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Ban Chiang and Northeast Thailand; the Palaeoenvironment and Economy

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Beginning with a detailed presentation of the faunal spectra from Ban Chiang and related sites in Northeast Thailand, this essay reconstructs the palaeoenvironment during the period 3500 BC to the end of the prehistoric period. The evidence from the freshwater molluscs found in prehistoric layers suggests that the first occupants of Ban Chiang encountered a habitat with permanent lakes and clear, slow moving streams. Since the lakes contracted in the dry season, there were ideal conditions for practising wet swidden agriculture. From *c.* 1600 BC, the presence of water buffalo and associated changes in the faunal spectrum suggests the inception of wet rice cultivation. Such agricultural intensification, it is held, follows population pressure and accounts for subsequent settlement in the more arid plains of Thailand.

Keywords: THAILAND, CAMBODIA, BAN CHIANG, NON NOK THA, PREHISTORIC, KHMER, ZOOLOGY, *BIBOS*, *BUBALUS*, GASTROPODS, GROWTH RINGS, PLOUGHING, POPULATION PRESSURE, SWIDDENING, OSTEOLOGY, BONE STRESS.

Introduction

Excavations in the Sakon Nakhon Basin of Northeast Thailand have provided much environmental and economic data for the period from *c.* 3500 BC to the present (Figure 1). The objective of this paper is to summarize the faunal spectra from Ban Chiang and three related sites, and then to consider their implications for culture history in mainland Southeast Asia.

Ban Chiang, Udon Thani Province, is a mound of as yet undetermined extent located at the confluence of three small tributaries of the Songkhram River. Like all other known contemporary sites in the Sakon Nakhon Basin, its location gives it access to water and extensive, relatively flat low lying soils suitable for cultivation of rice under the inundation system (Higham, 1975*a*; Schauffler, 1978). Excavations undertaken there in 1974/5 document a six-phase prehistoric sequence followed by a series of historic occupation layers (Gorman & Charoenwongsa, 1976). The mound was used for both occupation and a cemetery. As was the case at the culturally related site of Non Nok Tha, the occupants placed grave goods with the inhumed dead (Bayard, 1972). These offerings provide much data on ritual, technology and economy. Unlike Non Nok Tha, however, there is also much material from occupation contexts, including shell middens. The fine screening and flotation methods of data recovery have provided biological samples of unrivalled richness from a lowland site in Southeast Asia.

Excavations by Schauffler (1976) at Ban Tong, Ban Phak Top and Don Khlang have

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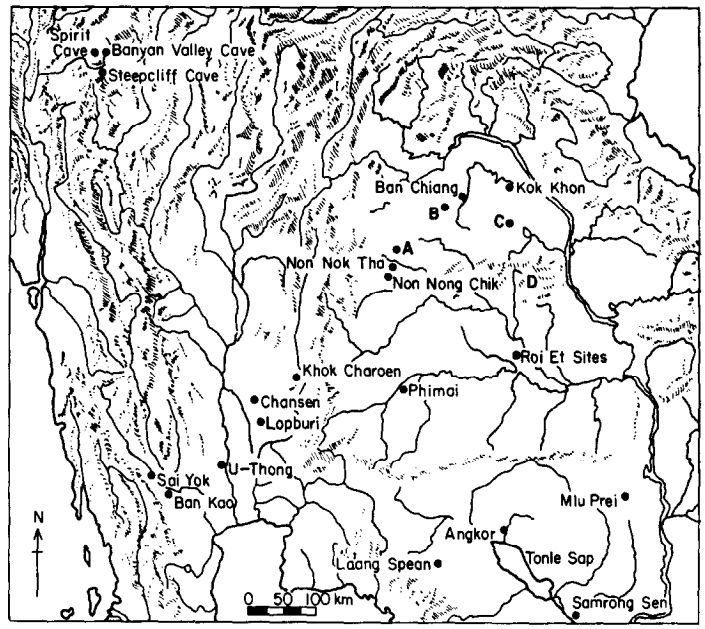

Figure 1. Northeast Thailand: site location map. **A**, Don Khlang; **B**, Ban Phak Top; **C**, Ban Don Khung; **D**, Don Mun Hills.

also provided biological data. These samples, though small, are important in that they allow investigation of parallel trends in the basin as a whole. There are few reports of non-human bone from Southeast Asia on which to build. Gorman (1971) has summarized the data relating to the widespread Hoabinhian technocomplex. He concluded that between the end of the Pleistocene and *c.* 3000 BC, the limestone uplands of Thailand were occupied by hunter-gatherers exploiting a wide range of local plants and animals. Subsequently, Higham (1977*b*) has published faunal spectra from Spirit and Banyan Valley caves. Each site has yielded mammalian, mollusc, fish and bird remains indicating broad-range foraging. Moreover, the occupation of Banyan Valley Cave has been shown by Gorman to last until *c.* AD 900.

Of excavations among lowland sites in which agriculture is highly likely, if not definitely proven (Yen, 1977), only the Non Nok Tha fauna has been fully published and commented upon (Higham, 1975*b*). Animal remains from excavations at Lopburi, U-Thong, Chansen, Phimai and Ban Kao need detailed study.

The Faunal Spectrum of Ban Chiang

The detailed correlations between layers within the four excavated squares are not currently available. Consequently, the faunal spectrum of Ban Chiang is presented in two different ways. Initially, the number of individual animals per species has been set out for square D5 (see Table 1). This particular square yielded more specimens than any other, and gives an impression of the detailed nature of the data available. The second faunal spectrum results from an attempt to portray changes in the composition of species with time (Figure 2). This diagram results from the following procedure. The layers from the individual squares were pooled to represent, as far as possible, the sequence of cultural phases described by Gorman & Pisit (1976). The number of individual animals from each layer were then combined to provide an estimate of their

relative frequencies. The correlation between the cultural phases and individual layers was based only on experience gained when excavating the site and does not refer to an analysis of the notes taken by the site excavators. Doubtless there will be modifications when layer correlations across squares become available.

Since only one square was excavated at Ban Phak Top, Don Khlang and Ban Tong, the raw data from each site are presented in Tables 2–4.

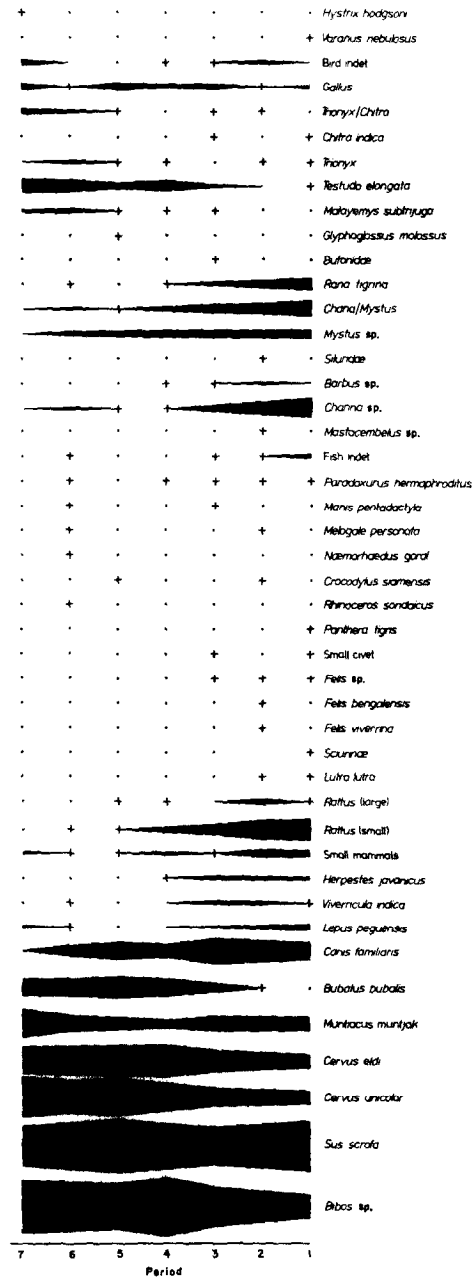

Figure 2. Ban Chiang—the faunal spectrum. +, Trace; ·, absent.

Table 1. Ban Chiang, Udon Thani Province, Thailand: The faunal spectrum for 1975 square D5

Layers	*Bibos* sp.	*Sus scrofa*	*Cervus unicolor*	*Cervus eldi*	*Muntiacus muntjak*	*Bubalus bubalis*	*Canis familiaris*	*Lepus peguensis*	*Viverricula indica*	*Herpestes javanicus*	*Rattus* (small)	*Rattus* (large)	Civet	*Rhinoceros sondaicus*	*Crocodylus siamensis*	*Naemorhedus goral*	*Melogale personata*	*Manis pentadactyla*	*Channa* sp.	*Barbus* sp.	*Channa/Bagrid*	*Bagrid*	*Rana tigrina*	Bufonidae	*Glyphoglossus molossus*	*Malayemys subtrijuga*	*Testudo elongata*	*Trionyx cartilagineus*	*Chitra indica*	*Gallus*	Bird indet.	*Varanus nebulosus*
S	1	1	1		1	1																										
1	1	2	1	1	1																											
2s	—	—	—		—																											
2	1	1			1																											
3s	—	—	1																													
3	2	1	2	1	1	1								1																		
4s	1	2	1	2	1	2													1								2					
4	2	2	1	1	1	1	1	1									1						1				3					
5s	1	1	1	1					1									1														
5	2	3	2	2	1	1	1								1				1							1						
6s	2	2	1		1																											
6	2	2	1	1	1	1	1															1										
7s	1	1																														
7	2	1	1	1	1	1													1													
8	1	2	2	1	1	1	1																									
9s	—	1	1	1			1																									
9	1	2	1	1		1	2																			1						
10s	1	1	1	1	1																											
10	1	2	1	1		1																								1		
11s	—	—	—	—		1																										
11	2	1	2	1		1	1																							1		
12	1	2	1	1	1	1	1																			1						

13s	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	2	2	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
14s	2	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	2	3	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	1	—	—
15s	2	2	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—
15	2	1	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	2	—	—	—	—	—
16s	1	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
16	1	1	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—
17s	2	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
17	2	1	2	1	1	—	2	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—
18s	4	2	1	1	1	1	3	—	—	—	1	—	—	—	—	—	—	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—
18	1	2	1	1	—	—	4	1	—	—	2	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	2	—	—
19s	1	1	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	2	2	1	1	1	—	2	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—
20s	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	2	—	—	1	1	1	1	—	—	—	1	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
21s	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
21	1	1	1	1	1	—	—	—	1	2	1	1	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—
22s	1	2	1	1	1	—	1	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	1	1	1	1	—	—	2	—	—	1	1	—	—	—	—	—	—	—	1	1	1	1	1	—	—	—	—	—	—	—	—	—
23s	1	2	1	1	—	—	1	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
23	1	2	1	1	—	1	—	—	—	—	2	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—
24s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	1	2	1	1	—	—	1	—	—	—	1	1	—	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—
25s	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—
25	1	3	—	1	1	—	1	—	—	—	2	—	—	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—
26s	1	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	1	3	1	—	1	—	1	1	—	1	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
27s	1	3	—	1	—	—	1	—	—	—	1	—	1	—	—	—	—	—	2	—	1	1	—	—	—	—	—	—	—	—	—	—
27	1	3	—	—	1	—	—	1	—	—	1	1	—	—	—	—	—	—	1	—	1	2	1	—	—	—	—	—	—	—	—	—
28s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
28	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	1

Table 2. Ban Phak Top, Udon Thani Province, Thailand: The faunal spectrum

Layers	*Bibos* sp.	*Sus scrofa*	*Cervus unicolor*	*Cervus eldi*	*Muntiacus muntjak*	*Canis familiaris*	*Lepus peguensis*	*Herpestes javanicus*	Small mammal	*Rattus* (large)	*Felis viverrina*	*Channa*	Fish indet	*Malayemys/Testudo*	*Trionyx/Chitra*	*Gallus*	*Varanus nebulosus*	Civet
2	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—
3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	1	—	—	1		—	—	—	—	—	—	—	—	—	—	—	—	—
5s	1	—	—	1	1	—	—	—	1	—	—	—	—	[a]	—	—	—	—
5	1	1	1	1	—	—	—	—	1	—	—	—	—	[a]	—	—	—	—
6	1	2	1	1	1	1	—	1	—	—	2	—	—	[a]	—	1	—	1
7	2	3	1	1	1	3	—	1	1	—	—	—	1	[a]	1	—	—	—
8s	—	2	1	1	1	1	1	1	—	—	—	—	—	[a]	—	—	—	1
8	1	2	—	1	1	1	1	—	—	1	—	1	1	[a]	—	—	—	1
8/9	—	5	1	1	1	3	—	—	—	—	—	1	—	[a]	—	—	—	—
9	2	3	—	1	1	1	—	—	—	—	—	1	—	[a]	1	—	1	—
10	1	2	—	—	—	2	—	—	—	—	—	—	—	[a]	—	—	—	—
11	1	1	—	—	—	—	—	—	—	—	—	—	—	[a]	—	—	—	—
12	1	1	—	1	—	—	—	—	—	—	—	—	—	[a]	—	—	—	—

[a] = Present.

In Figure 2, the columns for cattle (*Bibos*) and pig (*Sus*) include, it is presumed, an unknown fraction of wild animals. In the case of the former, cattle frequencies increased from barely 10% of all individuals in period 1 to 25% by period 2, and remained at about 20% thereafter. Pigs comprised about a fifth of all animals throughout the site's occupation. In all periods, the three deer species at Ban Chiang were always frequently represented, with the sambar (*Cervus unicolor*) and brow antlered deer (*Cervus eldi*) commoner than the muntjak (*Muntiacus muntjak*). There is a distinct impression that the deer became more abundant with time, particularly during and after period 4.

With the water buffalo (*Bubalus bubalis*), we find a species which made its appearance during the course of the site's occupation. There was only one bone, a second phalanx, in layers ascribed to phase 3. Thereafter, water buffalo were always present, but never exceeding a figure of 9%. *Canis familiaris*, the domestic dog, was present in all but period 7 but its frequency fluctuated quite considerably, up to 11% in period 4.

There follows an assemblage of species which were relatively common at the beginning of the site's use, but which became rare or absent with time. This group includes the three principal varieties of fish: *Channa*, *Barbus* and a bagrid species. Among the small mammals, there is the hare (*Lepus peguensis*), civet (*Viverricula*), mongoose (*Herpestes javanicus*), otter (*Lutra*), and rat (*Rattus* sp.). The frog (*Rana tigrina*) was relatively common in period 1, but it was scarcely represented at all after period 4.

In association with the decrease in the above species, there was an increase in others, particularly the grass turtle (*Testudo elongata*), and the water turtle (*Malayemys subtrijuga*). There is, further, a group of species which are always rare and which do not, therefore, show any definite time trends. This group includes the rhinoceros (*Rhinoceros sondaicus*), tiger (*Panthera tigris*), lizard (*Varanus nebulosus*), goral (*Naemorhedus goral*), Burmese ferret-badger (*Melogale personata*), toad (Bufonidae), spiny eel (*Mastacembelus* sp.), porcupine (*Hystrix hodgsoni*) and crocodile (*Crocodylus siamensis*). While rare, some nevertheless indicate particular environmental preferences.

There remain the birds and molluscs. The former are either the domestic chicken or are unidentified. Bird remains were never common, but were present throughout the site's use. The molluscs are relatively very abundant during periods 1 to 3, whereupon they became either rare or absent.

In interpreting the Ban Chiang faunal spectrum, it must be stressed that certain species have marked environmental preferences. This applies in particular to the molluscs, of which a long term study has been begun by Higham and Mason. During the course of a fieldwork programme in the vicinity of Ban Chiang during May–June 1978, particular attention was paid to the habitats of those shells common or present in the basal shell middens at Ban Chiang and related sites. It was found that the large gastropod *Pila polita* requires permanent water for survival, while the related *Pila ampullacea* survives the dry season by aestivating, breeds during the early weeks of the rainy season, and occupies and feeds in paddi fields between May and October. It both aestivates and lays its eggs close to the surface of banks between paddi fields. *Pila ampullacea* also lives in steams and ponds, and further laboratory analysis of the age-size ratios is expected to allow paddi-field and pond-living individuals to be distinguished.

Further species identified include the Viviperid gastropod *Filupaludina javanica*, a species which was found in streams, ponds and paddi fields. It is possible that changes in the spire angle will allow detailed inferences on the prehistoric water regime. Thus, the rapidity of water flow may well affect shell shape. While of a preliminary nature and based only on field observations, initial conclusions are that the inhabitants of Ban Chiang, at least during periods 1 and 2, enjoyed an environment in which permanent bodies of water, as well as clear slow moving streams, were present.

A small number of landsnail fragments were also found, including *Hemiplecta* sp. This snail is found in shaded woodland, in the vicinity of tree roots. Such snails are collected today when woodland is burnt and cleared to create new paddi fields.

In view of the preponderance of molluscs only during the early layers, attention is now centred on the environmental demands or preferences of the other species which also predominated only during the early levels. Among these is *Lepus peguensis*, the Siamese hare. This species prefers open terrain and avoids forest. Being a herbivore, it is attracted to open grassy clearings. Of all the civets native to Thailand, *Viverricula malaccensis* is prepared to occupy territory close to human settlement. Boonsong & McNeely (1977) note a preference for long grass and scrub. A similar habitat preference is noted for *Herpestes javanicus*, the Javan mongoose. It prefers grassland to forest, and is terrestrial rather than arboreal. It is particularly unfortunate that the rat bones cannot be identified more precisely, because they have a similar distribution to the above three grassland-scrub indicators. There are, however, twenty-four species of rat recorded in Thailand and it is necessary to have well-preserved crania to make a reasonably sure identification. Moreover, while some species have particular habitat preferences, others, such as *Rattus rattus*, are practically ubiquitous.

The otter is, of course, an aquatic species, with a diet which included frogs, crabs and rats. Their presence in periods 1 and 2 is in accordance with the abundance of molluscs. Indeed, fish themselves are more frequent in early periods and decline with time. Of these, *Channa* sp., the serpent headed fish, shows the greatest tendency towards being preferred in the early periods. Smith (1945) describes this genus, with eight species, as the commonest of the staple food fish in Thailand, with a range of habitats from mountain streams to lakes, ponds and swamps. Of the eight species, the most widely distributed are *Channa striatus* and *Channa melasomus*. Both occur in the northeast of the country and are the most likely species to be found at Ban Chiang. The former is still caught in streams and paddi fields, but the latter is very rare in the vicinity of the site. *Channa striatus* has a suprabranchial cavity which allows it to survive the dry

Table 3. Ban Tong, Udon Thani Province, Thailand: The faunal spectrum

Layers	*Bibos* sp.	*Sus scrofa*	*Cervus unicolor*	*Cervus eldi*	*Muntiacus muntjak*	*Bubalus bubalis*	*Canis familiaris*	*Lepus peguensis*	*Viverricula indica*	*Herpestes javanicus*	*Rattus* (small)	*Rattus* (large)	*Lutra lutra*	*Felis bengalensis*	*Felis* sp.	*Rhinoceros sondaicus*	*Crocodylus siamensis*	*Manis pentadactyla*	*Channa* sp.	*Bagrid* fish	*Barbus* sp.	*Rana tigrina*	*Malayemys subtrijuga*	*Testudo elongata*	*Trionyx/Chitra*	*Gallus*	*Varanus nebulosus*	Small mammal
1s																												
1	1			1	1																							
2s																												
2	1	1																										
3s																												
3	1	1		1																								
4s																												
4	1	1		1			1																					
5s																												
5	2	3		2	1		1																					
6s																												
6	3	3	1	2	1	1	2													1				2				
7s																												
7	2	3	1	2	1		1	1													1							

8s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	3	3	1	2	1	—	2	—	—	—	—	—	—	2	—	—	—	—	—	1	—	—	—	—	—	—	—	—
9s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	3	4	1	2	1	1	2	—	—	—	1	1	—	—	—	—	—	—	1	—	—	—	—	2	1	—	—	1
10s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	2	4	1	2	2	—	3	1	—	1	1	—	—	—	—	—	—	—	2	1	—	1	—	1	—	—	—	1
11s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	3	7	1	2	2	—	3	—	—	2	2	1	1	—	—	—	—	1	—	1	—	—	1	6	—	—	—	—
12s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	3	5	1	2	1	—	2	1	—	—	—	—	—	—	—	—	—	—	2	1	—	1	1	6	1	—	—	1
13s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	3	5	1	3	2	1	1	—	2	1	—	—	—	—	—	—	1	1	—	1	—	—	1	4	1	1	—	2
14s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	4	5	2	3	1	1	3	—	—	—	—	—	—	—	1	1	1	—	2	1	1	—	5	7	1	—	—	—
15s	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	5	6	1	2	1	—	1	1	—	1	—	1	—	1	—	—	—	—	1	1	—	—	2	3	1	1	1	—
16s	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	1	2	1	1	1	—	1	—	—	—	—	1	—	—	—	—	—	—	1	1	—	—	1	—	1	—	—	—
17s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18s	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	—	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 4. Don Khlang, Khon Kaen Province, Thailand: The faunal spectrum

Layers	*Bibos* sp.	*Sus scrofa*	*Cervus unicolor*	*Cervus eldi*	*Muntiacus muntjak*	*Bubalus bubalis*	*Canis familaris*	*Lepus peguensis*	*Tragulus napu*	*Herpestes javanicus*	Small mammal	*Rattus* (small)	Civet	*Crocodylus siamensis*	*Bagrid* fish	*Rana tigrina*	*Gallus*
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3s	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	1	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—
5	2	3	—	1	1	1	1	—	1	—	1	—	—	—	1	—	1
6	2	3	1	1	1	1	1	1	—	1	—	—	1	1	1	1	1
7	3	3	1	1	1	—	1	—	—	—	—	1	—	—	1	—	—
8	1	3	1	1	1	—	—	—	—	—	—	—	—	—	1	—	—
9	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—

season by sinking into mud as swamps and ponds dry out. It breeds prolifically in shallows around the margins of swamps and ponds, and can grow up to a metre in length. It is carnivorous, relying on small fish, snakes, frogs and insects. It can be caught by hook and line or with traps. During the dry season, the fishermen can obtain specimens by excavating in the mud from dried out bodies of water. Catfish belonging to the family *Bagridae* are present throughout the sequence in a relatively consistent proportion of the entire spectrum. These catfish are omnivores, preferring warm, well oxygenated water. Small specimens are netted in the seasonal streams in the vicinity of Ban Chiang at present. The Cyprinid genus *Barbus* is widespread and diverse in Thailand. They are to be found in the artificial lake near Ban Chiang today, where they provide a dry season catch. It is, however, present only during periods 1 to 4 at Ban Chiang. The spiny eel, *Mastacembelus*, is represented by only one bone in a period 2 context. Eels of this type are known to occupy holes in the banks of rivers and lakes. They are not caught by the present inhabitants of Ban Chiang.

There are at least two species of frog, nearly all of which come from periods 1 and 3, after which they become extremely rare. Only one bone was identified as *Glyphoglossus molossus*, a frog found by Inger & Colwell (1977) in deciduous woodland following their trapping programme at Sakaerat research station. At Ban Chiang however, this species was commonly collected in paddi fields during the early rainy season and Inger (pers. comm.) confirms it as an occupant of paddi fields. Nearly all other frog bones are ascribed to *Rana tigrina*. This species is common to paddi fields today, and according to Inger (pers. comm.), is adapted to river flood plains. Unlike many Thai frog species, it is not found in forested environments.

Trionyx cartilagineus and *Chitra indica* are soft shelled water turtles. Both are rare, but *Trionyx* is found throughout the sequence at Ban Chiang, with a slight increase in phases 5 to 7. *Chitra* is confined to periods 1 and 3. *Malayemys subtrijuga* is a small water turtle now found in streams and paddi fields. It has been possible to distinguish only the frontal portion of the carapace from the corresponding part of the grass turtle *Testudo elongata*. In period 1–5 layers at Ban Chiang, there are many fragments of carapace and plastron from either *Testudo* or *Malayemys*, but few can be assigned to

either without question. Consequently, the apparent rise in the numbers of grass turtle may well be illusory. The grass turtle in question is commonly reported from secondary forest, and is often caught when burning and clearing such forest for the creation of paddi fields. It has particular significance in that it is remarkably adapted to withstand heat. Of all land tortoises, this one can withstand forest burns best.

There remain the species which are found only rarely at Ban Chiang. *Melogale personata*, the Burmese ferret badger, occupies a wide range of habitats, from forest to grassland, and is of little value therefore as an indicator of any specific habitat. The Javan rhinoceros, *Rhinoceros sondaicuss* currently occupies dense rain forest, but this may well indicate hunting pressure in different habitats. They prefer the vicinity of mud or water wallows and their diet entails browsing, particularly in disturbed woodland. They themselves modify their habitat by flattening trees and shrubs to gain access to leaves and twigs. *Panthera tigris*, the tiger, needs shade, water and of course, access to a steady supply of large game animals. The faunal spectrum of Ban Chiang indicates the presence of all three during period 1.

There are a few fragments of bone ascribed to small cats. *Felis viverrina*, the fishing cat, and possibly *Felis bengalensis* or *marmorata*, the leopard and marbled cat respectively are present. The fishing cat is widespread from India to Java, but avoids dense forest. Indeed, Boonsong & McNeely (1977) stress its preference for scrub forest near water. Their diet is centred on aquatic species, including molluscs, fish, crabs and rodents. The leopard cat is very adaptable to a range of environments, and is particularly widespread in distribution from Korea to Java. It is often found living near human settlements, whence it raids domestic stock. The few specimens ascribed to a cat of this size are more likely to be the common leopard cat rather than the rare and little known marbled cat.

It is difficult to determine which of the many species of civet is present in the absence of well-preserved crania. There are a few specimens ascribed to an animal the size of the common palm civet, *Paradoxurus hermaphroditus*, but it is inadvisable to draw any environmental inferences from such a tentative identification. There is, however, no doubt that the pangolin (*Manis*) is present. Both the Chinese and Malayan pangolin have similar habitat preferences. They occupy primary and cleared woodland areas if there is a steady supply of ants and termites.

The identification of a molar fragment from the goral (*Naemorhedus goral*) in period 6 is most unexpected because this animal prefers precipitous slopes and uplands. They are not found within 100 km of Ban Chiang. The porcupine is also represented by a single tooth fragment, the species in question probably being *Hystrix hodgsoni*. This animal occupies forest, and consumes inner and outer tree bark. Another forest dweller is the squirrel, of which a small assemblage of bones was identified from period 1 only.

The careful sieving procedures undertaken at Ban Chiang and determined objective not to overlook any biological data make it feasible to review which species are *not* present, or are unexpectedly rare. The absence of any non-human primate bone is particularly notable. The langur, macaque and gibbon are indigenous to the area given the presence of a suitable forested habitat. Apart from a few species in period 1 levels, squirrel bones are absent. The flying lemur, marten, mouse deer, wild dog and hog badger are likewise absent. It should be stressed that all the above species are particularly well adapted to a forested habitat.

It is not, at present, possible to offer a precise integration—chronological or cultural—between the layers of Ban Chiang and the three sites excavated by Schauffler in 1975. He has, however, noted a number of important facts regarding Don Khlang, Ban Phak Top and Ban Tong (Schauffler, 1978). Don Khlang contains basal layers corresponding to the early period at nearby Non Nok Tha. This should, if Bayard's

long chronology is accepted, date in the late 3rd and early 2nd millennium BC. Later pits were dug into the early occupation and burial layers and these are held to belong to the period 500 BC to AD 250. While too small for detailed comment, the sample provides some interesting parallels with that from Ban Chiang. Pig and cattle bones predominate numerically, and water buffalo are absent from the first three fauna-bearing deposits. All three deer species found at Ban Chiang recur there. Mongoose and hare, indicators of open country, are present, as are frog, crocodile, bagrid fish and molluscs. The molluscs, at Ban Chiang, were restricted to the early layers. Turtles were present throughout the sites use. Only the greater mouse deer, *Tragulus napu*, was found at Don Khlang but not at Ban Chiang. These small, shy herbivores are still found in the wooded hills above the site. It was represented by one tooth fragment.

A radiocarbon date for basal Ban Phak Top suggests occupation there by 2500 bc, that is a millennium later than at Ban Chiang. The actual associations and dates of the later levels are not at present available. The faunal spectrum is again very similar to Ban Chiang and Don Khlang, with the exception that no bones of the water buffalo were located there. Excavation of more squares would probably redress this situation. Pig and cattle again predominate, and Eld's deer, sambar and muntjak were hunted regularly. The hare and mongoose are again present, turtles are found in all layers and *Channa*, together with fish bones unascribed to species, also indicate exploitation of water resources. Again, there was a thick shell midden at the base of the site including *Pila polita* and *Pila ampullacea*.

The initial occupation of Ban Tong occurred *c.* 3100 BC. Schauffler has yet to comment on the cultural affinities or dates of subsequent layers at this site, but Gorman (pers. comm.) has commented that the top layers are equivalent to the Om Kaeo (period 4) at Ban Chiang, which is a bare 8 km to the northwest. In many ways, the faunal spectrum is remarkably similar to that from Ban Chiang. There is a preponderance of cattle and pigs, water buffalo bones occur in layers 14, 9 and 6 but are absent from the earliest ones. The three deer species recur consistently, fish, crocodile, otter and water turtles indicate exploitation of water resources nearby. Hare, mongoose and civet suggest an open habitat. Some of the rarer species from Ban Chiang are present but rare at Ban Tong also: rhinoceros, pangolin, the lizard *Varanus nebulosus*, golden jackal and small felids. Indeed, one of the most suggestive facts linking the occupants of the two sites, is the presence of parallel, congenital abnormalities in the dentition of domestic dogs.

There is also a hint that the same time trends are present. Thus small and large rats are found only in early levels. Hare and civet are not found above layer 7. Fish become scarce above layer 9 and absent above layer 5. In only one respect is there a major difference between Ban Chiang and Ban Tong: the latter has yielded very few molluscs. This, however, should be treated cautiously. At the recently excavated site of Ban Non Chai (Khon Kaen Province), Charoenwongsa (pers. comm.) has shown clearly that an early shell midden had a restricted areal distribution, being 20 cm thick in the centre, but tapering out at the margins. Schauffler's 3×3 m square at Ban Tong may have missed any early shell middens which existed at other parts of the site.

Aspects of the Prehistoric Environment

One of the principal reasons why such time and effort has been devoted to as precise an identification as possible of the faunal remains from Ban Chiang, is the notion that results will illuminate not just the stock raising, hunting and collecting activity, but also broad aspects of the prehistoric environment and economy. Central to such a study is the prehistoric climate and vegetation. Thus the analysis of early farming communities

in Northwest Europe (Clark, 1952) or upland Mexico (Flannery, 1973) has been greatly enhanced by the availability of pollen spectra and macro-floral remains respectively. The student of culture history in Northeast Thailand is not so fortunate, although pollen cores are currently under investigation by Tsukada. The same situation applies to the plant remains, including rice, currently being studied by Yen.

The probable forest cover in Northeast Thailand during the 4th millennium BC and later will ultimately turn on the former bioclimate and precipitation pattern. Recent research undertaken on Thai forest types has stressed several relevant variables. Thus Holdridge *et al.* (1971), in applying the concept of life zones to Thai forest associations, have underlined the importance of the duration of the dry season to the prevalence of deciduous trees, and impact of edaphic conditions, such as poor or excessive drainage, and the influence of altitude on bioclimate. The closest of their study areas to Ban Chiang lay in the vicinity of Khon Kaen. Under an altitude of 400 m, which would include all the prehistoric sites described above, natural forest cover today is classed as subtropical moist, with:

> "open to fairly dense stands and simple floristic vegetation. Upper canopy of fairly uniform height, being 15 m in the driest, 25 m in the moist, parts."

In drier areas, such forest is fully deciduous, and in moister areas, such as river margins, it is partially so. In terms of the traditional forest classification of Thailand, the former type is called dry deciduous dipterocarp forest. At *c.* 400 m, the vegetation changes to subtropical wet, or in the traditional classification, broad-leaved evergreen forest.

Stott (1976) has examined the problem of classifying the dry deciduous dipterocarp forest, or *pa tengrang* of Northeast Thailand, noting that it responds to climatic regimes with a dry season of 5–6 months duration and annual rainfall of between 1000 and 1500 mm. He has described the most widespread type as *Dipterocarpetum obtusifolio-tuberculatia* which, as a result of burning and exploitation, has succeeded the edaphic climax of the *Shoreeto-Pentacmetum* type.

Now the contrast between a dry deciduous and a broad-leaved evergreen forest is held to be one of considerable importance ecologically, and quite possibly to the culture history of Thailand as a whole. In their review of the herpetofauna of these two associations at the Sakaerat Experimental Station near Korat, Inger & Colwell (1977) recorded that the broad-leaved evergreen forest had two canopies, one 20–35 m high, and that during March/April, 17% of the forest floor received sunlight. The corresponding figure for the dry deciduous forest is 48%. The composition of the forest floor varied as follows:

	Evergreen (%)	*Deciduous* (%)
Dead leaves	98	20
Bare soil	1	37
Erect dead grass	—	41

Temperatures are higher and more variable, humidity lower and evaporation greater in the deciduous type. In general, the evergreen forest is more insulated against the sun, and has a more predictable microclimate. This may partly explain its greater species diversity. Moreover, the faunal composition of the dry deciduous forest is closer to that of cleared agricultural land.

That each forest type is adaptive to elements of the Thai herpetofauna is interesting in itself and makes, for example, the presence of the fossorial microhylid *Glyphoglossus molossus* in a period 5 context at Ban Chiang relevant, all ten specimens at Sakaerat being found in dry deciduous dipterocarp woodland. Of more significance is the greater

growth of grasses in the open sunlit deciduous forest, a factor which encourages concentrations of herbivorous ungulates, such as the gaur, banteng, sambar and Eld's deer. Being subjected to the desiccating effects of the long dry season, deciduous forest is easy to fire, either accidentally or deliberately, which leads to the presence of open, grassy glades and encourages a freshening of grass growth. Dry season firing to promote new growth and thereby attract herbivores is, indeed, recorded by Wharton (1966) in northern Cambodia. Moreover frequently burned over open woodland which favours ungulates and *Testudo elongata* is less acceptable to leaf eating and frugivorous arboreal species. In a word, each forest type favours a particular range of species, with the arboreal animals preferring evergreen forest, but ground dwelling herbivores, the deciduous. Naturally, some species cross-cut this division, in particular the crepuscular predators such as leopard, tiger and smaller cats. Nevertheless, a comprehensive collection of faunal remains from a prehistoric site should permit inferences on contemporary vegetation patterns, the degree of detail increasing with the more specialized, smaller species.

Another important point to prehistoric economies, is that the moister upland evergreen forest canopy insulates against a variable climate and reduces the sharp difference between dry and wet seasons experienced in the dry deciduous form. In consequence, while the number of large animals declines in the former, the number of species increases. There is also more likelihood of a lean season for hunter-gatherer societies in the dry deciduous habitat, and therefore more reason to amass wet season surpluses and develop techniques of food storage.

If it is assumed that the duration of the dry season and amount of rainfall 6000 years ago was similar to that experienced today, and a detailed analysis of the growth of prehistoric specimens of the gastropod *Pila ampullacea* should show whether this is correct, then the forest cover on the gently undulating Sakon Nakhon basin would have comprised a dry deciduous forest, grading to a greater incidence of evergreen trees along permanent watercourses and around lakes and swamps. It is important to remember that heightened flows in the Mekong during the wet season causes the rivers draining the basin to back up, thereby impeding drainage and creating seasonally extended surface water. Moreover, being flat over a considerable area, the artificial expansion of lakes and swamps could be affected by the simple expedient of obstructing outflows. That permanent bodies of water existed during the 4th millennium BC, together with clear, gently flowing streams is documented by the analysis of the molluscan and herpetofauna.

The Om Kaeo Phase and Wet Rice Agriculture

In turning to a review of the Ban Chiang faunal assemblage, it is clear that a major discontinuity occurred with the advent of the water buffalo during period 3. While it never attained a high proportion of all individuals represented, its significance today as the principal source of tractive power is hard to overstate. With the presence of water buffalo, certain other species became rare, or disappeared. The list is long and intriguing: *Channa* sp. and *Rana* sp. became rare. The mongoose, otter, ferret badger and many molluscs ceased to be represented. It is paradoxical that the advent of large animals reliant on access to water should be associated with a decline of such aquatic species as *Pila*, *Lutra* and *Rana*. Moreover, the demonstrable presence of permanent lakes in periods 1 and 2 is associated with the puzzling absence of water buffalo bones. When the animal does appear at Ban Chiang, all bones but one corresponded in size to that of the modern, domestic animal. The wild water buffalo today is considerably larger than its domestic counterpart. It is, of course, possible that the large and dangerous wild water buffalo were present in the vicinity of Ban Chiang during the 4th and 3rd millennia BC, but were avoided for ritual or economic reasons. On the other hand,

these may have been rare or absent from the area. Whichever is the case, their regular appearance at the commencement of period 3, the Om Kaeo phase of Gorman and Pisit, coincided with the first evidence for iron technology. The water buffalo were of domestic size from the outset. There is no evidence suggesting a period of domestication.

The explanation of this faunal discontinuity, which also applies to aquatic species and some small terrestrial mammals, is, it is held, central to an interpretation of the Ban Chiang economy. After reviewing all the variables, an explanatory hypothesis was formulated as follows:

> "The introduction of the water buffalo and iron technology occurred with the occupation of the Om Kaeo phase. This phase saw the inception of wet rice cultivation, the use of ploughs, and the quickening of forest clearance for the creation of permanent paddi fields."

There are several ways of falsifying this hypothesis, some of which will be described below, while others await the results of related analyses currently under way. The two main avenues followed below are the reasons for the decline in aquatic species, the detailed analysis of water buffalo terminal phalanges and the human palaeopathology and mortality frequences.

Before a detailed consideration is given, it is necessary to comment on the likely environmental effect of extensive forest clearance and the impounding of rainwater within paddi fields. The removal of forest, even of the dry deciduous variety, has the effect of increasing the rate of surface evaporation: the temperature of water in paddi fields during May 1978 exceeded 40 °C. Breaking the insulating effect of a tree canopy would permit heavy rains to fall directly on to the ground, thence to induce erosion and introduce turbid water into the adjacent streams and lakes. Again, impounding rainwater in rice fields themselves reduces inflows into the natural waterways. It is also important to stress that heavy rains on unprotected ground can create a hard laterite pan, thus promoting a lowering of the water table, and less steady flow of spring water into streams during the dry season. When Ban Chiang was re-occupied by Laotian rice farmers three generations ago, forest reached to the village outskirts, and streams were perennial. Widespread forest clearance followed, and streams are now empty for most of the dry season.

It is therefore stressed that the creation of paddi fields and clearance of forest, which would have been greatly facilitated by the use of iron tools, may well have profoundly altered the water regime. Permanent streams, it is argued, would either have reduced flows, or dried out, during the dry season. Permanent lakes and swamps would have been reduced in extent, or even have disappeared. Reference to individual species is now necessary to support or falsify the hypothesis outlined above.

Pila polita requires permanent water for survival. It was found in early periods at Ban Chiang, but is not currently found in the vicinity of the village, apart from a colony recently introduced into a modern artificial pond. *Pila ampullacea* was also a component of early prehistoric middens at Ban Chiang, and being able to survive the dry season by aestivating, is found near the village today. These gastropods were found aestivating close to the surface of the low banks which demarcate modern rice paddis. By mid-May, with the onset of early rains, they commence laying eggs and with the regular rains by the end of May, they move into paddi fields to feed. The creation of paddi fields would, then, be expected to favour the proliferation of *Pila ampullacea*. Yet they became scarce in the extreme after period 3 at Ban Chiang. This becomes hard to explain when one notes that *Pila ampullacea* are collected today from paddi fields near the village, but it may be that we are dealing with an ecological web of some complexity. Thus, apart from man, there are very few natural predators of this species today. A village dog has been observed cracking shells but not with regularity. All other likely natural predators

are now locally extinct, and the list of potential predators is long, from otters and fishing cats to the larger catfish and particularly, birds. The Ban Chiang area has hardly any predatory birds left. There is a further important source of mortality for this and other paddi-field gastropods: the act of ploughing itself. Quite apart from the trampling of the hooves, the paddi banks are often shaved by the plough at just the time when eggs are developing, while the rebuilding of paddi banks kills many molluscs. Then again, the sharp bamboo points of the harrow kill more. The number of dead molluscs and crushed eggs in paddi fields during and after the period of field preparation is considerable. It may well be that ploughing, in addition to the activities of other predators when they still existed, reduced the number of *Pila ampullacea* to such a level that intensive collecting was no longer rewarding.

The reduction in the area under permanent water would clearly affect the numbers and availability of fish, otters, crocodiles and aquatic frogs. It should, however, be emphasized that the decline in some of these species is relative: aquatic resources declined after period 3, but did not by any means disappear altogether.

At this juncture, it could be argued that the reduction in the number of aquatic species from period 3 indicates a change in food preferences, just as was the case for the Tasmanian aborigines and the consumption of fish. It is therefore expedient to turn to the actual evidence for ploughing. It is rare to find prehistoric ploughs, and none is known for Thailand. There are, however, the bones of the animals which may have provided the traction. As part of a detailed consideration of the third fore phalanx in *Bovidae*, Higham and Moore have devised a procedure for describing the extent to which a third phalanx comes from an animal subjected to unusual stress. Essentially, the third phalanx is the seat of insertion of major extensor and flexor tendons used in movement. By comparing the dimensions and configurations of the exorstoses on to which such tendons are attached with the fixed points on the phalanges articular surfaces, they have been able to show that modern bovids known to have a history of traction, are significantly more robust than animals of a similar age but unused to work. Clearly, this study, which is still in the preliminary stage, is directly relevant to the present review. Consequently, they undertook a multivariate comparison of prehistoric buffalo phalanges from Ban Chiang with modern male and female animals known to have been used for ploughing. The values indicate that the prehistoric specimens are as robust as the modern ones. This situation does not, of course, prove that they were used for ploughing in prehistory. But, had they been markedly gracile, it would have undermined the hypothesis under discussion.

In his review of the human skeletal material from Non Nok Tha, Pietrusewsky (1974) has shown that the early sample had higher infant and child mortality, shorter life expectancy and lower mean age at death than the later burials. Moreover, 13 of the 24 crania examined exhibit porotic hyperostosis, a condition which may well provide indirect evidence for falciparium malaria, which acts to maintain such a pathology. Finally, by AD 200, tuberculosis of the spine was probably present, a condition requiring a population density great enough to provide the necessary medium to maintain the disease. Pietrusewsky hinted that wet rice cultivation may not only have entailed the water necessary to support the mosquito, but also have led to greater life expectancy and a denser population. More detailed conclusions based on the actual Ban Chiang material are now awaited.

Swidden Rice Cultivation and Broad Spectrum Foraging: 3500–1600 BC

In due course, it is anticipated that a study of the rice remains and pollen spectra will

further illuminate the Om Kaeo economy. If, however, it is conceded that the faunal spectrum is consistent with the presence of wet rice cultivation by the mid 2nd millennium BC, then the next question to be posed is the nature of the economy during the preceding two millennia. It should be noted that the remains of rice were found from the earliest levels at Ban Chiang, remains described by Yen (1976) as "on the pathway to the domestic variety", and by Chang (1976) as "intermediate between the weed and wild variety". The technology of period 1 included the casting of bronze implements and manufacture of stone and ceramic artifacts.

Given the fact that rice grows wild in marshy habitats in Northeast Thailand today (Akihima & Watabe, 1970), and the documentation through the gastropod and frog remains that permanent water was to be found near early Ban Chiang, it must be stressed that the first three cultural periods there could have seen extensive wild rice collection. If this was indeed the case, then the shallow margins of lakes and swamps would have been the logical place for that plant to have flourished. Doubtless intensive analysis of the rice remains will throw light on this possibility. A society which cast bronze tools, had a sophisticated pottery industry, maintained domestic stock but which collected rather than cultivated wild grasses would add a new dimension to theories on the origins of agriculture. There are, however, certain indications that such was not the case. Firstly, attention is drawn to the increase from period 1 in the number of cattle and deer. Pfeiffer (1968) has observed that forest clearance greatly favours the proliferation of large herbivores. Secondly, the consistent numbers of hares, small Indian civets and mongooses are consistent with a habitat incorporating areas of open terrain, probably with regenerating secondary forest. Again, the extraordinary rarity of mammals requiring denser woodland, such as the slow loris, squirrels and monkeys indicates either a rarity, or at the very least a lack of interest in animals associated with forest. If the period 1–3 faunal spectrum indicates anything, it would be the presence of a dry, deciduous woodland with open clearings within reach of permanent stands of water.

When we examine ethnographic data drawn from societies which today practise forest clearance to establish rice fields, we find a number of interesting facts. Thus Izikowitz (1951) has shown that the Lamet of northern Laos find it necessary to fence their fields and lay traps against marauding animals: spear traps for deer, gaur and wild pigs, and spring traps against rats and other small mammals. Thus the rice fields attract wild game, and trapping augments the food supply. The British Colonial Commission of Enquiry into game protection in Malaysia was told repeatedly of depredations in forest-ringed rice fields by the gaur and sambar deer. Moreover, when clearing woodland today in Northeast Thailand for rice fields, the landsnail *Hemiplecta* sp., which lives under tree roots, as well as the small tortoise (*Testudo elongata*), are found even after the area has been burnt over. Both species are present in period 1–3 levels.

A critical feature of swidden cultivation is that the fields rotate, but the settlement can be permanent over several generations. The Lamet, according to Izikowitz, use fields for rice just once, and then fallow for between 12 to 15 years, a village of 150 people needing just over 500 ha to allow permanent occupation. Given this supporting area, no rice field is further than 1·28 km from the home village. Prehistoric Ban Chiang would have offered certain advantages when compared with the hilly Lamet habitat. There was more extensive flat land, and the ebb and flow of seasonally full lakes would enrich agricultural land just as the Tonle Sap does on a greatly magnified scale today. An essential characteristic of such a swidden system however, is the area left under fallow. In the Lamet area, this is over 90% of all land under rotation for rice cultivation. It is precisely this regenerating vegetation which would, it is claimed, have favoured the small mammals such as hares and larger ungulates such as the gaur, banteng and deer.

Two further questions require consideration. Firstly, why should the small, open

fauna decline with the advent of wet rice cultivation, and secondly, could not domestic cattle have been used to draw hard wood or even bronze tipped ploughs during periods 1–3? The first point must be considered in relation to a basic fact concerning paddi cultivation. The essential nutrients for rice maturation are in nitrogen-fixing water-borne algae. Rice can be grown, practically indefinitely, on infertile soils provided that water is allowed to percolate slowly through the fields. In consequence, regenerating grass to secondary woodland associations characteristic of the swidden system are not needed under the paddi regime. The conversion from a swidden to a paddi system need not, however, affect the larger ungulates which can adapt to forest-fringe ecotones and exploit the rice fields unhindered during the dry season.

The second point draws attention to the degree of robustness found in the third phalanges of domestic cattle from periods 1–3 at Ban Chiang. As was the case for the water buffalo, a multivariate comparison was undertaken between these and modern specimens from animals known to have been used for traction, and those with no work history. The prehistoric specimens are all markedly gracile, and are most unlikely to have been used for work.

Speculations on the Origins of Rice Cultivation and Animal Husbandry in Northeast Thailand

Of fundamental importance, given the possibility that rice cultivation occurred with bronze technology and domestic stock raising during phase 1 at Ban Chiang, is evidence for the location and evolution of these developments. The simple answer at present is that we have no data despite much hypothesizing and some fieldwork. There are two main possibilities: either these innovations developed within the Sakon Nakhon Basin and we have yet to find the sites, or there was a process of movement into the basin and adaptation to local conditions.

Certain factors are held to favour the latter. The first refers to burial practices. Where Hoabinhian burial techniques are known, the body was interred in a flexed position (Gorman & Charoenwongsa, 1976). This technique occurred only during the early period at Ban Chiang, and changed thereafter to a fully extended posture. Since there was Hoabinhian occupation to the southeast and west of the Sakon Nakhon Basin, any group expanding on to it may have introduced traditional methods of burial.

Secondly, while tin and copper ores are not found on the basin, the first settlers at Ban Chiang were already proficient at bronze casting. It is held that early bronze technology (Charoenwongsa, 1976) is likely to have developed in close proximity to sources of ore.

The early faunal spectrum indicates that the first settlers were by no means specialized agriculturalists, but rather hunter-gatherer-fishers who maintained some domestic stock and probably grew some rice under the swidden system. The foraging component matches that documented for the upland Thai Hoabinhian. It is, however, necessary to allow some time for the establishment of domestic breeds of cattle and probably pigs prior to settlement of the basin. Again, the shape of the early canid mandibles from Ban Chiang has affinities with the wolf, *Canis lupus*, rather than the jackal, *Canis aureus*. Yet the wolf is not native to Southeast Asia. Indeed, the nearest indigenous wolves are to be found in India (*Canis lupus pallipes*) and China (*Canis lupus chanco*). It is thus hard to rule out contact of some sort with either or both of those areas, although the mechanics, whether it be immigration, diffusion, or a combination of both, is beyond the scope of the available data.

Taken in conjunction, all the above variables suggest that the culture of early Ban Chiang is exotic to the Sakon Nakhon Basin. The nearest known human settlement

prior to its occupation was the Hoabinhian of the upland wet evergreen forest in the Central Mountain chain to the west, where by *c.* 6000 BC, the occupants of Spirit Cave had access to pottery and polished quadrangular adzes. There is, therefore, a 2½ millennium hiatus between the appearance of these traits and the occupation of Ban Chiang during which one or more Hoabinhian groups could have undergone rapid cultural changes. The most attractive likely setting could have been a group exploiting lake and river margins, growing familiar with rice, bringing the behaviour of wild bovines under human influence, coming into contact with domestic dogs and experimenting with metal technology. Giving substance to such a hypothetical group is now the principal research objective in this area.

Implications and Conclusions

If the replacement of a swidden by a wet rice-plough system of producing rice has any validity, then it may well have influenced profoundly the pattern of Thai culture history. Swiddening relies more on rainfall than does the wet rice system, because basic to the latter is the retention and gradual circulation of water through small rice fields. There is no reason to expect that swiddening in Northeast Thailand is centrifugal in Heizer's sense, because stability of settlement is compatible with rotating fields provided that the population growth does not exceed the economic system's ability to provide the necessary energy. If, however, pressure on resources does develop under a swidden system, then either expansion within the same environmental province or intensification of produce may follow. One way of intensifying rice production is, of course, to expand the area under cultivation and maximize the essential commodity, water. An inundation system without animal traction is possible, but the increased acreage would demand an expanded labour input. Ploughing reduces competition by killing weeds at the critical commencement of the rainy season and increases production by aerating soil. Moreover, wet rice cultivation is open to many further methods of increasing returns, including transplanting, ploughing in the previous year's stubble, mucking out farm manure, allowing animals to graze dry season grasses, harrowing and regulating water flows to harmonize with the growing plant's requirements. Most critically, the step from swiddening to wet rice cultivation is not conceptually complex, since it is principally a method of expanding low wetlands by arresting natural drainage patterns. The essential prerequisite, namely an extensive, gently sloping terrain is present in all known Ban Chiang type sites. Naturally, iron expedites the application of wet rice methods, but the technology, even today, does not extend beyond an iron digging implement and an iron ploughshare attached to a plough made from local hardwood.

As one proceeds southwards from the Mekong to the Dang Raek Mountains, the rain shadow effect of the Petchabun Mountains increases and rainfall, particularly in the Korat Basin, declines sharply. The only intensive site survey undertaken there was in Roi Et Province (Higham, 1977*a*). The earliest occupation there was dated to *c.* 500 BC. A further problem is the extent to which iron and animal traction in conjunction may have permitted settlement in the margins of the Bangkok Plain. Again, only one excavation has relevance, that of Chansen. Bronson & Dales (1973) report an initial occupation by *c.* 800 BC. It will be most interesting if Welch's planned research in the Upper Mun Valley confirms the late occupation of areas now among the most densely populated in the Kingdom. Currently, we don't know whether the Om Kaeo innovation described above occurred in the Sakon Nakhon Basin, or whether initial occupation of the Korat Basin reflects expansion from elsewhere. Many more faunal spectra from sites like Ban Chiang will be necessary, together with pollen and associated biological studies, before the results outlined above are confirmed or modified.

The Ban Chiang and associated faunal spectra from Ban Phak Top, Don Klang and Ban Tong suggest certain economic trends between 3500 BC and the present. At all periods, raising domestic and hunting wild cattle and pigs, together with hunting three species of deer, provided most of the edible meat until firearms and more intensive forest clearance during the past century led to the local extinction of large game animals. Being an omnivore, the numbers of pigs varied little with time. The proportion of large herbivores however, showed an increase with time, a process attributed to progressive forest clearance. During phases 1–3, the small mammalia, molluscs and fish remains indicate an environment with lakes and swamps fed by permanent, clear streams and within which, forest clearance was under way. This pattern is compatible with swidden farming, presumably for rice and possibly other crops.

During phase 4, that is *c.* 1600 BC, iron technology and the water buffalo were present. The drastic reduction in aquatic species probably reflects quickening forest clearance and reduction in standing water. Cultivation of rice by impounding rainwater in permanent fields is compatible with the above pattern. Water buffalo bones show stress areas indicative of certainly traction, and probably ploughing. This type of economy appears to have continued to the present day although religious and cultural changes occurred in the interim.

The advent of ploughing and impounding rain water within rice fields may well have encouraged agricultural settlement in the relatively arid Korat Basin and the margins of the Bangkok Plain. The earliest occupation of those areas post dates the presence of iron and water buffalo at Ban Chiang (Higham, 1977*a*).

There is no evidence to suggest that the dams, reservoirs and canals which were a basic feature of the Funan and Khmer economies from the beginning of the Christian era south of the Dang Raek Mountains ever reached the Sakon Nakhon Basin (Malleret, 1959–1963; Paris, 1931). Khmer settlement of the Mun Valley however, assuredly brought knowledge of, and quite probably the practice of intensive reservoir fed irrigation into the Southern Korat Plateau, by AD 1000 (see Figure 3).

During all periods at Ban Chiang, the occupants of the site practised fishing, hunting, collecting and trapping in conjunction with agriculture. This mixed economy continued to within living memory, and elements persist to this day. Fishing by net, trap and line are common in the wet season, mollusc and frog collecting continue, and the plants of the riverbank and scrub forest supplement food supplies in the early wet season. Fifty years ago, however, much more land was under forest, and water courses were permanent, allowing fishing even during the dry season. There followed replacement of the forest by rice fields and intensified hunting with firearms, such that wild animals which for 5500 years contributed much to the diet, are now only a memory. Crucial faunal resources are now very much more impoverished, human settlement denser, and the habitat more extreme than at any time in the past. Nevertheless, no one can recall a food shortage. Sechan Yaysomanang said that his grandfather came to Ban Chiang because there was plenty of everything. This land has provided for 5½ millennia of human occupation, but for how much longer is an open question.

Summary

The Ban Chiang sequence illuminates aspects of culture change which may have had widespread parallels in similar environmental areas in Southeast Asia. These allow the first images of a pattern to be perceived. It begins with the familiar Hoabinhian techno-complex, which, at least in northern Thailand, concentrated in the evergreen forested uplands. The first occupation of the Sakon Nakhon Basin, which was probably under dry deciduous dipterocarp forest at the time, occurred in the 4th millennium BC. The

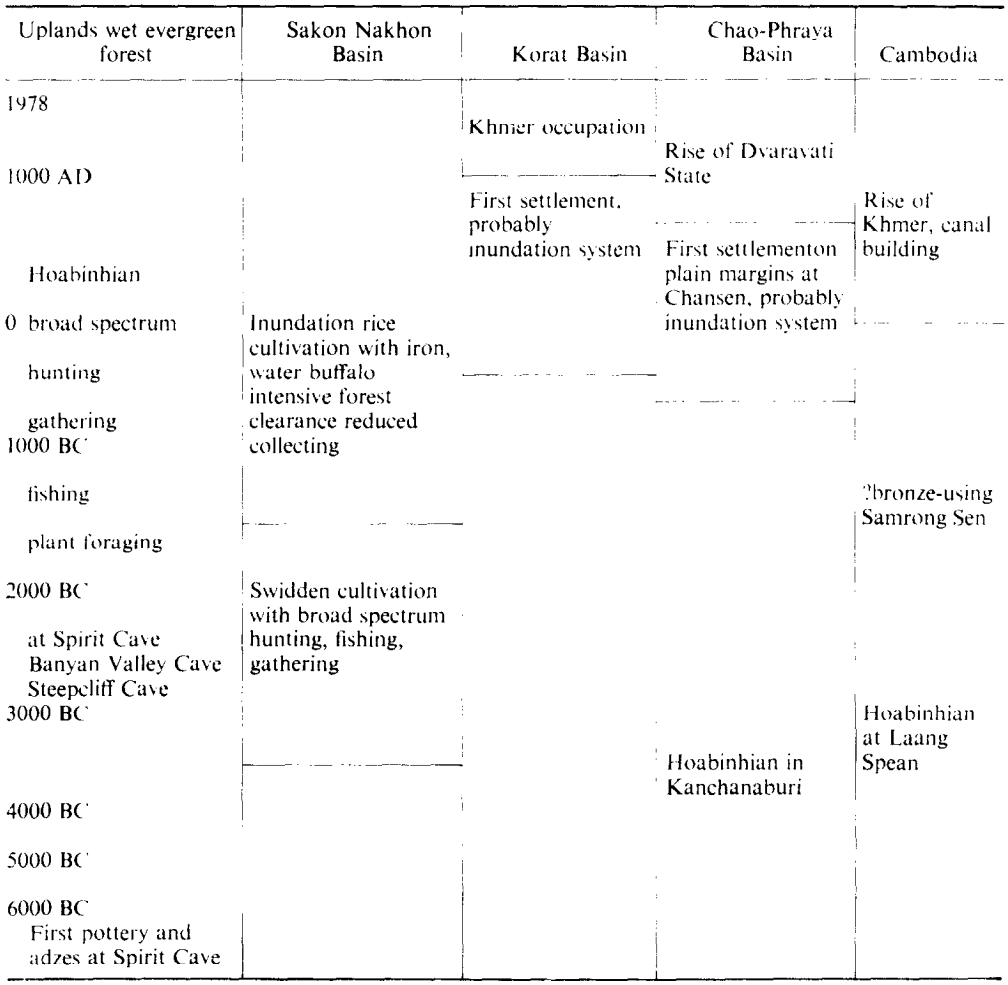

Figure 3. A summary of settlement and economic trends in Mainland South-east Asia: 11,000 BC—historic period.

culture in question incorporated inhumation burial, sophisticated pottery and bronze casting, an exotic domesticate (the dog), domestic cattle and pig, probably rice grown under the swidden system, and broad-range hunting and gathering and fishing.

By the mid 2nd-millennium, there was a marked technological and economic discontinuity with the advent of iron and the water buffalo, which has been interpreted as indicating ploughing and the inundation system of rice cultivation. Shortly thereafter, the first settlement of the Korat Basin and Chao Phraya Basin occurred. Higham (1977*a*) proposed that the first settlement of the Korat Basin may have reflected a build-up of population pressure in the small, but relatively well watered enclave of the Sakon Nakhon Basin. The present paper indicates that during the millennium prior to settlement there, the occupants of Ban Chiang were familiar with a technique of growing rice that would have pre-adapted them to the occupation of the more arid Korat Basin, and gives thereby a good reason for such an expansion being possible. Moreover,

Pietrusewsky (1974) has suggested that the possible presence of tuberculosis of the spine at Non Nok Tha by at least 200 AD indicates a reasonable population density.

About 2000 years ago, there is evidence that large scale water-diversion works were underway in the Transbassac, to drain the Mekong Delta. Trade relations with India and, later, China were active. The problem of water diversion and retention were certainly overcome by the Khmer of the Tonle Sap area, and probably by the Dvaravati of the Chao Phraya Basin. This allowed multiple cropping, and was associated with a state system of water control as well as marked social stratification.

Both Khmer and Dvaravati states impinged on to the Korat Plateau, but this concentrated in the Korat Basin. The establishment of Phimai (*c.* 1000 AD) and many other Khmer centres probably saw the introduction of Khmer techniques of water conservation and control, but there is no evidence for such techniques being employed as far north as Ban Chiang.

It is self evident that the above bare outline of economic and technological trends leaves many gaps, not least the origin of the period 1 culture at Ban Chiang and the indigenous development, if any, of water diversion and storage south of the Dang Raek Range and within the Chao Phraya Basin. Provided the present outline stimulates further research, it will have achieved its objective.

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