

麋鹿研究与管理

MILU RESEARCH AND MANAGEMENT

中国麋鹿国际学术研讨会论文集

The International Academic Workshop Papers on Milu

(*Elaphurus davidianus*) in China

丁玉华 主编

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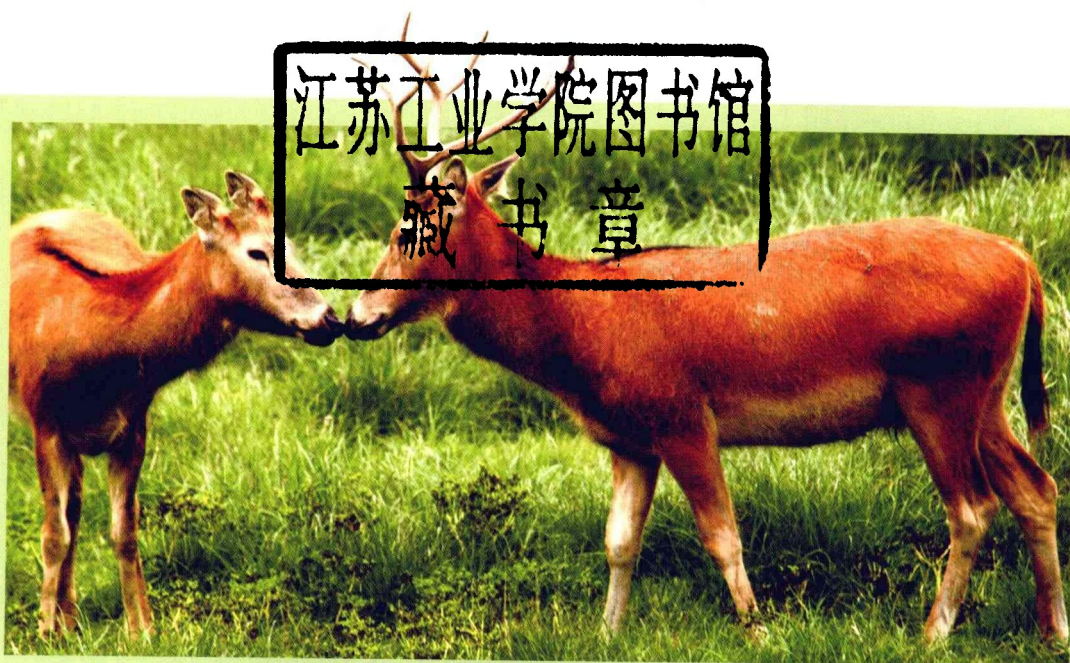
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序

为了推动麋鹿(*Elaphurus davidianus*)研究的发展,促进国内外学术交流,江苏大丰麋鹿国家级自然保护区在纪念 20 世纪 80 年代中期国家大规模启动重引进工程国际合作项目以及建区 20 周年以来取得全面胜利的凯歌声中,隆重推出两本论文集:一本是将这期间已发表的有关麋鹿的论文搜罗成集,另一本则是前不久特意邀集有关专家专为纪念活动而撰写的。承蒙保护区再三荣委为这两本论文集作序,本人虽力难胜任,但却之不恭,只得勉为其难。惟有寄语同行继往开来,在论文集所反映的成果的基础上,继续协力奋发,展望并筹划未来,让今后麋鹿研究得以更快发展,为中国和世界作出新的更大的贡献。

现代意义上麋鹿的科学研究始于 1866 年爱德华兹(Alphonse Miline-Edwards)的学术定名。但是由于清末腐败,国运衰微,列强频频掠夺,麋鹿不断流向异邦。1900 年八国联军攻陷北京时竟将我国当时惟一的南海子皇家猎苑的宝贵麋鹿群一扫而空。从此这种动物便在我中华大地上彻底绝了种,少数流入欧洲,而有幸成活繁衍的也就开始了漫长的海外“游子”生涯。因之,此后的百余年里国内研究标本缺乏,国人不可能参加什么研究工作。显然,麋鹿研究国外比国内开始得早,历时长,在个体生物学和基础研究方面占据着优势。至于国人自己投入研究,主要则是近 20 年的事,以 1985 年国家重引进重大工程启动为标志,以古今原自然栖息地群体生态生物学为特征,以自然原栖息之地为研究对象。鉴于麋鹿是个土著动物,我国在这方面的研究条件得天独厚,是国外无条件取代的,也正好弥补上了国外研究的不足。这期间国人做得十分出色,成果蔚为大观,而且边理论、边实践,取得了研究和重引进双丰收,举世瞩目。这两本论文集正是十分具体地反映了这 20 年的壮观成就。重温这 20 年来在重引进、建区、扩群、风土再驯化、回归大自然以及全国自然保护区和饲养点在数量和质量上突飞猛进的科学进展等方面节节胜利的那些激动人心的岁月,也许就能见到奋斗的足迹,触发智慧的火花,十分有利于进一步在学术的前沿开始一轮新的接力。

这两本论文集内容十分丰富翔实,文理渗透,学科交叉,古今结合,见解兼容,包含着许许多多新的发现、新的认识和新的思路。它信息量很大,是 20 年来诸位学者默默从野外到室内辛勤劳作、探索麋鹿奥秘的一笔惠泽现今和未来的庞大的精神财富。它对于麋鹿研究中应该涉及的诸多理论和实践问题均有深入而致用的论述,反映了近 20 年来中国麋鹿研究的全貌;它还包含着不少深具战略性和前瞻性的学术见解,反映了麋鹿研究的某些动态和走向。因而,这两本麋鹿研究百科全书式的论文集在今后相当长的时期内都极具重要的参考价值,可供长期使用和保存。

麋鹿是文化动物中的一个明星。麋鹿文化起源于地史和上古,贯穿到现代,资料已经比较明晰的时段就连绵至少达万年以上,经、史、子、集都有反映,其发展历久而弥新,是多地域、多层位、多方位的立体网络,在中原、齐鲁、荆楚、吴越、岭南和闽台等诸文化层里都有其闪光之处。它长期不断参与各民族文化的交融,是凝聚我海内外炎黄子孙的龙文化的极其重要、且不可或缺的有机组成部分。更可喜的是,前不久又在巴蜀文化层(化石)、三峡(化石)、东北(岩画)、西北(岩画和器物)、西南(器物)和海南岛(皮张)等地,以前曾经认为是完全不可能的地方发现到古代麋鹿存在的证据或蛛丝马迹,可见今后对麋鹿在认识上进一步丰富的前景仍然十分诱人。了解过去的优秀文化是为了创造未来的新的文化,对提高民族自尊心、自信心,

增强民族凝聚力有着不可估量的重大价值,而我国学者当继续不辱使命,责无旁贷地不断发掘探索,付出艰辛劳动,奉献自己的聪明才智。

回顾胜利起了步,并已进入快跑道的这 20 年,我国麋鹿研究日益欣欣向荣,正走向日丽中天。20 年来研究人员至少增加了数倍,论文数至少增加了数十倍。更要紧的是科研质量在快速攀升。20 年中的前 10 年,素材积累式的、跟踪他人的、短平快而追逐热点的研究短文较多;20 年中的后 10 年,特别是时至今日,综合性的、创新性的、基础性而理论和实践意义兼备的高品质、重分量的洋洋长方频频出现,而且后劲十足。可以肯定,当今我国麋鹿研究的不少方面已经能够毫无愧意地屹立于世界学术之林。依笔者知识所及,目前我国麋鹿研究正处在一个新的起点之上,方兴未艾,今后定会以加速度的方式更多更快地刷新成果纪录。也许今后一段时期,我国具规模或突破性的重大成果主要集中在保护区以外的大自然里和野生种群的恢复和研究上,集中在家养品系的研发、应用、饲养的规模化、产业化和永续利用上,集中在麋鹿的历史和文化上。这些别开生面的重大建树和成就必将不断催生和涌现系列论文和学术专著,并且必将迅速付诸科学实践和生产实践,不断造福祖国、造福全人类。

曹克清

2006 年 8 月 26 日

于上海

前言

麋鹿(*Elaphurus davidianus*)是世界上已经灭绝于野外,但被安全地保存在园囿条件下,20世纪80年代,试行在中国其原生地恢复自然种群的濒危物种。麋鹿因角似鹿、面似马、蹄似牛、尾似驴,俗称“四不像”,是一种原产于我国的世界珍稀物种。麋鹿的野生种群由于自然条件的变迁、人类的活动和自身物种特化等因素,导致其在近代野外灭绝。少数处于皇家猎苑豢养状态的麋鹿也因西方列强的掠夺,致使原本中国特有的物种在中华大地上绝迹近一个世纪。

1986年,在世界自然基金会(WWF)和中国林业部的友好合作下,成功地将39头麋鹿从英国7家动物园重引进至它们的原生地,放养在滩涂广袤、港汊遍布、树林茂盛、水草丰美的江苏大丰麋鹿国家级自然保护区。

今年是麋鹿回归原生地22周年和野生种群突破118头的特殊年头。也就是说,我国实施麋鹿的重引进项目已经有了20多年的历史。在此期间,我国麋鹿的保护和科学研究工作已取得了举世瞩目的成就。仅大丰麋鹿种群的发展而言,其数量已从当年的39头壮大到2008年的1317头,约占世界总数的33%,占中国总数的50%。我们认为,麋鹿就物种种群数量而言,已基本脱离了濒危状态。然而,麋鹿仍是一个脆弱的物种,人类社会的发展对麋鹿所产生的威胁并没有绝对消除。因此从社会意义上说,麋鹿还需要人类的呵护,否则将重蹈覆辙。

22年的实践证明,由于有效地保护了麋鹿栖息地,麋鹿在其原生地繁衍扩群,风土再驯化和野生行为重塑才取得了初步成功。特别是大丰麋鹿种群的发展速度,已位于世界之首,现已成为世界上最大的麋鹿种群,并分别于1998年、2002年、2003年及2006年成功地实施了人工有计划的野生放养试验,麋鹿在大自然中产下了纯野生麋鹿的子二代(F_2),从而结束了中国100多年以来没有野生麋鹿群的历史,为保护、发展、研究世界珍稀动物作出了重大的贡献。

麋鹿回归原生地20周年时,我们编印了《麋鹿研究与保护》论文选集,收集了20年来国内外专家、学者以大丰麋鹿群为基础,进行科学研究撰写发表的部分论文。2006年10月22~25日,在江苏大丰麋鹿国家级自然保护区召开了中国麋鹿国际学术研讨会,我们又收集了与会者提交的研究论文,编制成集,定名为《麋鹿研究与管理》,与《麋鹿研究与保护》形成姊妹集。

《麋鹿研究与管理》论文集所收集的论文内容丰富,研究方法先进而独特,古今结合,科学交叉,思路新鲜,说理性强。本论文集为今后的麋鹿保护科研工作提供了一些新的思维和认识,祈盼能起到抛砖引玉的作用。论文集中所涉及的内容时空跨度很大,具有一定的科学文化价值和珍贵的历史价值。

本论文集以江苏大丰麋鹿国家级自然保护区、北京麋鹿生态实验中心及湖北石首麋鹿国家级自然保护区的麋鹿科研成果为主线,结合国内外一些知名麋鹿专家的研究方略,将麋鹿的古生物研究与现代管理有机地融合在一起,形成了一个独特的理论体系,这将有益于人们今后对麋鹿和其他野生动物及其栖息地作进一步的保护和研究。

本论文集来稿一律文责自负。编者对所用文章在文字上作了一些润饰,排版上作了一

些调整。由于编撰时间仓促,疏漏和错误之处在所难免,敬请各位同仁批评指正,并在此向给予本论文集赐稿的各位中外专家及蒋志刚研究员、曹克清研究员、于长青教授、李春旺博士、Philippe Chouteau博士、徐惠强高级工程师、姚志刚博士、王锋教授、杨道德教授、张林源副研究员、夏经世副研究员、Maria del Mar Otero Villanueva 博士、任义军工程师、温华军先生、黎佳女士等给予的支持和帮助表示诚挚的谢忱。杨国美先生为本论文集提供了部分图片,在此一并致谢!

丁玉华

2008年5月16日

目 录

序	(1)
前言	(1)
Milu in China: Current Status and Conservation Strategies	
Jiang Zhigang Li Chunwang Yang Daode Zeng Yan Fang Hongxia	(1)
Père Armand David (1826—1900) and Milu (<i>Elaphurus davidianus</i>)	
Philippe Chouteau	(15)
Conserving Marshes in Dafeng Milu National Nature Reserve	
Maria del Mar Otero Villanueva	(20)
化石与现生麋鹿学名的归并及其汉译和英译词汇的选择以及与古名相关的麋鹿文化	
曹克清	(24)
中国上古麋鹿与东亚早期稻作渊源关系的解读	
曹克清	(34)
江苏泰州出土的麋鹿骨架研究	
汪维寅 丁玉华 钱 专 任义军 解立新	(42)
与麋鹿相关的同族汉字的剖析	
蓝之中	(59)
湖北石首放野麋鹿的现状与面临的挑战与展望	
张树苗 陈 耘 张林源 夏经世 温华军 李鹏飞	(64)
盐城海涂麋鹿潜在生境分区	
张新生 方淑波 安树青	(69)
湖北石首麋鹿种群的生境选择	
何 振 杨道德 李鹏飞	(78)
大丰麋鹿自然保护区可持续发展的问题及对策分析	
陈 勇	(87)
从古代麋鹿兴衰看今日石首麋鹿保护与利用	
李鹏飞	(93)
大丰麋鹿保护区环境质量评价与分析	
陈 勇 丁玉华	(99)
大丰麋鹿保护区生态、经济和社会效益评价	
徐安宏 陈 勇	(106)
北京南海子麋鹿保护与栖息地管理及设想	
李 坤 夏经世 王宝祥	(111)
麋鹿初生仔卧息地选择初探	
丁玉华 任义军	(116)
野生放养麋鹿栖息地选择初探	
王立波 袁国祥 侯立冰 解生彬	(122)

麋鹿野化的综述	
沈 华 解生彬 袁国祥	(126)
临安麋鹿上山行为的发现和初步研究	
丁玉华	(129)
麋鹿的发情行为与交配对策研究	
于长青 蒋志刚 冯祚建	(136)
麋鹿的警戒行为与人类干扰的关系	
李春旺 蒋志刚 汤宋华 曾 岩 徐爱春 丁晶晶	(147)
麋鹿野放初期应对环境变化的行为对策	
丁玉华 任义军 徐安宏 解生彬	(155)
南黄海湿地野生麋鹿的生存策略	
丁玉华 任义军 丁晶晶	(160)
大丰麋鹿种群动态与遗传多样性分析	
徐惠强 丁玉华	(165)
半野生状态下环境容纳量与麋鹿种群消长之间的关系	
侯立冰 丁晶晶	(170)
大丰半散养麋鹿的种群调节研究	
丁玉华 解生彬 任义军	(175)
雌性麋鹿的异常哺乳行为探析	
丁玉华	(180)
野生麋鹿产仔期活动时间分布	
任义军 丁玉华 徐安宏 解生彬	(184)
麋鹿分娩行为研究	
丁玉华 侯立冰 徐安宏 王立波	(190)
初生麋鹿体温及成年麋鹿剧烈运动后体温变化的测定	
徐安宏 丁玉华	(195)
麋鹿肝功能检测结果初报	
徐安宏 丁玉华 任义军	(199)
南海子成年麋鹿体重及体尺指标的回归分析	
钟震宇	(203)
博物馆科普工作中材料取舍与处理——以北京麋鹿苑麋鹿科普工作为例	
靳 旭	(208)
麋鹿共生动物——圣水牛在苏北平原的新发现(研究简报)	
丁玉华 任义军 汪维寅 钱 专 解立新 曹克清	(211)
首次发现野生麋鹿采食互花米草的情况报告(简报)	
丁玉华 任义军 解生彬 侯立冰	(212)
附录:与麋鹿相关的主要文献	(213)

Milu in China: Current Status and Conservation Strategies^{*}

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Abstract We first introduced the evolutionary history of Milu with stress on its extinction in wild and extirpation of captive herd in the Beijing Nanyuan Royal Hunting Garden around at the turn of the 20th century. After decades of ex situ conservation, Milu breed successfully in captivity. Milu were reintroduced into China for restoration in mid 1980s. We reviewed the status of Milu in China. Beijing and Dafeng breeding herds had been established for two decades, and sister populations in Tian'ezhou, Hubei and Yuanyang, Henan had been established with relocated Milu from the Beijing Milu Park. Milu had been also allocated to zoos, wild animal parks and nature reserves. Now, there are 53 large or small herds of Milu in the country. Nine folds of these herds have deer fewer than 25, 75.5% have fewer than 10 deer. Such small herd sizes raise question about the small effective population size and genetic health of those populations, since those herds are isolated and there are no gene exchange among them. We conduct population demographic, behavioral and genetic studies on the Milu. We summarize our findings in the paper. Finally, we discuss conservation strategies for Milu in relation to demographic and genetic management.

Key words Milu; Wetland; Genetic diversity; Rut; Ex situ conservation; Reintroduction

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中国麋鹿现状与保护策略

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摘要 麋鹿早已在野外灭绝, 19 世纪末 20 世纪初, 北京南苑皇家猎苑的最后一个圈养种群也在中国消失。本文首次介绍了灭绝压力情况下麋鹿的进化历史。迁地保护的 20 年间, 麋鹿在圈养条件下成功繁殖。在 20 世纪 80 年代, 为了恢复中国麋鹿种群, 麋鹿被先后多次再引入到国内。回顾麋鹿在中国的恢复情况, 北京和大丰繁殖种群已经建立 20 年, 通过北京麋鹿苑的重引建群先后又建立了湖北天鹅洲和河南原阳两个姊妹群。麋鹿还被分配到一些动物园、野生动物园和自然保护区。迄今为止, 中国国内共有 53 个大小不等的麋鹿群体。其中九成群体的麋鹿数量少于 25 头, 75.5% 的群体麋鹿数量少于 10 头。这种小群体引发了一些有效种群大小和群体遗传健康方面的问题, 因为那些群体是隔离的, 彼此之间没有基因交流。为此, 我们在麋鹿种群动态、行为和遗传方面开展了一系列研究工作。本文总结了我们的研究结果, 并讨论了与建群和遗传管理有关的麋鹿保护策略。

关键词 麋鹿; 湿地; 遗传多样性; 发情; 迁地保护; 再引入

Introduction

Fossils of *Elaphurus bifurcates*, *E. chinanensis*, *E. lantianensis* sp. nov. were excavated from the region east of Xi'an and south of Harbin. Modern species of the Milu (*Elaphurus*) which is called Milu in Chinese, was evolved in the Pliocene period of Tertiary, the fossils was excavated in south Japan. One million years later, it was found in Machunria in Pleistocene period (Hofmann, 2007). After last glacial period, Milu was restricted to swamp and wetland in the region east of 110°E and south of 43°N in mainland China during the Holocene (Cao, 1992; Zhou, 2007). However, the distribution of Milu shrank while population of Milu declined due to human hunting and land reclamation in the swamp areas as human population expanded in Holocene (Jiang and Li, 1999). Milu was finally extinct in the field in the late 19th century (Cao et al, 1988).

Nanyuan Royal Hunting Garden in the Qing Dynasty (1616—1911) hosted a last herd of Milu in its 200 km² hunting ground, and the landscape in the hunting garden in south suburb of Beijing was a predominant wetland of swamp, ponds and lakes where the Yongding River transected. The hunting garden had been sealed off ever since the Yuan Dynasty (1205—1368) as a royal garden. Besides Milu, many game species were also kept in the hunting

garden for the royal family. The Milu in the Nanyuan Royal Hunting Garden was “discovered” by French missionary Père Armand David during one of his field expedition who was on a religion mission in 1864. Priest Armand David was keen to natural history than his Christian mission. Perceiving the deer was an unknown species to western, he bribed the wardens for hinds and skeletons of an adult male, an adult female and a young male Milu and smuggled them to Paris in 1866, where the deer was named Milu. At the end of 19th century, the wall of the Nanyuan Hunting Garden was first destroyed by a heavy flood in the Yongding River, and then by the cannon fire of the allied foreign forces during the Second Opium War, the Milu escaped and were hunted.

Before the demise of the royal herd of Milu in the Nanyuan Royal Hunting Garden in 1900, the deer had been introduced into the United Kingdom, France and Germany. During the last decade of the 19th century, the 11th Duke of Bedford in the United Kingdom gathered all last 18 Milu in the world to form a breeding herd at the Woburn Abbey, England. Only 11 of these deer were capable of reproducing (Bedford, 1951—1952). Nevertheless, the heavily inbred Milu safely passed through the genetic bottleneck of inbreeding and adopted the vast open parkland of mid England estate (Jones and Manton, 1983).

The Woburn population continued to grow despite two world wars. At the end the WW II, the size of the Woburn Abbey herd reached 250. Since then Milu have been shipped to other zoological gardens, first to other sites in England, including the Whipsnad Wild Animal Zoo, then to other parts of the world. In the 1950's, the number of Milu reached several hundreds (Beck and Wemmer, 1983). Milu was brought to Beijing Zoo and Canton Zoo for exhibition (4 ♂ : 4 ♀) in 1950s by London Zoological Society (Wang et al., 2007).

Current Status

After decades of ex situ conservation, the species breeds successfully in captivity (Beck and Wemmer, 1983). Now, Milu has been recovered from the brink of extinction and has become an example of rescuing an endangered species (Ebenhard, 1995). Since mid 1980s, Milu was reintroduced into China. Now, the Beijing, Dafeng, Tian'ezhou and Yuanyang populations have been established. The restoration of Milu in China provides an example of restoring populations of an endangered species. Studies have been carried out on the behavior, ecology and reproduction of Milu since the reintroduction in Beijing since 1985 and in Dafeng since 1986, and in Tian'ezhou since 2001. We recorded the original herd size, number of calves born in the population, number of death in the population, calculated the density, birth rate (number of per adult hind), death rate and net population growth rate and the number of individuals shipped out to other sites from the Beijing and Dafeng Milu populations. We have been monitoring the population trend of reintroduced Milu in the Tian'ezhou, Shishou Milu National Nature Reserve. We analyzed the effects of density on the birth rates (Jiang et al., 2001). General vegetation surveys were carried out at the Beijing Milu Park, Dafeng Natural Reserve and the Tian'ezhou, Shishou Milu National Nature Reserve during the study. Status of the relocated Milu from the Beijing and Dafeng herds was investigated on site survey and by correspondence.

The first conservation reintroduction of Milu included two groups, of 20 deer (5 ♂ : 15 ♀) and 18 deer (all ♀), in 1985 and 1987 respectively. All 38 deer were donated by the Marquis of Tavistock of Woburn Abbey, England and the transportation was sponsored by the World Wildlife Fund (WWF). After a careful search and evaluation by a group of zoologists, botanists, wildlife managers and officers the relic site of the Nanyuan Royal Hunting Garden in the south suburb of Beijing was chosen as the site of reintroduction. The deer were transported to the original site of the Nanyuan Royal Hunting Garden. For the reintroduction, the Beijing Milu Park (116°03'E, 39°07'N) was created at a site located in the heartland of the original Nanyuan Royal Hunting Garden (Plate I).

Beijing Milu Park is 60 hm² in area. Annual average temperature is 13.1°C, with mean temperature of -3.4°C in January and 26.4°C in July. Average precipitation is about 600 mm. About 86% of the precipitation falls in June—September. Spring drought often retards the growth of grasses. The land was dominated by reed (*Phragmites australis*), and grasses, such as *Eleusine indica*, *Eragrostis cilianensis*, *Digitaria sanguinalis* and *Setaria viridis*. Where the grass is overgrazed, *Amaranthus roxburghianus* dominates the vegetation. Since the reintroduction of Milu till early 1990s, the deer grazed on natural vegetation in summer and autumn while they received supplementary feed in the winter in the Beijing Milu Park. However, since 1990s, climate became drier in the Beijing area. Furthermore, sand mining around the Beijing Milu Park lowered the underground water table level further. The original vegetation inside the park was damaged by over grazing and heavy droughts. The park managers started to plant artificial grasslands in the park. The deer in the park receive supplemental feeding year round (Jiang et al., 2000a).

The second reintroduction of Milu were carried out in August of 1986, organized by former Ministry of Forestry and WWF. A group of 39 Milu was selected from five Zoological Gardens in the United Kingdom, with the deer mainly from the Whipsnade Wild Animal Park. An even more extensive search which covers a vast area in eastern China for potential reintroduction site was conducted before the reintroduction. Finally, the Dafeng State-Owned Forestry Farm was chosen, where is located on the Yellow Sea coast in eastern China and was lightly populated. More important, semi-fossils of Milu have been excavated from the neighboring counties (Cao, 1992). The introduced Milu herd was transported by air and released into 3 fenced paddocks, each about 100 hm² in area. Formerly a part of the state-owned forestry farm, the area was being reserved as the Dafeng Milu Natural Reserve (33°05'N, 120°49'E) to host the reintroduced Milu. The two reintroduction sites, Nanhaizi, Beijing and Dafeng, Jiangsu are all located in the historical range of Milu (Cao, 1992).

The Dafeng Milu Natural Reserve (Plate II) is located on the coast and is 2~4 m above sea level. The area has a sub-tropic monsoon type climate. Annual average temperature is 14.1°C, with the average temperature of 0.9°C in January and 22.4°C in July. Average precipitation is 1 068 mm. About 60% of the precipitation occurs in June—September. The vegetation in the region is dominated by cogongrass (*Imperata cylindrica*), reed (*Phragmites australis*), locust false-indigo (*Amorpha fruticosa*) and locust (*Robinia pseudoacacia*) (Yu et al., 1996). The original size of the Dafeng Milu Natural Reserve was 10 km², with 3 fenced paddocks of 273 hm². The reserve purchased another 30 km² land in 1995, more than doubling its original size. In 1997, the Dafeng Milu Natural Reserve was

approved by the National Nature Reserve Commission as a National Nature Reserve. The Dafeng Milu Nature Reserve has the potential to host a large population of Milu; the reserve kept the reintroduced Milu and their offspring on its land. There were 950 Milu in the reserve in 2006. Annual average population growth rate of Milu in the reserve was 17.01%. This conservation strategy is called on site expanding strategy(Jiang et al. , 2000b).

Ultimate goal of captive breeding of endangered species by zoos and conservation centers is to eventually introduce those captive-bred animals into wild habitats to restore or to recruit wild population(Sheldon 1986, Stanley Price 1991). In 1998, the Dafeng Milu Nature Reserve released the first group of Milu into field(Plate III ; Hu and Jiang, 2002). In the field, the released deer modified the daily rhythm to adapt new environment. The coast offers them space to exhibit more behaviors, especially social behaviors. The released deer grew better in the field than those in the pen. It meant that the released deer acclimatized themselves to the surroundings in the field. In 2003, and 2006 another two groups of deer were released into the field. Now, the released deer gave birth to second generation in field. The released deer are in conflict with local community near the reserve, they started to graze vegetables and wheat in the marginal farmlands in winter. For a successful reintroduction, one should understand the spatial requirements, dietary specialization and environmental needs, such as temperature, light cycle, humidity (IUCN/SSC Re-introduction Specialist Group, 1998). Re-introduction is a multidisciplinary task, which needs the involvement of governmental natural reserve management agencies, local communities, research institutes and non-governmental organizations. We should follow the oryx re-introduction program, in which the socio-economic impacts, costs and benefits of the release program were assessed(Stanley Price, 1989). A habitat with natural or artificial boundary must be found. Otherwise, the wildlife-human conflict cannot be solved(Hu and Jiang, 2002).

The Beijing Milu Park is in the suburb of national capital with limited area and is engulfed by city development whereas the Dafeng Milu Nature Reserve is located in a remote coastal region with little human settlement, where it is possible to acquire more land for conservation. Therefore, the Beijing Milu Park while keeping a healthy nuclear breeding herd of about 100 deer at the park, it shipped Milu to other sites in east China(Yang et al. , 2007), the translocations thus reduced the grazing pressure on the park vegetation and expands the distribution range of the Milu in country. The average annual population growth rate for Milu in Beijing Milu Park from 1987—1997 was 17.3%. This conservation strategy is called artificial dispersal strategy(Jiang et al. , 2000b).

Milu of Beijing Milu Park have been relocated to the lower reaches of the Yangtze River in eastern China and Hainan Island in the South China Sea. In October 1993, a group of 30 Milu (8 ♂ : 22 ♀) arrived and was released in a paddock on a small peninsular in the Yangtze River, Tian'ezhou(29°49'N, 112°33'E). This site was then established as the Tian'ezhou Milu Nature Reserve in 1993. The size of the reserve is 11.67 km² with average altitude of 35m. Another group of 34 Milu (10 ♂ : 24 ♀) was transferred from the Beijing Milu Park to the paddock of Tian'ezhou in the following year to enlarge the population. These 30 Milu (15 ♂ : 15 ♀) were released into the paddock of the reserve in 2002.

The Tian'ezhou Milu Nature Reserve is located on a peninsular by the Yangtze River

(Plate IV). South of the reserve is the dyke of Yangtze River and east of the reserve is a “U” shaped old riverbed of Yangtze River, which is about 1.5 km wide and 21 km long. Water table in the old riverbed increases during the summer flood season. The land of the reserve is flat, the elevation of the highest place is 38.44 m whereas the lowest point is 32.91 m. The climate is subtropical monsoon-type in the lower reach of the Yangtze River drainage, where is much humid and warmer than that in the Beijing region. Average annual temperature is 16.5°C, mean temperature is 3.5°C in January and 28.5°C in July, annual precipitation is about 1 200 mm in the reserve. Important vegetation types in the reserve are wetland woods which is primarily *Populus nigra* var. *italica*, *Phragmites communis*, and *Salix matsudana*, *Phragmites communis* and *Miscanthus floridulus*, *Cynodon dactylon*, *Leonurus artemisia*, *Scirpus triquetra* Community, *Scirpus yagarna* and *Eleocharis acicularis*. The re-relocated Milu have green forages in the reserve all year round. They graze 129 grasses, sedges, legumes and forbs (Yang et al., 2002; Yang et al., 2005). The relocated deer reproduced in the second year after the relocation (Yang et al., 2002).

Until the end of calving season of 2006, there were 522 Milu in the Shishou Nature Reserve. Annual average population growth rate was 22.2%. The growth of the Milu population was fit with the equation: $N_t = 84e^{0.226t}$; the sex ratio was 1 : 1.22 (♂ : ♀) before the calving season of 2006. The birth rate and population growth rate in the Shishou Milu National Nature Reserve were significantly higher whereas the mortality rate was significantly lower than those of the Dafeng Milu National Nature Reserve. Even though, Milu population started to show a density-dependent pattern (Yang et al., 2007).

In November, 2002, 30 Milu (14 ♂ : 16 ♀) from Beijing Milu Park and 20 Milu from the Dafeng Milu Nature Reserve were introduced to Yuanyang Forestry Farm, Henan (Plate V). Those Milu free range in a enclosure on the Yuanyang Yellow River Nature Reserve (35°11'N, 114°15'E). The reserve is located in the northern temperate zone, climate type is continental monsoon type weather, annual sunny hours are 2 354.5 hours, and annual precipitation is 571.7 mm. The Yuanyang Yellow River Nature Reserve is located on the northern bank of Yellow River. Dominant vegetation in the area is artificially planted Japanese pagoda (*Sophora japonica*) forest. There are plenty of grasses in the forest for the deer, but the deer receive supplementary feeds in winter and early spring. In 2006, there were 53 Milu in the paddock of Yuanyang Yellow River Nature Reserve, however the sex ratio was predominately male biased (38 ♂ : 15 ♀) (Li et al., 2007).

Milu is relocated to zoos, wildlife parks and Nature Reserves in the country. Now, there are 53 large or small herds of Milu in the country. Nine folds of them have fewer than 25 deer, 75.5% have fewer than 10 deer (Yang et al., 2003). Such a small herd size raises questions about the effective population size and health of population genetics, since those herds are isolated and there is no gene exchange. The artificially dispersed Milu herds are similar to a meta-population. The viability of the meta-population depends on the man-made gene exchanging process by the managers.



Plate I A Milu stag with a harem in the Beijing Milu Park in 1996

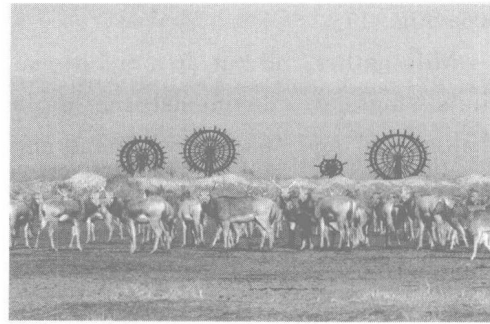


Plate II A Milu herd in the Dafeng Milu National Nature Reserve



Plate III Rewild Milu in coast of Yellow Sea, Dafeng



Plate IV Milu in Tian'ezhou Milu Nature Reserve, Shishou



Plate V Relocated Milu in Yuanyang Yellow River Nature Reserve, Yuanyang

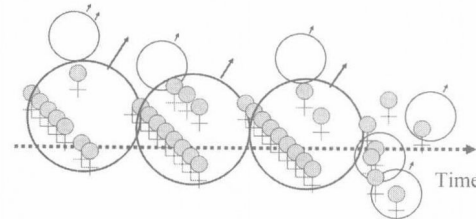


Fig. 1 Sequential harem mating system in Milu(Jiang et al. , 2006)

Behavior and Genetic Diversity

Milu has a harem defending mating system—a type of polygamy(Jiang et al. , 2004). One to several stags rut at a particular time(Li et al. , 2001). Dominant stag defends the receptive female herd and monopolizes the opportunity of mating. After one to several weeks, a second stag will rut and challenge the dominant stag that is exhausted by the energy-consuming activities in the near fasting status during the rut. The new dominant stag replaces the former reproductive herd master. Such a process may be repeated three to five times through the reproductive period. During the reproductive season, normally several adult stags rut at one time, most of the stags stay the bachelor group(Jiang et al. , 2004). The phenomenon was also reported by Liang et al. (1994). We term this phenomenon as “sequential polygamous dominance” or “sequential harem mating system”(Jiang et al. ,