widely spaced from each other. None of these patches is large enough to support a substantial number of deer, say exceeding 100 head. Although the intervening forests would probably support a very low density of free-roaming deer, the complex land ownership, management authorities, and high human use of the Park present a morass of problems.

For these reasons, we suggest that there may be other sites elsewhere on Taiwan with fewer problems and greater potential to establish a fourth subpopulation of sika deer. Certainly a thorough survey of potential sites should precede the establishment of the fourth subpopulation, whether in Yangmingshan National Park or elsewhere. We realize Yangmingshan National Park does not have jurisdiction over the rest of the island and cannot sponsor such a survey. Thus, if Yangmingshan National Park decides to proceed with the reintroduction program, the Park should plan for permanant commitment to the proper management of this subpopulation, to ensure that it functions properly as a part of the overall metapopulation management plan.

2. Enclosure Design at Lu-Chueh-Ping

If sika deer reintroduction occurs in Yangmingshan, an enclosure will be required to facilitate proper management of the deer population and to prevent habitat damage to the Ecological Protected Area adjacent to Lu-Chueh-Ping. Exact design must be made upon detailed examination of aerial photo pairs with a stereoscope, and thorough checking on the ground. Size of the enclosure will be set by the cost and feasibility of fencing. Size is further restricted by the boundary of the Ecological Protection Area to the northwest of the site.

Human recreational demand will probably require that the lower meadow be retained for human use. The deer fence on this side should be placed at a point where the meadow is narrow, and thick vegetation comes down close on both sides (Fig. 2 on p. 39). This schematic map illustrates the ideas in the following text. The purpose of this figure is not to give an actual plan, but rather to illustrate the concepts that should be incorporated into the plan. The intent is to minimize the section of the fence that is tempting for people to try to climb over. This exposed section can be protected by topping it with an outrigger barbed wire barrier.

By placing the fence in the meadow area at a narrow point, and using steep rises in topography and thick vegetation on either side, human movement along the fence can be discouraged. The existing hiking trail cuts across the heart of Lu-chueh-ping grassland so it needs to be rerouted. Also, by making a separate trail to a high lookout, use of the new trail rather than cutting across country can be encouraged.

The angular shape of the enclosure, an approximate triangle, will assist in capture of deer when required. By placing a fence (either permanent, or temporary made from nylon netting) from the high point inside the enclosure to the east fence, with a gap in the fence, deer can be accustomed to using the gap (probably place at the saddle). Then by placing a net mesh holding pen at the gap, deer can be driven into the holding pen by a human drive line. A relatively few number of people (perhaps 6 to 10) can move deer for capture. If nylon netting is used, it should have a small mesh size that deer cannot get their heads through to prevent entanglement. The netting should be stretched tautly, so that deer leaping into the fence will be not be injured or entangled. Experienced deer handlers from the Kenting Breeding Facility should be used to train local workers in the capture and handling of deer.

3. Carrying Capacity of Lu-Chueh-Ping

We can only guess about how many deer an approximately 20 to 25 ha enclosure will support. Based on results from Kenting (Wang et al. 1993,1994) we think about 50 deer (about 2 per ha) should be supportable. In our estimation, the ratio of grassland to forest of this site will be too great in favor of grassland. Enclosing sufficient forest to not have deer cause damage to forest vegetation is unrealistic given the cost of construction and maintenance of fencing. Thus the number of deer supported by the enclosure will be set by the forest rather than the grassland. Some impact on the forest is acceptable, because the tree species there are all common and widely distributed (Dr. Su Hung-chieh, personal communications). Some opening up of the forest understory, and some tree barking is to be expected. However, the forest should retain a visual screen, and tree barking should not exceed the rate of natural thinning that occurs among secondary growth stems of forest trees. Deer feeding should not obviously alter the forest canopy species composition.

In our judgement, the number of deer that the forest vegetation can support is not likely to maintain the early successional stages of the grasslands. We expect encroachment by woody vegetation. Consequently, it is likely that some level of grazing by water buffalo, in addition to sika deer, will be required to maintain the disturbed areas in grassland.

At first, the minimum number of water buffalo should be engaged to maintain the meadows while keeping their potential damage to the environment at the lowest level. For management flexibility, it is probably best that these buffalo be owned by the park. As the number of sika deer builds up, the number of water buffalo can be cut back. The best mix of sika deer and water buffalo can be achieved by trial and error, with careful monitoring of vegetation. We do not believe that academic level research is required. However, an explicit monitoring system should be put into place at the start of the project. This should include standard photo points in the grasslands, and both photo points and tree stem plots in the forest to measure the percent of stems barked, and detect any shift in tree species composition that may occur.

PART III

THE THREE EXISTING SIKA DEER SUBPOPULATIONS

1. KENTING NATIONAL PARK

The Kenting population as been the focus of sika deer conservation since the establishment of the captive breeding facility at Shi-Ting in 1984. A number of reports and publications have been published, and much useful information obtained. Currently there are about 130 deer within the various fenced areas, and 20 deer have been released into the wild. Kenting officials estimate that with reproduction, the current wild population is about 30. All free-roaming deer are currently within 2 Km of the fenced facility: 18 deer carried radio collars, but the number with functional batteries is down to 13. Most deer are southeast of the facility, but 2 are to the north.

Shi-Ting was selected for the breeding facility because of the occurrence of water buffalo and goat pastures, but unfortunately, much of the original grassland has been lost through succession. Now grass-lands being grazing by deer inside the fences occur as narrow strips along the fence lines. These areas are heavily grazed, but are insufficient to maintain a desirable mix of grassland and forest to meet the forage demands of the deer. At the same time, too many deer in pen 1 has resulted in greater impact on the forest vegetation than is desirable. A drive crew was used to move 25 of these deer to a holding pen, from which they will be released to the wild in October following fawning. An estimated 10 deer that were not gotten in the roundup remain in pen 1.

Unfortunately, at least 3 separate genetic stocks have been mixed in the Kenting population: the original stock from the Taipei Zoo, deer from a breeding facility at Tunghai University near Taichung, and 5 fawns from a deer farm in Kaoshiung. One of the 2 mtDNA types reported by Cook (1992) may have resulted from contamination by this mixing of stocks. There are also persistent rumors about stock from the Bronx Zoo in New York, although we have not been able to determine if this stock is represented in the Kenting population.

The breeding facility has reached its main goal of producing a surplus of deer to be released into the wild. The free-roaming population need not be supplemented with many more deer. All surplus deer should be retained in the facility until the genetics issues can be resolved. If genetics results show that deer at Kenting are as pure, then deer can be released. Surplus stock can continued to be produced for transplant to new sites if beaches, extensive coral reefs, hot springs, etc. There are few cultural attractions. The construction and operation of the kind of deer farm envisioned by the Hsiang would be very expensive. There is serious risk that the returns would not justify the investment, and heavy losses might occur. We believe that it is more realistic, and certainly far less risky, to utilize wild sika deer as a tourist attraction in a natural state in keeping with the theme of the East Coast Scenic Area.

a. Ecotourism Development

We believe that sika deer, if publicized as a featured attraction on Green Island, would be a significant tourist attraction. It would expand the range of activities that bring visitors to the island. The island could become known for its sika deer roaming free in a beautiful semi-natural environment. Deer can be readily observed at night by spotlight. Our spotlighting activities attracted passers by, and they were intrigued by seeing the deer and hearing about their history and the conservation efforts that are going on at present. There is potential for guided tours at night in which an interpretive ranger with a spotlight shows the deer and talks about their ecology, behavior and status.

People who have come to Green Island to enjoy the beaches, snorkeling, and natural scenery drive around the island at night looking for things to do (nightlife on the island is almost nonexistent). Nighttime deer tours at peak tourist times would probably prove to be popular. Perhaps fees could be charged to offset costs. We think, however, that the major economic value of sika deer lies not in fees for deer spotting tours, but rather in increasing tourist volume that a well developed and publicized deer program could attract. Increased visitation would spin off in increased income for hotels, restaurants, transportation, diving trips, etc., funds that flow primarily to the private sector. The difficulty will be in managing the tour groups. Open accessibility of the sika deer areas may produce over disturbance to the deer herds, as tourists may form their own groups, while local residents may organize many private tours without proper concern for the deer. Should this happen deer herds would hide away from being overly disturbed. This will defeat the original purpose of ecotourism. Obviously some sort of concensus must be reached by the Hsiang office and local residents in the management of these tours and the sharing of the revenue.

With more frequent benign contact with people sika deer are likely to become tamer on Green Island than at present, and their probability of being observed during daytime would increase as well. The major obstacle to dedication of most of the island to sika deer is the damage deer causes to agriculture.

b. Crop Damage Management

The present system of dealing with agricultural damages is concerned with solving immediate problems only. The netting is inefficient and expensive to maintain, and only partially successful at best. Many times it confines deer to the wrong side. The payment of damages is onerous for both farmers and the Hsiang. Ideally, agricultural interests would be completely bought out by the Hsiang or Tourism Bureau. Growing garden vegetables would be restricted to areas immediately adjacent to houses, and the owners would be entirely responsible for protecting them from deer. Farming on public land would be strictly prohibited, and there would have to enforcement to prevent illegal farming, which by Chinese common law carries squatter's rights. This solution would be useful in eliminating the ongoing problem, if it weren't for the high land prices.

An alternative solution would be to reach an agreement with farmers who have suffered deer damage previously. Appropriate compensation is given to each at the beginning of each year with the understanding that they must not plant on specific fields, unless they want to take full responsibility for the risk of deer damage.

For farmers who plant further up the mountainsides which is lower in productivity and harder to protect, perhaps they can be employed as deer watchers or such to keep them occupied instead of farming, since they tend to be elderly people growing crops partly as a passtime. If farming were confined to the better sites in contiguous patches, the fields could be protected from deer by perimeter fences that would be easier to patrol and maintain. Obviously, studies would have to be done to evaluate the economics and acceptability to the local people of these different approaches.

Eliminating agricultural concerns from Green island would clear the way for incorporation of sika deer in the natural tourism program.

c. Grazing by Domestic Animals

In contrast to farming, grazing of water buffalo is compatible with a sika deer program, being the most inexpensive and efficient way to maintain open grass-lands. These are the best habitats for sika deer, and are also the sites where deer are most likely to be observed by spotlight. It is also where they would be most likely to be seen in the daytime if the deer herds were allowed to build up. As deer increase, domestic stock can be reduced, but it seems unlikely that sika deer can maintain open grasslands without domestic stock on Green

Island.

If croplands were isolated from deer as proposed above, some decline in deer carrying capacity could be expected. This leaves the question of sika deer population control. Currently much of the need for control relates to prevention of crop damage. If crop damage problem could be solved by a more lasting solution as proposed, the need for control would be much less. Green Island is a relatively large, diverse area where high quality sika deer habitat is small in extent, and maintained by grazing. The likelihood that sika deer will eventually self-regulate in the island is high. Should control prove necessary, it should be relatively easily accomplished by shooting or trapping in the vicinity of the grasslands. So long as the sika deer remains legally a domestic species, the live animals or their products can be marketed to offset the costs of the control program.

LITERATURE CITED

1. Alverson, W. S., Waller, D. M. and Solheim, S. L. 1988. Forests too deer: Edge effects in northern Wisconsin. Conserv. Biol. 2:348-358.
2. Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63:215-244.
3. Chiang, S. S. 1985. The relationship between sika deer and early Taiwan history. pp. 3-62. in The 1984 annual report on the Formosan sika deer restoration study. Conservation Research Report No. 18. Kenting National Park.
4. Chiang, S. S. 1987. The relationship between sika deer and early Taiwan history. pp. 2-24. in The 1985 annual report on the Formosan sika deer restoration study. Conservation Research Report No. 38. Kenting National Park.
5. Cook, C. E. jr. and Wang, Y. 1992. An analysis of the population structure of Formosan sika deer (C. n. taiouanus) in Kenting National Park by amplification and direct sequencing of the mitochondrial cytobhrome b gene. Conservation Research Report No. 82. Kenting National Park.
6. Denniston, C. 1978. Small population size and genetic diversity implications for endangered species. Pages 281-289 in Endangered birds: management techniques for preserving threatened species, (S. A. Temple, ed.), University of Wisconsin, Madison, WI.
7. Gavin, T. 1978. Status of Columbian white-tailed deer Odocoileus virginianus leucurus: some quantitative uses of biogeographic data. Pages 185-202 in Threat ened deer, IUCN, Morges, Switzerland.
8. Gilpin, M. E. and I. Hanski. 1991. Metapopulation dynamics: empirical and theoretical investigations. Academic Press, New York, NY.
9. Hsia, L. C. 1990. Feeding behavior of deer. pp. 49-73. in 1989 Sika Deer Restoration Research Report. Conservation Research Report No. 61. Kenting National Park.
10. Kano, T. 1940. Zoogeographical studies of the Tsugitaka Mountains of Taiwan. Shibusawa Institute of Ethnographic Research. 145pp.
12. Lande, R. 1993. Risks of population extinction from demographic and environmental stochastic and random catastrophes. American Naturalist 142:911-927.
13. Leopold, A. 1949. A Sand County almanac. Oxford University Press, New York, NY.
14. Liu, H. Y. 1992. Study of the released sika deer on Green Island. East Coast Scenic Area of Tourism Bureau.

15. McCullough, D. R. 1969. The tule elk: its history, behavior, and ecology. University of California Publications in Zoology 88:1-209.
16. McCullough, D. R. 1974. Status of larger mammals in Taiwan. Tourism Bureau, Taipei, Taiwan. 36pp.
17. McCullough, D. R. 1978. Essential data required on population structure and dynamics in field studies of threatened herbivores. Pages 302-317 in Threatened deer, IUCN, Morges, Switzerland.
18. McCullough, D. R. 1985. Chemical composition and gross energy of deer forage plants on the George Reserve, Michigan. Michigan Agricultural Experiment Station Research Report 465, East Lansing, MI. 19pp.
19. McCullough, D. R. 1996a. Metapopulations and wildlife conservation. Island Press, Covelo, CA.
20. McCullough, D. R., J. K. Fischer, and J. Ballou. 1996b. From bottleneck to metapopulation: recovery of the tule elk in California. Pages 375-403 in Metapopulations and wildlife conservation, (D. R. McCullough, ed.), Island Press, Covelo, CA.
21. McCullough, D. R. and D. E. Ullrey. 1985. Chemical composition and gross energy of deer forage plants on the George Reserve, Michigan. Michigan State University Agricultural Experiment Station Research Report, 465, East Lansing, Michigan. 19 p.
22. Patel, A. D., Y-S. Lin, and H-Y. Wu. 1989. History of wildlife conservation in Taiwan. Ecology Lab, National Taiwan University, Taipei, Taiwan. 115pp.
23. Ralls, K., J. Ballou, and A. R. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conservation Biology 2:185-193.
24. Ralls, K., K. Brugger, and J. Ballou. 1979. Inbreeding and juvenile mortality in small populations of ungulates. Science 206:1101-1103.
25. Roy, M. S., E. Geffen, D. Smith, E. A. Ostrauder, and R. K. Wayne. 1994. Patterns of differentiation and hybridization in North American wolflike canids revealed by microsatellite loci. Molecular Biology and Evolution 11:553-571.
26. Ruhle, G. C. 1966. National parks and reserves for Taiwan. American Committee on International Wild Life Protection Special Publication No. 19, Bronx, NY. 77p.
27. Sampson, A. W., and B. S. Jepersen. 1963. California range and brushlands and browse plants. California Agricultural Experiment Station, Berkeley, CA. 162pp.
28. Severinghaus, L. L. 1989. Natural resources. Pages 49-127 in Taiwan 2000, The Steering Committee for Taiwan 2000 Study, Institute of Ethnology, Academia Sinica, Taipei, Taiwan.

29. Shaffer, M. L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.
30. Shaffer, M. L. 1983. Determining minimum viable population sizes for grizzly bears. International Conference of Bear Research and Management 5:135-141.
31. Su, H. J. 1985. Vegetation analysis on the native habitat of Formosan sika deer and proposal of its reintroduction area in Kenting National Park. pp. 63-101. in The 1984 annual report of the Sika Deer Restoration Study. Conservation Research Report No. 18. Kenting National Park.
32. Su, H. J. and Chen, Y. C. 1990. The effect of Formosan sika deer on the vegetation of Sheting area. pp. 18-48. in The 1989 annual report of the Sika Deer Restoration Study. Conservation Research Report No. 61. Kenting National Park.
33. Su, H. J., Yang, S. Z. and Chen, Y. C. 1989. The effect of Formosan sika deer on the vegetation of Sheting area, study on the vegetation ecology and succession. pp. 42-69. in The 1988 annual report of the sika deer restoration study. Conservation Research Report No. 56. Kenting National Park.
34. Taiwan Provincial Forestry Bureau. 1995. The third forest resources and land use inventory in Taiwan. Taiwan Provincial Forestry Bureau.
35. Wang, Y. 1985. A behavior study of Formosan sika deer. pp. 102-179. in The 1984 annual report of the Formosan sika deer restoration study. Conservation Research Report No. 18. Kenting National Park.
36. Wang, Y. 1987. Introduction to the 1985 annual report on the Formosan sika deer restoration study. Conser vation Research Report No. 38. Kenting National Park.
37. Wang, Y., Chen, S. C., Chan, S. K., Huang, C. L., and Wu, H. J. 1995. Yangmingshan National Park sika deer release study, No. 2. Yangmingshan National Park.
38. Wang, Y., Chen, H. S., Wu, H. J., and Su, M. Y. 1992. A study of the behavior and habitat utilization of the Formosan sika deer. Conservation Research Report No. 78. Kenting National Park.
39. Wang, Y., Guo, K. W., Hu, C. H., and Chen, M. T. 1994. Releasing study of the Formosan sika deer. Conserva tion Research Report No. 91. Kenting National Park.
40. Wang, Y., Guo, K. W. and Yang, M. Y. 1993. Releasing study of the Formosan sika deer. Kenting National Park.
41. Wang, Y., Su, T. H. 1994. Yangmingshan National Park sika deer release study, No. 1. Yangmingshan National Park.

42. Wu, Y. H., Liu, S. S., Hwang, H. J., Chang, T. C., Tsai, J. F. and Tsai, S. S. 1992. Medical examination and treatment of wild animals in Kenting National Park in Taiwan. pp. 32-42. in Research on the establishment of disease prevention system for sika deer released into the wild. Conservation Research Report No. 84. Kenting National Park.