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POPULATION GENETICS AND DEMOGRAPHY OF THE DOMESTIC CAT (FELIS CATUS L.: CARNIVORA, FELIDAE) IN THAILAND

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INTRODUCTION

Like their wild relatives, indigenous breeds of domestic animals are part of a nation's biological and cultural heritage. Thailand is rich in both wild (LEKAGUL & MCNEELY, 1977) and domestic members of the cat family (Carnivora: Felidae). It is feasible to survey domestic cat populations and to measure the frequencies of mutant alleles because domestic cats are abundant animals closely affiliated with human populations. Their genetics are simple and well-understood (ROBINSON, 1977). Domestic cat populations have been surveyed in many localities in Europe, North Africa, North America (TODD, 1977a), and Asia (AHMAD, BLUMENBERG & CHAUDHARY, 1980). Results of these surveys suggest that cats were domesticated in South Asia before they were domesticated in Egypt (AHMAD, BLUMENBERG & CHAUDHARY, 1980) and that human trade and migration, particularly oceanic trade, is the primary means of dispersal for the domestic cat. Data on current-day cat populations can be used to reconstruct the history of human movements and of ancient civilizations.

The domestic cats of Thailand are world-famous. At least three indigenous breeds are known. These three breeds (the Si Sawaat, Gow Thom and Thong Daeng), as well as many other kinds of domestic cats, are illustrated in the ancient Cat-Book Poems (Ayuddhaya period?) (Manuscripts Section, National Library, Bangkok). Cat books similar to

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these are also known from China (TORRANCE, 1926). The Chinese books, like the Thai books, place great value on cats of certain coat colors, and particularly on cats with clear golden yellow eyes. In western China, which includes part of the original homeland of the T'ai people, veneration of the cat, primarily for practical but also for aesthetic reasons, has represented a salient cultural element (TORRANCE, 1926) reminiscent of the significant recognition given to the cat by Thai culture. The lowland T'ai ("Pai-i") rice farmers of Yunnan are the only one of Yunnan's many native peoples known to keep cats on a regular basis (LIN, 1944). Therefore, it is possible to envisage early domestication of the cat from native Felis libyca or F. silvestris (POCOCK, 1951) by lowland T'ai rice farmers, somewhere in the fertile valleys that stretch from present-day Northern and Northeast Thailand through Northern Laos, the Shan State, and Yunnan to Szechwan. This area, the traditional T'ai homeland, is inhabited by some of the world's most remarkable wildlife (Boonsong & MCNEELY, 1977; PEN, 1962; SHELDON 1975; VAURIE, 1972) and is the earliest known site of domestication for many species (REED, 1977). That a sophisticated culture of T'ai speakers, based on lowland rice farming and relying on the domestic cat for protection of stored rice, silk, and paper against rodents, once extended across this vast area is a historical speculation that can only be proved or disproved by additional research. The geographical distribution of mutant alleles in the domestic cat can aid substantially in testing this hypothesis. Should the population genetics of Thailand's cats, especially the geographical distributions of the mutant alleles that characterize Thai breeds, indicate northern affinities and an ancient origin, this speculation would gain empirical support. For this reason we conducted surveys of domestic cats in North (Chiang Mai, Nan, Mae Hong Son) and Northeast (Loei, Nong Khai) Thailand.

MATERIALS AND METHODS .

Domestic cat survey methods are straightforward. Visual inspection of a cat at moderately close range (ca. 1 m) is sufficient to determine its phenotype with respect to 5-10 alleles that determine the cat's coat color and pattern. The cat need not be taken or tested at all. A sample of 100-200 cats per locality provides reliable statistical estimates of mutant

allele frequencies. To survey the cats of a locality in Thailand (city street, village, or wat) we found it most convenient to visit each household or building in turn. We explained the purpose and methods of our survey. We then asked to see any cats present in the place. This method also yielded estimates of the frequency of cat-owning households.

The following loci (ROBINSON, 1977) were scored: o, O (sex-linked orange), A, a (nonagouti), t^A , t^+ , t^b (tabby), D, d (dilute), L, l (long hair), S, s (piebald spotting), W, w (dominant white), B, b (brown), and C, c^b , c^s (albino). Length of the cat's tail was recorded using a fractional scoring system (full length, 3/4 length, 1/2 length, 1/4 length, no tail) and the presence of any kinks in the tail likewise recorded whenever possible.

These alleles include those responsible, so far as is known, for the characteristic phenotypes of the indigenous domestic cat breeds of Thailand. The Si Sawaat, a solid color ("self"), silvery blue cat, is homozygous for mutant alleles at three loci, namely nonagouti, dilute, and brown. Its genotype at these loci is aa, dd, bb (although some other kinds of cats are also termed "Si Sawaat" by the uninitiated). The effect of the brown allele in a dilute (dd) cat is to give the cat's coat a light silvery-grey color. A cat having only aa dd would be dark grey or slate grey. The breed commonly called "Siamese" in the West is aa cs cs, with various genotypes at the (B, b) and (D, d) loci accounting for the different colored "points." The "Burmese" is cbcb. Other present-day Thai cat breeds are the very dark brown, bb cat (Thai name not known) and the copper-colored Thong Daeng (bbcbc^s or bbc^bc^b or B-c^bc^s?). By scoring these alleles and the others cited we could accurately plot the geographical distribution of mutant alleles found primarily in Thailand, as well as mutant alleles with a cosmopolitan distribution such as O, a and S.

House-to-house surveys were conducted successively in Nan, Loei, Nong Khai, and Mae Hong Son in March and April, 1979. Cats were seen by chance in Bangkok and in Chiang Mai. (FAGEN, 1978b previously surveyed cats house-to-house in Chiang Mai.) These additional data augmented previously-reported results from Chiang Mai (FAGEN, 1978b) and Bangkok (FAGEN, 1978b; SALITERNIK, 1977) and "South China coast" (Hong Kong, Macau) surveys by the senior author (unpub).

Data were analyzed and allele frequencies estimated using standard methods of population genetics (AHMAD, BLUMENBERG & CHAUDHARY, 1980). Degree of piebald spotting was scored using DREUX's (1968) scale. Tail phenotypes were scored as "normal" and "mutant" (short and/or kinked, corresponding to grades K1, K2 and K3 of SEARLE, 1959). "Mutant" tails were further subdivided into "short" (K2, K3 of SEARLE, 1959) and "kinked" categories. Only one cat per household was included in the calculations of allele frequencies in order to minimize inclusion of closely related animals which would violate the assumption of independence used in the statistical methods for calculating allele frequencies and testing for panmixia. All statistical tests used an 0.01 level of significance. This criterion was employed because of the large number of tests performed on the data.

RESULTS

Population genetics. In all cases, analysis of phenotypes at the orange locus, assuming a 1:1 sex ratio (ROBINSON & SILSON, 1969), indicated panmixia (Table 1). In particular, no significant deficiency (or excess) of the tortoiseshell phenotype was found. At the piebald locus (Table 2), panmixia was demonstrated for all localities except Bangkok, where the data indicated an apparent excess of the highest grades of piebald spotting (equivalently, a deficiency of the middle grades) (Tables 3, 4). The lowest grades of piebald spotting were most frequent in all localities surveyed (Table 2). Average grades of piebald spotting ranged from 3.4 (Chiang Mai) to 4.6 (Bangkok) (Table 5). Table 6 presents observed phenotype frequencies corresponding to six coat color loci (agouti, tabby, dilute, dominant white, albino, and brown). Mutant tail phenotype observations are presented in Table 7, and the frequencies calculated from these observations in Table 8. Tables 9 and 10 present mutant allele frequencies calculated from data of Tables 1, 2, 6 assuming panmixia.

Loei, Nan, and Nong Khai survey results did not differ to a statistically significant degree at any locus. These three localities all lie on the western edge of Isan, the northeast region of Thailand, and will be referred to collectively as "West Isan." Pooled observations for "West Isan" yielded the allele frequency estimates of Table 1. Panmixia tests on these combined

data were satisfactory (Table 12). The apparent location of the homozygoteheterozygote boundary at the piebald locus, as indicated by chi-square signifibance tests, varied among locations: between S4 and S5 for Mae Hong Son, between S5 and S6 for Chiang Mai and "West Isan", and between S8 and S9 for Bangkok (Tables 3, 4, 12). Coefficients of (phenotypic) darkness BLUMENBERG & TODD, 1978; TODD, 1969) were calculated (Table 13). These coefficients ranged from 0.33 (Mae Hong Son) to 0.53 (Chiang Mai). Results of the Thailand surveys are compared with other domestic cat population genetics data from the Indian Ocean region and from East Asia in Table 14.

Demography. The numbers and frequencies of households and wats surveyed that included at least one cat are presented in Table 15. Cat ownership in Thailand varied from 33%-47% of all households in large towns and cities. Ownership exceeded 25% in every locality surveyed with the exception of two lowland villages in Mae Hong Son province. Most catowning households contained one or two adult cats (Table 16). The average number of cats (including kittens) per cat-owning household varied from 1.1 (Chiang Mai) to 2.0 (Mae Hong Son) (Table 17). As indicated by the data of Table 18, many cats were seen with kittens, especially in Nan. Table 19 summarizes the demographic data obtained.

DISCUSSION

The cultural history of Thailand indicates long, close affiliation between cats and humans. Evidence for this history includes a remarkable corpus of ancient Thai cat poems and paintings (FAGEN, 1978a), notable tolerance of cats in traditional Thai village life (TAMBIAH, 1969), and several cherished and uniquely Thai breeds of cats, including the Si Sawaat ("Korat"), the Thong Daeng ("Copper"), and the "Siamese" (FAGEN, 1978a). Our ownership data indicate a high frequency of cat ownership in Thailand as compared with the West (e.g., TODD, 1977b). However, the average number of cats per cat-owning household appears to vary little if at all between Thailand and the West (compare TODD, 1977b).

Thailand, long isolated from the West; has a history of political, trade, and cultural contact with its immediate neighbors, present-day Laos, Malaysia, Cambodia, and Burma. Active long-distance trade with other

Asian countries occurred along Indian Ocean and China Sea routes and by overland caravan. Sea trade occurred primarily with India and China, but pottery from Thailand has also been found farther west, particularly in Iran and in the Levant (D. GIBSON, pers. comm.). The distinctness of Thailand's cat populations must be evaluated against possible influences from Indian Ocean trade.

A typical genetic profile for domestic cats of the Indian Ocean region may now be provisionally defined, based on results of cat surveys from Ahwaz and Karachi in the west to Singapore in the east. Additional evidence is offered by the South China coastal populations of Hong Kong and Macau, which undoubtedly reflect the influence of Indian Ocean trade.

The data of Table 14 suggest a smooth frequency gradient in the orange allele, from Mishima, Japan (.39) down the south China coast (.38) to Singapore (.32), Karachi (.26), and Ahwaz (.21). The values for two Indian Ocean islands, Seychelles (.28) and La Réunion (.25, small sample) are consistent with this picture. Indian Ocean coastal nonagouti frequencies are generally low (.45 to .58). Abyssinian and blotched tabby are both present (t^A absent from Ahwaz, the westernmost site, but present in Karachi; AHMAD, BLUMENBERG, and CHAUDHARY, 1980). Frequencies of the dilute allele are low (.09-.13), long hair is absent, and piebald is frequent (.41-.50).

In sharp contrast to these values are those for two northern Thailand cat populations, Chiang Mai and "West Isan." (Mae Hong Son, with closer historical links to Burma and India than to Thailand, will be discussed separately). The frequency of orange decreases from south to north in Thailand (Singapore, .32; Bangkok, .30; "West Isan", .26; Chiang Mai, .28). Nonagouti frequency increases from south to north (Singapore, .60; Bangkok, .75; "West Isan", .75; Chiang Mai, .86). Blotched tabby is absent, Abyssinian tabby decreases from south to north (Singapore, .24; Bangkok, .04; Chiang Mai, .02; "West Isan", .003). The frequency of dilute increases sharply from south to north (Singapore, .13; Bangkok, .13; Chiang Mai, .34; "West Isan", .34). Piebald is unexpectedly low in Bangkok but decreases from .50 (Singapore) to .38 (Chiang Mai) and .41 ("West Isan"). Of particular interest are the mutant alleles at the albino and brown loci.

Siamese (C^s), present at trace frequencies in Islamabad and Quetta, Pakistan (AHMAD, BLUMENBERG, and CHAUDHARY, 1980) was observed near Penza, Russia in 1793 ((FAGEN, 1973), is absent from Hong Kong and Macau, and increases in frequency from south to north in Thailand (Singapore, .13; Bangkok, .19; Burmese (Cb) frequency increases in "West Isan", .28; Chiang Mai, .35). parallel with that of C^S. Brown (B), present on the South China coast, reaches high frequencies in Chaing Mai (.45) and "West Isan" (.83). The frequencies of mutant tail phenotypes in Thailand are lower than those observed in Singapore (.65) and in Mishima (.82) but higher than that for the South China coast (.22). In summary, cat populations of northern Thailand differ from those of Indian Ocean ports in that Thailand cats exhibit higher frequencies of a, d, b, c^b, c^s; they also exhibit lower frequencis of O, t^A, S, and of mutant tail phenotypes. Unfortunately, it is not possbile to speculate about Chinese influences on Thailand cat populations, but the high frequancies of O and a reported for Mishima suggest two possible characteristics of the East Asian background.

Data on piebald spotting further indicate contrasts within Thailand. For Bangkok, the data of Table 2 yield the unusual result that the best-fitting boundary between Ss and SS lies between S8 and S9-a pattern previously known only from the Seychelles (AHMAD, BLUMENBERG, and CHAUDHARY, 1980). The other piebald spotting results are more consistent with results from elsewhere in Asia, indicating boundaries for best fit between S4-S5 or S5-S6.

Despite its apparent proximity to Chiang Mai and the North, Mae Hong Son is a distinct phenomenon. Until recently, Mae Hong Son was only accessible by caravan, or, in the wet season, by boat from the Salween River Valley in Burma. Thailand's highest mountains separate Mae Hong Son province from the remainder of the nation. The cat population of Mae Hong Son diverges from other Thailand cat populations and towards Indian Ocean values for O, a, and c^{s} . However, d is unexpectedly high. In addition, t^A achieves its highest Thailand frequency observed (east to west gradient: "West Isan" .003, Chiang Mai .02, Mae Hong Son .13). Appropriately, the cb ("Burmese") allele also achieves its highest observed Thailand frequency, .15, in Mae Hong Son ("West Isan" .06, Chiang Mai .02). Finally, mutant tail phenotypes are relatively uncommon in Mae Hong Son (.08, lower than any other value observed for Thailand).

The mutant alleles whose frequencies exceed Indian Ocean values are also those that characterize the most cherished Thai cat breeds. Speculatively, cb appears to have spread from western Thailand or the Shan State, cs and b from the Northern Thai-Lao kingdoms of Chiang Mai, Chieng Saen, Nan, and Luang Prabang, and b from the upper Mekong Valley. The dilute (d) allele may have a broader focus across the North from the Shan State to Laos. These distributions coincide with a long history of agricultural civilization in the upper Mekong valley (REED, 1977), including rice culture and sophisticated pottery making as early as 6000 B.P. Cats may have been welcomed by humans who stored rice, silk, and paper. (Cats do not necessarily control the numerical growth of rodent populations. They can control damage to human valuables by affecting rodent activity, distribution, microhabitat selection, or time budgets). However, Ban Chiang, a meticulously excavated 8,000-year old archaeological site in northeast Thailand, which has yielded identifiable bones of hundreds of mammal species including wild and domestic canids, small wild felids, and some of the earliest domestic artiodactyls known from Asia, yields no archaeological evidence of the domestic cat (KIJNGAM, 1979). It is not known why domestic cat bones are absent from the Ban Chiang material identified to date.

Additional information on cats of northeast Pakistan (AHMAD, BLUMENBERG, & CHAUDHARY, 1980) and western China TORRANCE, 1926) lends support to the hypothesis that Thailand's cat populations, although influenced by Indian Ocean and China Sea oceanic trade and by Inner Asian overland trade, are distinct from other known cat populations. AHMAD, BLUMENBERG & CHAUDHARY (1980) compared preliminary survey results from Thailand (FAGEN, 1978b) with genetic profiles of other Asian cat populations using Nei's measure D of genetic distance. Bangkok and Chiang Mai exhibited close genetic affinities to several localities in northeast Pakistan, particularly to Lahore. Lahore, like Chiang Mai, shows frequencies of nonagouti and dilute that exceed corresponding Indian Ocean coastal values. Presumably, these relatively high frequencies of nonagouti and dilute represent a common Inner Asian background. However, Chiang Mai's frequencies of these two alleles exceed the corresponding Lahore values. It may also be that Lahore's high frequency of blotched tabby reflects Lahore's relative proximity to the apparent focus of this allele in Iran.

TORRANCE (1926) reviewed the history of Chinese cats in their cultural context, with particular reference to western China. In Szechwan, a larger variety of colors is seen than "at home" (meaning England, presumably): "blacks, whites, yellows, natural greys, light greys, dark greys, slates, etc." Prized colors or combinations thereof include "a pure colour of any kind" (aass), "a white throat and breast with a black neck and back" (aa S1-3), and a phenotype "when the colour from a distance shows to be one, but when nearer there appears a faint variation of brownish stripes" (t^A or cs?)-"True tortoise-shell cats are few and hard to find; the black, white, and yellow colours are very often mixed with patches of wild grey. When found they are greatly prized."

Tail phenotypes are valued when the length of the tail matches the length of the body up to the neck. "A long, fine tail is thought to be ideal." "In the best sort, the bones of the tail are not perfectly round but slightly flat."

"Persian, Angora, Chartreuse, Manx or Siamese breeds" are reportedly unknown to the Chinese in Szechwan, although the writer observed one long haired cat, presumably from the north, in Chengtu. It is not clear whether the writer was referring solely to fancy cats.

The cat coat and tail phenotypes that TORRANCE reported as being of value in Szechwan closely parallel those featured in the ancient Thai *Cat-Book Poems* (FAGEN, 1978a). This resemblance extends even to the common preference for a golden eye color. Ten of the seventeen valuable cats portrayed in the *Cat-Book Poems* have yellow or gold eyes. The poems that accompany these portraits state "Her eyes are like gold dust set with topaz," "Her eyes are the color of the yellow chrysanthemum," "Her eyes are like the dew when dropped on the leaf of the lotus." Compare the reported Chinese preference for eyes "as yellow as gold and as clear as silver with the brightness of sparkling water" (TORRANCE, 1926).

Evidence of various kinds, as reviewed above, clearly suggests two fundamentally distinct genetic profiles for the domestic cat in Asia. The first profile is characterized by low mutant allele frequencies and close genetic affinities to the wild type (e.g., Ahwaz, Quetta, Trabzon). The

second is characterized by high mutant allele frequencies, particularly O, a, and d, (e.g., Chiang Mai, Lahore, "West Isan"), by the absence of *I*, and perhaps by the presence of rare alleles of presumed East or Southeast Asian origin (e.g., b, c^b, c^s). The Indian Ocean populations bear witness to the mixing effect of oceanic trade routes that facilitate dispersal of cats over long geographic distances (TODD, 1977a).

A measure of the degree of differentiation of a cat population is its genetic distance from the wild type, as plotted in Figure 1. The northern extent of the contours plotted is uncertain, but the figure clearly shows that the domestic cat populations of Chiang Mai, West Isan and Lahore have diverged greatly from the wild type and that the focus of differentiation appears to coincide with the mountainous backbone of Asia as well as with well-known overland trade routes. Even on the basis of the relatively limited data available, the transition from east-west to north-south contours in western China is clearly marked, as is the Indus Valley separating the Hindu Kush and the Karakorams from the Great Himal. The focus of greatest differentiation appears to extend north from Chiang Mai into western China. Had two additional loci (brown, albino) been included in the calculations on which this figure is based (they were not), the uniqueness of cat populations in the old kingdoms of Northern Thailand would have shown up even more strikingly. Of interest in this context are reports (cited above) of the "Siamese", cs allele at low frequencies in Islamabad, Quetta; and Penza. Data from western China (especially Yunnan and Szechwan provinces), Laos, and Shan State are needed to complete the picture suggested by the limited information presently available.

AHMAD, BLUMENBERG, & CHAUDHARY (1980) speculate that the cat may have been domesticated in southwest Asia as early as 6000 B.P. Possibly domestication could have occurred all along the fringe of Inner Asia, wherever *F. libyca*, *F. silvestris* and *F. bieti* came in contact with early agricultural civilizations. None of these three species presently range into Southeast Asia, where the small felid niche is occupied in the wild by the unrelated *Prionailurus bengalensis*. To my knowledge, there is no direct evidence that *P. bengalensis* was ever domesticated. The origin of Thailand's domestic cats was presumably exogenous, either China or the Indian subcontinent,

at a date sufficiently early to permit Thailand to become the focus for at least four separate mutant alleles-d, b, c^b, and c^s. This multiple focal pattern is unique, so far as is known. Surveys of domestic cat populations in Japan, Taiwan, Burma, and mainland China, as well as perusal of the unique historical record of cats in Asian visual art, should shed additional light on the history of Asian domestic cats.

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Table	1.	The test for p	panmixi	a at the orange	locus.		
Bangko	k			Chian	ng Mai		
	0/?	0/+	+/+		0/?	0/+	+/+
Obs.	42	52	133	Obs.	27	45	102
Pred.	44	48	135	Pred.	31	35	107
. 24	X ² :	= 0.4 on 1 d.f			$X^{2} = 3$	3.6 on 1 d.	f.
Hong K	Long			Loei			
	0/?	0/+	+/+		0/?	0/+	+/+
Obs.	52	45	93	Obs.	9	20	58
Pred.	52	45	93	Pred.	12	15	60
	X ²	= 0.0 on 1 d.f	Mac l		$X^2 = 2$	2.5 on 1 d.	f
Macau				Mae	Hong Son		
	0/?	0/+	+/+		0/?	0/+	+/+
Obs.	58	38	117	Obs.	18	34	102
Pred.	52	49	111	Pred.	22	27	105
	X ²	= 3.5 on 1 d.f			$X^2 = 2$	2.6 on 1 d.	f.
Nan				Nong	Khai		
	0/?	0/+	+/+		0/?	0/+	+/+
Obs.	12	29	74	Obs.	25	35	82
Pred.	16	20	78	Pred.	28	- 30	84
	X2	= 5.3 on 1 d.f	Pred.		$X^2 =$	1.2 on 1 d.	f.

Table 2. Phenotypic observations at the S locus.

Population	++	S1	S2	S3	S 4	S5	S 6	S7	S8	S9
Nan .	45	11	10	10	16	8	4	3	6	2
Loei	22	8	11	10	12	9	6	3	3	3
Chiang Mai	71	47	10	8	9	15	12	5	3	7
Mae Hong Son	59	17	16	16	24	6	3	2	3	4
Nong Khai	51	13	15	13	16	10	6	3	4	9
Bangkok	110	28	7	7	7	19	5	7	17	13
Hong Kong	47	23	22	16	15	12	7	4	6	5
Macau	61	32	24	20	24	13	9	5	7	8

 Table 3. The test for panmixia at the piebald spotting locus, assuming homozygote-heterozygote boundary between S4 and S5.

Nan				Loei			
	++	S1-4	S5-9		++	S1-4	S5-9
Obs.	45	47	23	Obs.	22	41	24
Pred.	46	54	16	Pred.	22	44	22
	$X^2 = $	4.0 on 1 d.f.			$\mathbf{X^2} = 0$.39 on 1 d.	f.

Chiang Mai

	++	S1-4	S5-9
Obs.	71	74	42
Pred.	72	88	27
	$X^2 = 1$	10.5 on 1 d.	.f.

Mae Hong Son

	++	S1-4	S5-9
Obs.	59	73	18
Pred.	59	70	21
	$X^{2} = 0$.56 on 1 d.f.	limit

Nong Khai

	++	S1-4	S5-9
Obs.	51	57	32
Pred.	50	67	22
	$X^{2} = 0$	5.0 on 1 d.f	

Bangkok

	++	S1-4	S5-9
Obs.	110	49	61
Pred.	111	91	19
	$\mathbf{X}^2 = 1$	12. on 1 d.f	

Hong Kong Macau S5-9 S5-9 ++ S1-4 S1-4 ++ Obs. 47 76 34 Obs. 61 100 42 47 78 Pred. 32 Pred. 61 100 42 $X^2 = 0.18$ on 1 d.f. $X^2 = 0.0$ on 1 d.f.

Table 4. The test for panmixia at the piebald spotting locus, assuming
homozygote-heterozygote boundary between S5 and S6.

Nan				Loei			
	++	S1-5	S6-9		++	S1-5	S6-9
Obs.	45	55	15	Obs.	22	50	15
Pred.	46	54	16	Pred.	22	44	22
	$X^2 =$	0.06 on 1 d.	f.		$X^2 =$	3.04 on 1 d.f.	
Chiang	Mai			Mae I	Hong S	on	
	++	S1-5	S6-9		++	S1-5	S6-9
Obs.	71	89	27	Obs.	59	79	. 12
Pred.	72	88	27	Pred.	59	70	21
	$\mathbf{X}^2 =$	0.02 on 1 d.	f.		$\mathbf{X}^2 =$	5.0 on 1 d.f.	
Nong F	Chai			Bangko	ok		
	++	S1-5	·S6-9		++	S1-5	S6-9
Obs.	51	67	22	Obs.	110	68	42
Pred.	50	67	22	Pred.	111	91	19
	$\mathbf{X}^2 =$	0.02 on 1 d.	.f	$X^2 = 33.6$ on 1 d.f.			
Hong K	Long			Macau			
	++	S1-5	S6-9		++	S1-5	S6-9
Obs.	47	88	22	Obs.	61	113	29
Pred.	47	78	32	Pred.	61	100	42
	$X^2 =$	4.4 on 1 d.f			$X^2 =$	5.7 on 1 d.f.	
							Julian 12

Table 5. Average	degree of piebald s	potting.		
	All cats (ss $= 0$)	18 .	I	Piebald cats
Bangkok	2.3			4.6
Chiang Mai	2.1			3.4
Hong Kong	2.9			4.2
Loei	3.0			4.0
Macau	2.6			3.6
Mae Hong Son	2.1		·17. 24	3.5
Nan	2.4			3.9
Nong Khai	2.6			4.1

Table6.Observed coat color phenotypic frequencies in cat populations
of Thailand, Hong Kong, and Macau.

Bangkok

	aa	102	tA	9	dd	4	+	230	C ^S C ^S	8	bb	-
	+	78	tb	0	+	220	W-	3	c ^b -	1	+	-
			+	119					+-	219		
Chiang M	ai											
	aa	103	tA	4	dd	19	+	180	c ^s c ^s	23	bb	3
	+	39	tb	0	+	149	W-	2	c ^b -	3	+	12
			+	76					+-	161		
Hong Kon	ng											
	aa	30	tA	42	dd	0	. +	190	C ^S C ^S	0	bb	1
	+	109	tb	35	+ ·	190	W-	0	c ^b -	0	+	23
	•		+	72			n in		+-	190		
Loei												
	aa	52	tA	0	dd	8	+	87	C ^S C ^S	5	bb	14
	+	25	t ^b	0	+	78	W-	0	c ^b -	3	+	10
			+	37					+-	77		
Macau												
	aa	30	tA	66	dd	. 0	+	213	C ^s C ^s	0	bb	2
	+	121	tb	25	+	213	W-	2	c ^b -	0	+	30
			+	75					+-	213		
Mae Hong	g So	n										
	aa	62 -	tA	21	dd	24	+	155	c ^s c ^s	1	bb	9
	+	72	t ^b	0	+	127	W-	3	c ^b -	7	+	11
ates lunds			+.	66					+-	120		
Nan												
	aa	53	tA	1	dd	9	+	117	cscs	3	bb	14
	+	50	tb	. 0	+	105	W-	2	c _p -	8	+	5
			+	67					+-	92		
Nong Kha	ii											
	aa	62	tA	0	dd	22	+	145	c ^s c ^s	18	bb	19
	+	52	tb	0	+	122	W-	0	c ^b -	1	+	6
			+	84					+-	120		

			Mutant	
	N	Short	(Short and/or kinked)	Normal
Bangkok	93	44	47	46
Chiang Mai	162	31	50	112
Hong Kong	175	39	43	132
Loei	79	23	31	48
Macau	187	33	36	151
Mae Hong Son	159	8	15	144
Nan	105	25	50	55
Nong Khai	135	44	55	80

Table 7. Frequencies of tail phenotypes observed.

Table 8.Tail phenotypic frequencies in cat populations of Thailand,
Hong Kong, and Macau. Other Asian cat populations listed
for comparative purposes.

	Short tail	Mutant (Kinked and/or short) tail
Bangkok	.38	.51
Chiang Mai	.19	.31
Hong Kong	.22	.24
Loei	.29	.39
Macau	.18	.19
Mae Hong Son	.05	.09
Nan	.24	.48
Nong Khai	.33	.41
Mishima		.82 (Searle 1959)
Singapore	.34	.65 (Searle 1959)

	N	<u>0</u>	a	<u>t</u> ^A	<u>t</u> b	d	1	<u>s</u>	W	b	<u>c</u> b	<u>c</u> ^s
Bangkok	233	.30 (<u>+</u> .04)	.75 (<u>+</u> .02)	.04 (<u>+</u> .01)	0	.13 (<u>+</u> .03)	0	.30 (<u>+</u> .02)	.006 (<u>+</u> .004)	?	.01 (<u>+</u> .03)	.19 (<u>+</u> .03)
ChiangMai	182	.28 (<u>+</u> .05)	.86 (<u>+</u> .02)	.02 (<u>+</u> .01)	0	.34 (<u>+</u> .04)	0	.38 (<u>+</u> .03)	.006 (<u>+</u> .004)	.45 (<u>+</u>)	.02 (<u>+</u> .03)	,35 (<u>+</u> .04)
Hong Kong	190	.39 (<u>+</u> .05)	.44 (<u>+</u> .04)	.15 (±.02)	.48 (<u>+</u> .04)	0	0	.45 (<u>+</u> .03)	0	.20 (<u>+</u> .10)	0	0
Loei	87	.22 (<u>+</u> .06)	.82 (<u>+</u> .03)	0	0	.31 (±.05)	0	.50 (<u>+</u> .05)	0	.76 (<u>+</u> .07)	.08 (<u>+</u> .05)	.23 (<u>+</u> .05)
Macau	215	.36 (<u>+</u> .05)	*.44 (<u>+</u> .04)	.23 (<u>+</u> .02)	.39 (<u>+</u> .04)	0	0	.46 (<u>+</u> .03)	.005 (<u>+</u> .003)	.26 (<u>+</u> .09)	0	0
Mae Hong Son	158	.23 (<u>+</u> .05)	.68 (+.03)	.13 (+.01)	0	.40 (+.04)	0	.38 (+.03)	.01 (+.006)	.67 (+.08)	.15 (+.04)	.08 (+.04)
Nan	119	.23 (<u>+</u> .06)	.72 (<u>+</u> .03)	.01 (<u>+</u> .009)	0	.28 (<u>+</u> .04)	0	.38 (<u>+</u> .04)	.008 (<u>+</u> .006)	.86 (<u>+</u> .06)	.16 (<u>+</u> .05)	.17 (<u>+</u> .05)
Nong Khai	145	.30 (<u>+</u> .06)	.74 (<u>+</u> .03)	0	0	.39 (<u>+</u> .04)	0	.40 (<u>+</u> .03)	0	.87 (<u>+</u> .05)	.01 (<u>+</u> .04)	.36 (+.04)

Table 9. Mutant allele frequencies in cat populations of Thailand, Hong Kong, and Macau (± 1 S.E.))

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Table 10. Phenotypic frequencies and mutant allele frequency estimates for "South China coast" (Hong Kong and Macau combined).

Mutant	Phenotype	Observation	Allele frequency
Orange	0/?	110	q0 = 0.38 + .03
	0/+	83	
	+/+	210	
Nonagouti	+	220	
	22	60	$q_{\underline{a}} = 0.45 \pm .03$
	1111	00	
Tabby	t ^A -	108	$qt^{A} = 0.19 + .02$
E0010 0 - 20	t ⁺ -	147	$qt^{b} = 0.44 \pm .03$
	t ^b t ^b	60	
Dilute	+-	403	qd = 0
	dd	0	
	186.00		
Piebald	S-	252	pS = 0.45 + .02
	SS	108	The state
Dominant white	W	2	pW = 0.0025 + .002
	WW	403	
Brown	bb	3	qb = 0.23 + .07
	+-	53	
-6014.66*0 × Gb			
Tail	Short	72	freq. short = 0.20
	Kinked and/or short	. 79	freq. mutant= 0.22
	Normal	283	

 Table 11. Phenotypic frequencies and mutant allele frequency estimates for "West Isan" (Loei, Nan, and Nong Khai combined).

Mutant	Phenotype	Observation	Allele frequency
Orange	0/?	46	$q0 = 0.26^+ 03$
	0/+	84	
	+/+	214	and some
Nonagouti	A-	127	$q_{\underline{a}} = 0.75 \pm .02$
the state of the	aa	167	
Tabby	t ^A -	1	$qt^{A} = 0.003 \pm .003$
	t ⁺ -	188	
	t ^b t ^b	0	
Dilute	D-	305	$ad = 0.34 \pm 0.03$
	dd	39	42 0.00 1.00
Piebald	SS	52	aS = 0.41 + 02
	Ss	172	42 0112 1102
	SS	118	
Dominant white	W-	2	$qW = 0.003 \pm .002$
	ww	349	
Brown	В-	21	$qb = 0.83' \pm .03$,
	bb	47	
Albino	C-	289	$qc^{b} = 0.06 \pm .03$
	c ^b -	12	$qc^{s} = 0.28 \pm .02$
	c ^s c ^s	26	
Tail	Short	92	freq.short = 0.29
	Kinked and/or show	rt 136	freq.mutant= 0.43
	Normal	183	

Table 12.	Tests for panmixia	on combined	data	("South	China	coast",
	"West Isan").					

		W. Issan						
Orange :		0/?	0/+	+/+	in in	0/?	0/+	+/+
	Obs.	110	83	210	Obs.	46	84	214
	Pred.	104	95	204	Pred.	55	66	223
		$X^2 = 2.0 o$	n 1 d.f.		X2	= 6.7		

			S. (China coa	st			W. Iss	an
Piebald :			++	S1-4	S5-9		++	S1-4	S5-9
	Obs.		108	176	76	Obs.	118	145	79
	Pred.		108	178	74	Pred.	118	166	58
		X2	= 0.08	on 1 d.f.		X ²	= 10.3	on 1 d.i	
			++	S1-5	S6-9		++	S1-5	S6-9
	Obs.		108	201	51	Obs.	118	172	52
	Pred.		108	178	74	Pred.	118	166	58
S. 3.		X2	= 10.1	on 1 d.f.		X2	= 0.84	on 1 d.f	

Table	13.	Coefficients	of	darkness	(c d)	
laule	15.	Coemetents	UI	uarkness	(0.4.)	

Bangkok				0.44
Chiang Mai				0.53
Hong Kong				0.28
Loei				0.52
Macau	*			0.24
Mae Hong Son				0.33
Nan				0.41
Nong Khai				0.38
Britain				0.64
Iran				0.37
Pakistan				0.30
Seychelles	- 2			0.34
Singapore				0.29
"South China coast"				0.26
Thailand				0.43
USA				0.42

0	ther A	sian ca	t popula	ations l	isted fo	r comp	arative	purpos	es.			
Locality	0	a	tA	tb	d	1	S	W	Ъ	cb	cs	Reference
Vladivostok	.11	.53	0	.31	.20	.23	.41	.013	-		-	Boronin et al., in press
Mishima	.39	.79	5-2	23		-	-	.02	-	-	-	Anon., 1969
"South China coast"	.39	.45	.19	.44	0	0	.45	.002	.23	0	0.	This paper
Singapore	.32	.06	.24	.11	.13	0	.50	.012	-	-	.13	Searle, 1959
Bangkok	.30	.75	.04	0	.13	0	.30	.006	-	.01	.19	This paper
Seychelles	.28	.61	.07	0	.32	.28	.41	-	-		-	Jaffe, 1978
La Réunion (small sample)	.20	.80	.03	.32	.27	0	.18	0	-	4	.27	Dreux, 1972
Karachi	.26	.58	-	.14	.11	0	.41	.04	al al		Inter	Beek 1978 (pS from Ahmad et al. 1980).
Ahwaz	.21	.53	0	.19	.09	0	.45	:004	- 2	-	-	Saliternik & Todd 1977
Chiang Mai	.28	.86	.02	0	.34	0	.38	.006	.45	.02	.35	This paper
Mae Hong Son	.23	.68	.13	0 .	.40	0	.38	.01	.67	.15	.08	This paper
"West Isan"	.26	.75	.003	0	.34	0	.41	.003	.83	.06	.28	This paper
Baku	.09	.52	0	.16	.33	.17	.31	0	- 12	-	-	Borodin et al., in press
"Islamapindi"	.30	.64	.035	.14	.11	.24	.46	.019	-		-	Ahmad et al., 1980
Mashhad	.18	.69	0	.46	.13	.09	.35	.008	-	-	-	Saliternik & Todd, 1977
Lahore	.37	.74	.02	.14	.19	.05	.51	.015	_		-	Ahmad et al., 1980

Table 14.Genetic profiles of domestic cat populations located around the Indian Ocean and in eastern Asia.
Other Asian cat populations listed for comparative purposes.

Chiang Mai province		Cat (s)	No Cat	Total	Freq.
Chiang Mai city	Households	113	126	239	0.47
	Wats	3	10	13	0.23
Loei province		Cat (s)	No Cat	Total	Freq.
Loei town	Households	94	157	251	0.37
	Wats	1	1	2	0.50
Mae Hong Son province		Cat (s)	No Cat	Total	Freq.
Mae Hong Son town	Households	138	224	362	0.38
	Wats	9	0	9	1.00
Ban Huay Dua	Households	7	8	15	0.47
village	Wats	1	0	1	1.00
2 lowland villages	Households	2	11	13	0.15
	11 1 11		F	-	0.00
2 highland villages	Households	2	С	1	0.29
Nan province		Cat (s)	No Cat	Total	Freq.
Nan town	Households	109	202	311	0.44
	Wats	• 11	5	16	0.69
Nong Khai province		Cat (s)	No Cat	Total	Freq.
Nong Khai city	Households	135	275	410	0.33
	Wats	5	0	5	1.00
		Cat (s)	No Cat	Total	Freq.
Si Chiang Mai town	Households	13	37	50	0.26

Table 15. Domestic cat ownership frequencies in Thailand

 Table 16.
 Domestic cat demography in Thailand. Frequencies of cat-owning households with particular numbers of adult cats.

its/cat-owning
usehold
1.1
1.1
1.3
1.1
1.3

Table 17. Total cats (adults plus kittens) per cat-owning household in Thailand.

	Cats	Cat-owning households	cats/cat-owning household
Chiang Mai	123	113	1.1
Loei	132	77	1.7
Mae Hong Son	258	129	2.0
Nan	184	79	1.9
Nong Khai	205	121	1.7

Table 18. Kitten/adult cat ratios in Thailand.

	Kittens	Adults		Ratio	
Chiang Mai	45	78		.58	
Loei	59	73		.81	
Mae Hong Son	110	148	1020 300	.74	
Nan	89	95		.94	
Nong Khai	52	153		.34	

Table 19. Cats per household in Thailand.

Location	% Households with Cat (s)	Average no. cats/household	Average no. cats/ cat-owning household
Chiang Mai	.47	0.51	1.1
Loei	.37	0.53	1.7
Mae Hong Son	.38	0.71	2.0
Nan	.44	0.59	1.9
Nong Khai	.33	0.50	1.7



Contour map of Asian domestic cat genetic distances from the wild type, estimated from survey data. Locations of northern Figure 1. contours are uncertain (dashed lines). Values plotted correspond to NEI's genetic distance measure D, e.g., a value of 36 on the map is equivalent to D=0.1360. For D greater than or equal to 0.1, map values= $(1000 \times D)-100$. For D less than 0.1, map values of $100 \times D$ were plotted rather than the negative quantities that would have resulted from the previous formula. Consequently, the map actually tends to underemphasize differences between Southwest and Southeast Asian cat populations. FAGEN & MEESWAT