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Abstract

An exciting topic in the prehistory of Mainland Southeast Asia (MSEA) is where, when and why matriliney/matrilocality existed in certain regions during the rise of complex societies. Linguistic and genetic evidence have been used to infer kinship questions on a broad, continental scale. To contribute to this discussion on the site scale, here we summarize and compare, for the first time, almost two decades of isotopic work on prehistoric skeletons from across the region. For comparability of mobility patterns between sexes and between sites, we introduce simple normalized conversions of the (strontium, oxygen and carbon) isotopic data. Taking the evidence together, we find support for our hypothesis that matriliney/matrilocality was most likely at times and places with maritime or riverine trade, as exhibited at several coastal/deltaic sites of Thailand and Vietnam. In any case, there is an exciting future ahead for multi-method investigations into prehistoric kinship and social differentiation in Southeast Asia.

Keywords	Matrilocality; Thailand; Myanmar; Vietnam; Neolithic; Bronze Age; strontium isotopes
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“Kinship and migration in prehistoric Mainland Southeast Asia: An overview of isotopic evidence”
R. Alexander Bentley, Baptiste Pradier, Aung Aung Kyaw, Thomas Oliver Pryce

Professor Lisa Kealhofer
Associate Editor, *Archaeological Research in Asia*

10 August, 2020

Dear Professor Kealhofer:

We would like to submit our paper, “Kinship and migration in prehistoric Mainland Southeast Asia: An overview of isotopic evidence” to *Archaeological Research in Asia*, with 7,000 words, 104 references, eight figures, and two tables.

This paper was originally prepared by invitation from Chin-hsin Liu and Vince Pigott for the *ARiA* special issue you had accepted in January 2020, “Paradigms shift: New interpretations in mainland Southeast Asian Archaeology.” We understand this special issue has just been cancelled, so we would like to submit our paper as a regular submission.

Although written by invitation, this is by no means a simple review. By synthesizing available isotopic evidence, for the first time, from prehistoric sites in MSEA over the past two decades, we were able to make unique new conclusions from the aggregated evidence, particularly when viewed in context with rapidly-evolving archaeological, genetic and linguistic evidence from MSEA.

Specifically, we explore temporal and spatial patterns of potential matriline/matrilocal in prehistoric MSEA. Taking the evidence together, we find support for our hypothesis that matriline/matrilocal was most likely at times and places with maritime or riverine trade, as exhibited at several coastal/deltaic sites of the region. Hence while the paper began as a review, it turned into an exciting, multidisciplinary exploration of prehistoric kinship and social differentiation in Southeast Asia.

We hope that you will consider our paper for *Archaeological Research in Asia*.

Sincerely yours,



R. Alexander Bentley

Kinship and migration in prehistoric Mainland Southeast Asia: An overview of isotopic evidence

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An exciting topic in the prehistory of Mainland Southeast Asia (MSEA) is where, when and why matriliney/matrilocalty existed in certain regions during the rise of complex societies. Linguistic and genetic evidence have been used to infer kinship questions on a broad, continental scale. To contribute to this discussion on the site scale, here we summarize and compare, for the first time, almost two decades of isotopic work on prehistoric skeletons from across the region. For comparability of mobility patterns between sexes and between sites, we introduce simple normalized conversions of the (strontium, oxygen and carbon) isotopic data. Taking the evidence together, we find support for our hypothesis that matriliney/matrilocalty was most likely at times and places with maritime or riverine trade, as exhibited at several coastal/deltaic sites of Thailand and Vietnam. In any case, there is an exciting future ahead for multi-method investigations into prehistoric kinship and social differentiation in Southeast Asia.

In most regions of the world, the prehistoric rise of complex societies was initiated by the transition from hunting-gathering to intensified agriculture, which typically instigated a millennia-long process of increasing population densities, permanent settlements, specialization of subsistence and craft activities, local and long-distance exchange, and heritable wealth inequality. In some regions—such as sub-Saharan Africa from about 5,000 BP, Oceania from about 3,500 BP, central Europe from about 7,500 BP, out of central China from about 7,000 BP (Bellwood 2005; Cobo et al. 2019; Higham 2019)— agricultural practices diffused rapidly and fairly completely, displacing indigenous foraging systems. In other regions, including Mainland Southeast Asia (MSEA), hunting and gathering persisted alongside agriculture, often amid more flexible broad-based subsistence systems, for many centuries after the arrival of agriculture (Bellwood 2005; Griffin 1984; Headland and Reid 1989; Hoffman 1984; Pietrusewsky and Douglas 2002).

In MSEA, archaeological, linguistic and genetic evidence support two demographic expansions from southern China in recent millennia. Ancient DNA patterns reflect agriculture being first

practiced in MSEA (east of Myanmar) by probable Austroasiatic speaking migrants from southern China, with subsequent contact and admixture with hunter-gatherers (Lipson et al. 2018; McColl et al. 2018). The expansion of farming communities out of the Yangtze Valley probably took a maritime route along the coast of Fujian (Higham 2019), reaching Thailand, Cambodia Vietnam starting in the late third millennium BC (Bellwood 2014; Cobo et al. 2019; Lipson et al. 2018; McColl et al. 2018; Zhang & Hung 2010). In Myanmar, ancient DNA evidence (Lipson et al. 2018) and archaeological evidence (Dal Martello et 2018, Li et al 2016) tentatively suggest that agriculture arrived via a second pathway from China through Yunnan.

Following the demic diffusion of farming, originating in China, proto-state societies in Thailand and Vietnam began forming in late 3rd/early 2nd millennium BC. There, the rise in social complexity—intensification of agriculture, wealth inequality, specialized pottery industries accelerated in the Bronze Age, second millennium BC, stimulated at least in part by the production, exchange and consumption of copper-base artefacts (e.g. Higham et al. 2019a; O’Reilly 2008, Pryce et al. 2014, 2018). The Iron Age, or protohistoric period (c. 500 BC – AD 500) is associated with evidence for warfare, intensified maritime exchange with East and South Asia via incipient littoral urban settlements, and the indigenous origins of state societies (Bellina et al. 2018; Stark 2006a; Kim 2013, 2015), coeval with the appearance of iron tools and weapons, and glass. Ever more closely interconnected exchange systems led to exotic items and commodities dispersing far inland along riverine routes (Higham 2014:266–269; Higham et al. 2019b; O’Reilly 2014; Pryce & Bellina 2018 ARA; Stark 2006a).

An important question in this process is the co-evolution of kinship systems with social transformation. As a general theory, we expect that kinship systems were *the* social organizing system in pre-modern societies, determining (or strongly affecting) not just relationships but wealth inheritance, subsistence, conflict and cooperation, exchange of food and exotic items, specialization and power relations (e.g. Ensor 2011; Fox 1983; Holden et al. 2003; Hrdy 2010).

In contrast with the evidence for patriliney and patrilocality in the European Neolithic and Bronze Age (e.g., Bentley et al. 2012; Mittnik et al. 2019; Feinman and Neitzel 2019), the rise of complex societies in MSEA appears to have occurred in contexts where kinship, subsistence and wealth

transmission were more flexible and heterogeneous (Fox 1983; Jordan et al. 2009; Ledgerwood 1995; Malinowski 1932; Mills 1997; Rácz et al. 2020; Reid 1988). A useful interpretive framework for this is the daughter-biased investment model for matriliney (Holden et al. 2003), which predicts matrilineal descent when there are high levels of paternity uncertainty and thus incentive to invest in daughters. This implies that the relationship between kinship, subsistence and economics is dynamic and adaptive (e.g. Fox 1983; Jordan et al. 2009). The introduction of cattle, for example, into a matrilineal horticultural society may tilt the economic priorities to favor patriliney over time, matriliney tends to be replaced by son-biased inheritance (e.g. Aberle 1961; Holden and Mace 2003; Opie et al. 2014).

On the other hand, prolonged male absence for purposes of trade, warfare, subsistence or long-distance voyaging, should favor matrilocal residence and matrilineal descent by leaving the women to manage the interests of the kin group (Fox 1983; Hage and Marck 2003; Jordan et al. 2009). As Hage and Marck (2003: S123) point out,

“In matrilineal societies, paternity is not an overriding issue. It matters little who the father is, since only women continue the lineage. In the Micronesian and larger Oceanic context, if husbands and fathers were lost (always a possibility in seafaring) they could be readily replaced by other men.”

Although they were discussing Island Southeast Asia (ISEA), we may hypothesize that coastal sites in MSEA, and potentially riverine sites within extensive exchange networks, would have the best likelihood of exhibiting matrilocality/matriliny. In particular, women producing exchangeable pottery, becoming more wealthy and prestigious, would tend to reinforce the matriline, especially in maritime exchange systems (Hage and Marck 2003; Holden et al. 2003; Lepowsky 1983; Petersen 2009:48).

Regionally, genetic and linguistic evidence indicate kinship systems were chrono-spatially heterogeneous across MSEA and ISEA. The coasts were likely an avenue for regional interaction. As Yang et al. (2020, p. 6) conclude, “[genetic] affinities between populations along the eastern coast of Asia (and island populations off the coast) that are not shared by more-inland Asian populations suggest that interactions along marine-related environments played an important role in the prehistory of coastal Asia.” While palaeo-genetic evidence indicates that Austroasiatic and

Tai-Kadai groups were mostly patrilocal (Kutanan et al. 2019; Lipson et al. 2018), genetic studies of a more diverse range of modern populations in MSEA—comparing within-population versus between-population diversity in mtDNA (matriline) versus Y chromosome (patriline)—have revealed both matrilineal and patrilineal patterns (Oota et al. 2001; Kutanan et al. 2019).

Testing kinship patterns at site scale invokes the spatial and temporal resolution of archaeological evidence (e.g., Rodning 2011; Ensor 2011). In recent decades, isotopic analysis of human remains offers a more direct analysis of prehistoric kinship. From burials of Neolithic and early Bronze Age central Europe, for example, strontium, oxygen and carbon isotope measurements in human tooth enamel, from a variety of sites and contexts, reveal patrilineal patterns—significantly more local isotopic signatures among males than females (e.g., Bentley et al. 2012; Bentley 2013; Mittnik et al. 2019; Schroeder et al. 2019). Although ancient DNA preserves poorly in subtropical Southeast Asia (Lipson et al. 2018; McColl et al. 2018), isotopic evidence in human remains is effective on its own, and can be interpreted in concert with burial goods and practices, heritable skeletal traits and other contextual information (e.g., Bentley et al. 2008; Bentley et al. 2009, 2012; Cox et al. 2010; Huffer et al. 2021; Ikehara-Quebral et al. 2017; Knipper et al. 2017).

Table 1. Isotopic studies reviewed and re-evaluated in this paper. The middle column shows number of human individuals in the sample, *N*, broken down into sexed females, males and unsexed (usually subadults).

Site	Dates	<i>N</i> (F, M, U)	Isotopes	References
Con Co Ngua	4250 BC (6,500-6,000 BP)	40 (21, 16, 3)	Sr	Huffer et al. (2021)
Khok Phanom Di	2100–1500 BC	70 (30, 23, 17)	Sr, C, O	Bentley et al. (2007)
Man Bac	1800 BC (3,800-3,600 BP)	27 (10, 15, 2)	Sr	Huffer et al. (2021)
BNW	1750 BC - AD 400	97 (48, 42, 7)	Sr, C, O	King et al. (2013, 2014, 2015)
BLK	1250 - 900 BC	27 (15, 12, 0)	Sr, C, O	Bentley et al. (2009)
Ban Chiang	early 1st mill. BC	41 (16, 24, 0)	Sr, C, O	Bentley et al. (2005)
Oakaie 1	12th to 8th c. BCE	13 (6, 4, 3)	Sr	Bentley et al. (2018)
NUL	300 BC - AD 500	34 (14, 17, 3)	Sr, C, O	Cox et al. (2010)
Vat Komnou	200 BC to AD 200	10 (5, 5, 0)	Sr, C, O	Ikehara-Quebral et al. (2017)

Of course, compared to prehistoric Europe, much less isotopic work has been done in MSEA or ISEA. Over a decade ago, isotopic evidence from Ban Chiang (Bentley et al. 2005) and Khok

Phanom Di (Bentley et al. 2007) in Thailand was interpreted as suggestive of a transition to a matrilineal kinship system. Here we re-visit these interpretations as well as review circa fifteen years of isotopic analyses of human remains in northeast Thailand, as well as Cambodia, Vietnam and Myanmar (Table 1).

Looking at the studies to date (Table 1), we now have a chance to compare the isotopic results from ten sites across MSEA (Figure 1). As some sites with small samples (Table 1) might not be statistically significant on their own, they may still contribute to our interpretation of regional trends, such as whether evidence for matrilineality appears more likely at the coastal/deltaic sites.

The sites in Table 1 span dates from about 4,000 BC to perhaps AD 800. Strontium isotopes in teeth from human remains were measured at all of the sites in Table 1, and at six of these sites strontium, carbon and oxygen isotopes were measured. Because the difference between sexed individual skeletons is our focus, all the results we will display are for adults. Two of the sites—Man Bac and Khok Phanom Di—lie on coastal river deltas, and one—Vat Komnou (ca. 200 BC to AD 200) at Angkor Borei in Cambodia—is located on a river network linked to the nearby Mekong Delta (Figure 1).

Figure 1

Further inland, three sites—Ban Lum Khao (ca. 1250 - 900 BC), Noen-U-Loke (ca. 300 BC - AD 500) and Ban Non Wat (ca. 1750 BC - AD 400) lie in the Upper Mun River Valley on the Khorat Plateau of northeast Thailand. Ban Chiang, further north on the Khorat Plateau, dates to the first millennium BC. Three sites—Khok Phanom Di, Ban Chiang, and Ban Non Wat—provide a temporal dimension through samples from different mortuary phases. Finally, we have preliminary data from Oakaie 1 in central Myanmar (Pradier et al 2019), and discuss future research at the UNESCO-listed multi-period site (mid-3rd mill. BC to early-2nd mill. AD) of Halin.

A synthetic approach to isotopic studies at multiple sites

Before reviewing the evidence from MSEA, we describe our approach to the interpretation of strontium isotope ratios in human remains—with all data reported here being values from tooth

enamel. The isotopic ratio $^{87}\text{Sr}/^{86}\text{Sr}$ in human tooth enamel reflects a weighted mixture of the food/water sources and geologic environment(s) in which the person's food was obtained during the years the tooth enamel formed (Bentley 2006; Ericson 1985; Montgomery 2010). The geology and geography of MSEA is vast and complex, as described in the respective site-specific publications listed in Table 1. Hence the expected isotopic baselines are quite different at sites across MSEA. At Khok Phanom Di, for example, the local individuals have $^{87}\text{Sr}/^{86}\text{Sr}$ just above the seawater value of 0.7092, whereas the individuals from Ban Chiang, on northern Khorat Plateau, have a mean $^{87}\text{Sr}/^{86}\text{Sr}$ of about 0.7117. This might seem like a small difference in $^{87}\text{Sr}/^{86}\text{Sr}$, but it can be substantial in terms of the standard deviation among humans at different sites – the standard deviation in $^{87}\text{Sr}/^{86}\text{Sr}$ among the 17 sampled children at Khok Phanom Di, for example, was just 0.00005 over the seven mortuary phases (Bentley et al. 2007).

The baseline oxygen isotope value will also vary from site to site in MSEA, but unfortunately in less predictable ways, due to multiple subtropical factors including atmospheric circulation, distance from the sea, altitude, water source, rain shadows and others (e.g., Kohn 1996; Krigbaum 2003; Poage and Chamberlain 2001). For this reason, we do not plot oxygen isotope data for most sites we review here (except one plot for Vat Komnou). In contrast, carbon isotope ratios are mostly determined by dietary sources, with deviations on the order of 1‰ due to elevation, humidity and other factors (Heaton 1999).

We expect most sedentary human groups tend to have identifiable clusters of Sr and C isotope ratios, in terms the mean and variance in each group's set of isotope values, which results from an averaging of the logistic, dietary and subsistence habits of the group (e.g. Bentley 2006; Bentley et al. 2004, 2007, 2008). These groups tend to appear in the data as arrays or clusters of data points on bi-variate plots of different isotope ratios (Montgomery et al. 2007; King et al. 2013), or by more formal cluster analysis (Huffer et al. 2021). In groups of individuals whose diet involves different end-members—such as rice cultivated in one location and protein obtained from another— their Sr or O isotope ratios, which reflect geographic parameters, will often correlate with C isotope ratios, which reflect differences in diet.

Most productively, the analysis of $^{87}\text{Sr}/^{86}\text{Sr}$ in human tooth enamel is directed toward a large sample of individuals (e.g. Bentley et al. 2004; Knipper et al. 2017). This allows the interpretation of the data not just in terms of regional geology, but also in terms of human groups (Bentley 2006). We expect that the human isotope values from one site will be normally distributed with a mode that corresponds to the local group (Bentley et al. 2004). With this basis, in order to compare isotope results across MSEA sites, can normalize the strontium, oxygen and carbon isotopic data as z -scores, which we will designate as $z\text{Sr}$, $z\text{O}$ and $z\text{C}$. Here we convert all Sr, C and O isotope ratios from the sites listed in Table 1 to a distance from the mean value at the site. Using the mean and standard deviation among all individuals at each site, each isotope ratio is thus expressed as a z -score, in units of standard deviation away from the site mean (cf. Bentley et al. 2012). We denote our conversion of isotope ratios to z -scores $z\text{Sr}$ and $z\text{C}$, where $zR = (R_i - \bar{R})/s$, where R_i is the isotope value ($^{87}\text{Sr}/^{86}\text{Sr}$ or $\delta^{13}\text{C}$) for an individual sample, i , \bar{R} is the mean isotope value for the site, and s is the standard deviation of that site-specific mean. This conversion to z -scores allows better comparison between sites and also allows us to view the distribution of $z\text{Sr}$ (density distribution plot) by sex at each site. The sharper the peak in the distribution of $z\text{Sr}$, the less variance there is in the variance of $^{87}\text{Sr}/^{86}\text{Sr}$; this helps to identify samples where females have less variance in strontium isotope signatures, potentially due to matrilocality.

Our main purpose is to identify differences of patterning between females versus males at each site. With an adequate sample size of individuals, grouped by sexed skeletons, systematic differences in isotopic variance among females versus males can potentially be indicative of patrilocal versus matrilocality residence (e.g. Knipper et al. 2017). Together with an overall synthesis of all the site-specific findings (Table 1), here we will show bi-variate plots of $z\text{Sr}$ versus $z\text{C}$ for sexed skeletons at each site. Along with statistical tests (e.g. Levene's test), the density distribution of $z\text{Sr}$, in the inset of each plot, will help determine if the pattern of strontium isotope variation is larger for males, indicating a candidate site for matrilocality. If variation were larger for females, we might have a candidate site for patrilocal residence. Among the sites in Table 1, the goal is to look for broader chronological and/or geographical patterning in these designations, testing our prediction of matrilocality residence at the coastal/deltaic sites.

Coastal/deltaic sites

We start with two contemporaneous coastal sites, Khok Phanom Di (KPD, ca. 4000–3500 BP) and Man Bac (c. 4100 to 3600 B.P.), on the Chao Phraya River Plain and Red River Delta, respectively, separated by ca. 1500 km by land or about 3000 km along the coast.

Khok Phanom Di (KPD), excavated in 1984-1985, was a stratified prehistoric mound, seven meters deep, on the Bangkok Plain in Thailand. Occupied between during the early second millennium BC, the site included shell middens, occupation and industrial remains, and human inhumation graves across multiple mortuary phases (Higham and Thosarat 1994). In human remains from the first six mortuary phases (MP 1 to MP 6), Sr, O and C isotopes were measured in 30 adult females, 23 adult males and 17 children of unidentified sex. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for all the males fall within a narrow range (0.70934 ± 0.00009 , $N = 23$) that is near the seawater value of 0.7092 and consistent with maritime subsistence supplemented by some terrestrial foods (Bentley et al. 2007).

The overall picture from early KPD (before MP IV) is one of female immigration (Bentley et al. 2007). In samples from MP II to MP III, the several adult females who appear in a diagonal array on the plot of zC vs zSr (Figure 2, left) were also of taller stature than the other KPD females (Bentley et al. 2007). For KPD phases MP I – III, the mean zSr is higher for females than for males ($p=0.003$, two-tailed t-test), as seen by the different peaks in the inset of Figure 2, left. During and after MP IV at KPD, however, the pattern among females changes abruptly. At MP IV, the variance in female zSr became significantly reduced to within the narrow range that characterizes males (Figure 2, right). From MP IV – VI at KPD there was also a reduction in the range of zO for both sexes (Bentley et al. 2007). In phases MP IV to MP VI, the zC values from both sexes show a somewhat broader range than in the preceding mortuary phases (Figure 2). In these later KPD mortuary phases, there is no longer any significant difference in mean zSr, zO or zC. If we compare late KPD (MP IV-VI) to early KPD (MP II-III), the variance in zSr is larger for females than males for KPD early ($p=0.003$, Brown-Forsythe test, $\alpha = 0.05$), but not for late KPD ($p=0.85$).

Figure 2

The isotopic evidence for this transition at KPD aligns with the independent assessment of Higham and Thorsarat (1994, 103–10), who identified an “increasing matrilocality aspect to the later people at Khok Phanom Di” from MP 4, based on the mortuary evidence for female craft specialists and venerated women in the community. Concurrent with these isotopic changes was a differentiation in burial treatments for males and females that began in MP4 (Higham 2002, 72–81). From MP IV to MP VI, richly-furnished female burials, including the so-called the “Princess” from MP V (Higham and Thorsarat 1994), who yielded $^{87}\text{Sr}/^{86}\text{Sr}$ ratios within the tight cluster (Figure 2, right). In summary, a sharp reduction in the variance of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios among females at Khok Phanom Di occurred in the same mortuary phase (MP 4) when burial contexts became differentiated by sex.

We turn to our second deltaic site, Man Bac, dated to ca. 3,800-3,600 BP, located south of the Red River Delta in northern Vietnam (Figure 1). The archaeology of this early Neolithic living and cemetery site indicates that the Man Bac population was engaged in broad spectrum foraging, including marine and farming subsistence, and also traded extensively from its delta setting (Oxenham and Matsumura 2011). The skeletal sample indicates genetic exchange between more northerly originating migrants and local indigenous groups (Oxenham and Matsumura 2011; Willis and Oxenham 2013). Ancient DNA evidence suggests that early farmers from Man Bac had a mixture of southern Chinese farmers and eastern Eurasian hunter-gatherer ancestry, similar to modern-day Austroasiatic speakers as far south as Indonesia reflecting "an expansive initial spread of Austroasiatic languages" (Lipson et al. 2018: 92).

At Man Bac, strontium isotopes were obtained from teeth of the 26 adults together with non-metric dental and cranial traits (Huffer et al. 2021). As at KPD, the overall $^{87}\text{Sr}/^{86}\text{Sr}$ ratios at Man Bac were low in variance, and not just due to location; in human remains at Con Co Ngua, also on the Red River Delta, ratios are more variable than at Man Bac (Figure 3). Consistent with hypothesis of matrilocality residence, the sampled Man Bac adult females yielded a significantly lower variance in $^{87}\text{Sr}/^{86}\text{Sr}$ than the males (Huffer et al. 2021); the standard deviation among the Man Bac female $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (0.00005) is less than half that among males (0.00012, excluding one outlier male). Figure 3 shows the data in zSr form. In the Man Bac sample, even when we exclude one male

outlier, the variance in zSr among males is significantly larger than for females ($p = 0.01$, Levene's test). From the heritable trait analysis, six putative kin lineages were identified at Man Bac, but without notable spatial clustering in the cemetery (Huffer et al. 2021).

Figure 3

The Vat Komnou cemetery, associated with the Angkor Borei site on the western Mekong Delta in Cambodia (Figure 1), dates from 200 BC to AD 200 (Stark 2006b). Closer to the sea than it is today—the Mekong Delta has since prograded—Angkor Borei was connected to Óc Eo, the port city of the kingdom of Funan, by rivers and canals (Stark 2003). The Vat Komnou population was thus engaged in the emerging international maritime trade associated with early state formation of Funan in the Mekong Delta (Stark 2006a). Beads made of glass from South Asia, for example, were recovered at sites along the and Thai-Malay Peninsula (Dussubieux and Bellina 2017) and in the Vat Komnou cemetery discussed here (Carter et al. in press; Ikehara-Quebral et al. 2017).

Although both sexes at Vat Komnou were similar in terms of ceramics in their graves and teeth stains from chewing betel nut (Ikehara-Quebral et al. 2017), females exhibit some distinctions. The adult female in Burial 44, for example, was interred with an elaborate bead assortment of beads made gold, garnet, carnelian, and glass. Ikehara-Quebral et al. (2017) report advanced levels of dental calculus (calcified tooth plaque produced via the oral microbiome) for half as many females (13%) as males (26%), suggesting unspecified dietary differences. The distribution of degenerative joint diseases at Vat Komnou suggest female activities stressed the back, whereas male activities stressed the neck, shoulder and feet (Ikehara-Quebral et al. 2018).

Of the 33 primary burials excavated at Vat Komnou, Sr, C and O isotopes were obtained from just nine individuals (Figure 4, left). Although the Vat Komnou sample is small, and the variances in zSr are not significantly different by sex, a grouping of females emerges on a plot of the ratios zO/zC versus zSr/zC (Figure 4, right). Compared to this group, all but one of the isotopic outliers are male (Figure 4), including a male (Burial 36) whose tooth $\delta^{18}\text{O}$ value suggests he migrated from northern uplands, possibly the Khorat Plateau (Ikehara-Quebral et al. 2018). Although about

a sixth of both males and females exhibited deliberate tooth filing at Vat Komnou (Ikehara-Quebral et al. 2018), including three within the main isotope cluster, there is just one (Burial 36) among the outliers. Out of nine Vat Komnou individuals with these ratios—four locals being 4:1 female, outliers 3:1 male—females were more likely to be in the local cluster ($p < 0.10$, chi-squared = 2.72).

Figure 4

Inland sites

Having reviewed the three coastal/deltaic sites, we now turn to several inland sites in northeast Thailand. We start with Ban Chiang, on the northern Khorat Plateau, whose excavations of the 1960s and 1970s yielded two cemeteries with over 140 burials across ten burial phases, beginning with Neolithic phases Early Period (EP) I and EP II (Higham et al. 2015). The single EP I burial has been radiocarbon dated between 1600–1450 BC (Higham et al. 2015). Bronze first appears in EP III, ca. 1,000 BC, and EP III-IV represent the earlier Bronze Age (Higham et al. 2015). Later Bronze Age burials, with a different spatial orientation, from EP V to Middle Period (MP) VIII (Higham et al. 2015). The Bronze Age EP V phase began between 890–835 BC and lasted anywhere between 60 to 375 years (Higham et al. 2015). These most recent radiocarbon dates, which are a millennium later than previous dating of the site (e.g., White & Hamilton 2009, 2018), bringing the site's developments more in parallel with those on the Upper Mun River valley as well as Non Nok Tha in central Thailand (Higham and Higham 2009; Higham et al. 2011; Higham et al. 2015).

Grave goods at Ban Chiang included pottery, bone tools, clay beads, stone tools, bracelets and pigs and cow bones. The prehistoric villagers of Ban Chiang had domesticated rice and animals but did not farm intensively, instead maintaining a broad-based subsistence system (Pietruszewsky & Douglas (2002). Evidence from faunal and plant remains indicate subsistence of hunting, gathering and fishing for centuries with a gradual increase reliance on domesticated rice, yams and domestic animals (Higham & Kijngam 1979; White et al. 2004), although without the typical changes

expected from the skeletal assemblage, such as shorter stature, increased fertility, dental caries or traumatic injury (Pietruszewsky & Douglas 2002).

Looking at the isotope data from early burial phases of Ban Chiang from EP I to EP IV (Figure 5, left), there is no significant difference between females and males in terms of either mean or variance in zSr or zC. A notable change occurs in EP V-VI (Figure 5, right), when females exhibit a narrow range of zSr, as indicated by the sharp peak in the density distribution for females (Figure 5 right inset). In EP V to EP VI, females have significantly less variance than males in zSr ($p = 0.083$ by Levene's test; $p = 0.002$ by Bartlett's test). In contrast to EP II-IV, there were no significant differences by sex in zO (or zC) among burials from EP V to EP VI.

Figure 5

Hence, like the change at Khok Phanom Di, isotope results at Ban Chiang suggest a transition at EP V, when the range of $^{87}\text{Sr}/^{86}\text{Sr}$ among females became considerably reduced. Notably, the predominant cardinal orientations of the graves underwent a change from burial phase EPV onwards, having been mainly along a north/south axis before EP V (Pietruszewsky & Douglas 2002).

We now turn to isotopic data from human remains from three sites on the Upper Mun River Valley (UMRV) of north-eastern Thailand: Ban Lum Khao, Noen-U-Loke, and Ban Non Wat (Table 1). These three sites comprise twelve occupation phases over two millennia, from initial settlement during the Neolithic (ca 1600 BC) through to the Iron Age (ca. AD 500). Overall, we observe few isotopic differences by sex at these UMRV sites. At Iron Age Noen U Loke (c. 300 BC – AD 500), there are no differences by sex in mean or variance of zC, zO or zSr (t -test, Levene's test, Brown-Forsythe test). In the NUL sample, the distribution of zSr for females peaks at a lower mode than for males (Figure 6, left inset), but the means are not significantly different ($p = 0.7$, t -test). hence at NUL we do not find compelling isotopic differences between males and females overall (Cox et al. 2010).

Figure 6

An interesting contrast to the results at Noen-U-Loke are the subtle differences favoring patrilocality at nearby Ban Lum Khao (Bentley et al. 2009). At Ban Lum Khao (Higham and Kijngam 2012), dated to ca. 1250 - 900 BC, there are no differences in mean zC or zSr , but the density of zSr is more sharply peaked for males than females (Figure 6, right, inset). This is suggestive of patrilocality, which is supported by the isotope data viewed in context with certain pottery types in the burials and sex of the skeleton (Bentley et al. 2009: Figure 5). In the Ban Lum Khao sample, females associated with small red-slipped open bowl—Types 1 and 1A—had higher $^{87}Sr/^{86}Sr$ than the other sampled females (Bentley et al. 2009).

The largest of the sampled UMRV sites, Ban Non Wat (BNW), is one of many moated village sites in the region, excavated from 2001-2007 (Higham et al. 2011). The hunter-gatherer occupation of Ban Non Wat date to 18,000 BP or older (Higham and Thosarat 2019). Overlying the hunter-gatherer levels was a massive cemetery sequence; over 650 burials were excavated in cemeteries that span over 1600 years, beginning with early Neolithic burials from about 3,600 BP, five Bronze Age phases beginning around 3,000 BP, and two Iron Age levels date from approximately 400 BC to AD 400 (Higham and Higham 2009). The early Neolithic middens at Ban Non Wat included rice chaff and the remains of fish, shellfish, deer, pigs and cattle (Higham and Kijngam 2012a, 2012b; Higham 2015). By the Late Iron Age at Ban Non Wat, iron ploughshares and sickles reflect more intensified, irrigated rice agriculture (Boyd et al. 1999; Higham and Kijngam 2012a, 2012b). The isotope results from BNW (Figure 7) reveal no significant differences in zSr , zC or zO values between males and females in terms of means or variance (MANOVA, ANOVA, Levene's test) for any of the chronological phases (Neolithic, Early Bronze Age, Late Bronze Age, Iron Age). When all BNW phases are considered together, there are still no significant differences between the sexes in these values. Figure 7 suggests one subtle pattern however, in that females and males cluster slightly apart in the Neolithic and Early Bronze Age (Figure 7, top row), but not the Late Bronze or Iron Age (Figure 7, bottom row). This

might not be significant but it is worth noting (for future reference) that the isotopic differences between sexes might have decreased through time at BNW.

Figure 7

Myanmar

Finally, we turn to new results from central Myanmar, where the newly identified Neolithic to Bronze Age transition for central Myanmar, 10th - 9th c. BC, dates to within about a century of the same transition in northeastern Thailand, 11th-10th c. BC (Higham et al 2015; Pryce et al. 2018), and two or three centuries of the central Thai transition (Pigott et al. in press. Radiocarbon dates at Ban Non Wat (Higham et al. 2015) have revised the chronological framework for prehistoric MSEA, such that Neolithic practices began in the second millennium and the earliest proto-states may have begun by the 4th c. BC at Co Loa and Khao Sam Kaeo (Bellina et al. 2017, 2018; Kim 2013, 2015). Co Loa and Co Loa and

Near the Chindwin river in central Myanmar, recent excavations (Pradier et al. 2019; Pryce et al. 2015, 2018) at the Late Neolithic to Mid Bronze Age site of Oakaie 1 uncovered 35 single and 9 collective burials. We have measured $^{87}\text{Sr}/^{86}\text{Sr}$ (but not yet $\delta^{13}\text{C}$ or $\delta^{18}\text{O}$) in tooth enamel samples from thirteen (twelve of which are Late Neolithic) individuals from Oakaie 1 (Bentley et al. 2018). The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios from Oakaie 1 individuals (Figure 3) favor patrilocality, in that there is a greater range of strontium isotope signatures among females (0.70723–0.70827) than males (0.70734–0.70772). The four identified as adult males fall within their own range of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, while all the adult females fall outside this range, as do the younger unsexed individuals. The mean $^{87}\text{Sr}/^{86}\text{Sr}$ among the four males was slightly lower than that of the six adult females, such that (so far) none of the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio from the adult females is within the range of the four adult males ($p < 0.001$, χ^2 test). There were no obvious differences among these individuals based on spatial arrangement, the area of the cemetery they were interred or the orientation of the burials (Bentley et al. 2018).

Discussion

Among the sites reviewed here (Table 1), the isotopic evidence indicates the best candidates for matrilocality were the coastal/deltaic sites of Khok Phanom Di, Man Bac and potentially also Vat Komnou. At Khok Phanom Di, the variance in $^{87}\text{Sr}/^{86}\text{Sr}$ ratios among females shifted from high to low in the very same mortuary phase (MP IV) when burials became clearly differentiated by sex and presumably gender. At Man Bac, the variation in zSr was significantly larger among males than among females. At Vat Komnou, we observed a sharper distribution of zSr among females and a small cluster of females when we plot ratios of zO/zC versus zSr/zC (Figure 4). If we pool these three sites with Ban Chiang phases EP V-VI, there is noticeably less variance among females in zSr (Figure 8, left). By contrast, the inland UMRV sites (Ban Non Wat, Noen-U-Loke, Ban Lum Khao), are either equivocal or moderately favor an interpretation of patrilocality. When we pool these UMRV sites with all the other sites and also early Ban Chiang and early KPD, there is no longer any difference between males and females (Figure 8, right). Indeed, the only difference in variance between males and females, according to by Levene’s tests in Table 2, is for the zSr values among the hypothesized matrilocal sites (Vat Komnou, Man Bac, KPD IV-VI and Ban Chiang V-VI) all pooled together, yielding $p = 0.084$; all other tests are highly insignificant.

Table 2. Levene’s tests for different variance among males and females, for three measured isotope systems. The hypothesized matrilocal samples are Vat Komnou, Man Bac, KPD IV-VI and Ban Chiang V-VI . All other samples are “Other”. The sample size is given in parentheses, these sample sizes differ by grouping and by isotope system, as C and O isotopes were not measured for all samples.

	zSr	zO	zC
Matrilocal(?)	0.084 ($n= 71$)	0.882 ($n = 45$)	0.783 ($n = 45$)
Other	0.636 ($n= 213$)	0.963 ($n = 205$)	0.664 ($n = 205$)

Figure 8

With the exception of Ban Chiang, discussed below, the patterns reviewed here from east of Myanmar are also consistent with our hypothesis that vibrant maritime or riverine trade would be conducive to matrilineal kinship. The three deltaic sites, Khok Phanom Di, Vat Komnou and Man Bac—on the Chao Phraya, Mekong and Red River Deltas, respectively— lay in primal locations in terms of Bronson’s (1977) model of upstream versus downstream access in drainage basins. In Bronson’s (1977) model, socio-economic structure was strongly affected by network distance from the coastal trading port. This is exemplified at Khok Phanom Di, where the isotopic change at MP4 corresponds with richer female burials which, starting in MP4, include clay anvils suggestive of specialization among generations of women potters at KPD (Higham and Thosarat 1994, 103–13). As Higham et al. (1992) described:

...here was a dramatic increase in some very rich graves, which incorporated an entirely new range of shell jewelry made from probably exotic species. At the same time, women predominated numerically and in terms of wealth. Some infants interred alongside these women were also very wealthy. It is suggested that the women were pottery makers and were able to engage in long-distance exchange as a means to attaining high individual status. A trend towards matrilocality saw young females becoming central in maintaining the social group.

By contrast, we find no isotopic evidence for matrilocality in the UMRV, where there are minimal isotopic differences between males and females. There are no major differences observed between males and females at Ban Non Wat or Noen-U-Loke. The isotopes from Ban Lum Khao could suggest patrilocality when the individuals were subdivided by sex and by pottery type in the burial. This suggests patrilocality may have existed in the UMRV before 1000 BC. (Bentley et al. 2009).

Overall, matrilocality is a parsimonious explanation for the coastal/deltaic sites, and consistent with our hypothesis. There are alternative hypotheses, however, for the isotope patterns. One alternative is that the $^{87}\text{Sr}/^{86}\text{Sr}$ value in seawater (0.70917) explains the homogeneity in $^{87}\text{Sr}/^{86}\text{Sr}$ among females these coastal sites—either via a shift from terrestrial-based diet to marine-based diet and/or because women were migrating from other coastal sites with the same $^{87}\text{Sr}/^{86}\text{Sr}$ ratio. The dietary shift hypothesis seems unlikely at KPD, however, as the carbon isotope signatures among KPD females show no change across the transition, with the $\delta^{13}\text{C}$ values virtually identical for females from MP1 to MP 3 (mean $\delta^{13}\text{C} = 0.754$, $n = 19$) versus MP 4 to MP 6 (mean $\delta^{13}\text{C} = 0.751$, $n = 13$). Although it is impossible to rule it out completely, female migration from other coastal

sites would not easily explain why $^{87}\text{Sr}/^{86}\text{Sr}$ was more variable at both Co Con Ngua than at Man Bac, for example, when both sites lie on the Red River delta (Hufffer et al. 2020). It also would not easily explain why at all three deltaic sites there are different isotopic patterns between females and males that are consistent with the matrilocality hypothesis.

It is notable that Khok Phanom Di and Man Bac, roughly contemporaneous, date to the same centuries as Austronesian expansion into ISEA. Linguistic and genetic evidence have suggested that proto-Austronesian society was matrilineal (Blust 1980; Burton et al. 1996; Hage 1998; Hage and Marck 2003). Jordan et al. (2009) concluded that “early Austronesian societies were predominantly matrilocal, and that patrilocality was a later development in some Formosan (Taiwan[ese]) societies,”—their analysis used phylogenetic comparative methods based on the Austronesian language (Gray et al. 2009), combined with ethnographic designations of marital residence systems in 135 regional societies (Murdock 1967). In their analysis, Western proto-Malayo-Polynesian, the oldest sub-branch of Austronesian, the geography of which includes the coast of Vietnam, was determined with 99% confidence to have originated among matrilocal societies (Jordan et al. 2009).

Also interesting in this respect is genome-wide ancient DNA evidence from these three sites and others (Lipson et al. 2018). On a principal component plot of genetic similarity, Man Bac, Ban Chiang and Vat Komnou all cluster with Austroasiatic speakers, whereas samples from Oakaie 1, albeit only two LN individuals, plot close to Sino-Tibetan speakers like present-day Myanmar (Lipson et al. 2018: Figure 1B). It should be noted that Oakaie lies far to the west and north of the MSEA comparator sites, having perhaps more in common with western Yunnan than eastern Yunnan and Guangxi like Thailand and Vietnam. Even if Austronesians never substantially settled on the coasts of MSEA, however, their maritime human dispersal likely increased the maritime export potential for pottery made by women in coastal communities such as KPD.

The one exception to the “inland-coastal” prediction is Ban Chiang, far inland on the Khorat Plateau in northeast Thailand, where we see a marked reduction at EP V in the variance of $^{87}\text{Sr}/^{86}\text{Sr}$ among women, but not among men. If this too was a transition to matrilocality, it obviously was not predicted by our “coastal” hypothesis. Our specific hypothesis is part of the broader theory of

women's control of labor and lineage (e.g., Fox 1983; Holden et al. 2003) to explain the cross-cultural observation that matriliney is more common among horticultural societies than intensified agriculturalists (Martin and Voorhies 1975: 283; Bentley et al. 2009b; Fox 1983; Hage and Marck 2003; Holden and Mace 2003; Marlowe 2004). For centuries the population at Ban Chiang is posited to have maintained a broad-based subsistence system rather than intensified agriculture (Pietrusewsky & Douglas 2002). Also, matrilocality is hypothesized to be likely when males are away from the settlement for prolonged periods (Hage and Marck 2003), which seems to apply to Ban Chiang, where males likely traveled widely while hunting and gathering while females remained closer to the settlement—based on skeletal evidence that males experienced more mechanical or repetitive stress throughout their body, and at an earlier age, than females (Pietrusewsky and Douglas 2002). Consistent with this, the new ancient DNA data suggest more indigenous admixture at Ban Chiang than at Man Bac (Lipson et al. 2018: Figure 2).

Finally, it bears noting that these isotope patterns from MSEA are all fairly atypical compared to the bulk of isotopic studies from Neolithic contexts elsewhere in Eurasia. In Neolithic and Bronze Age Europe, where the transition to agriculture was relatively rapid and complete, patterns of female exogamy, supported by genetic evidence (e.g., Seielstad et al. 1998; Rasteiro et al. 2012), are evidenced by strontium isotope measurements of hundreds of Neolithic human skeletons from across central Europe (Bentley et al. 2012; Bickle and Whittle 2013). The aggregated results revealed a co-association, among early Neolithic adult males, between local isotope signatures and distinctive stone adzes, which suggests that certain male adults—potentially patrilineages— had privileged access to farming land (Bentley et al. 2012), potentially at the onset of heritable inequality and patriliney in prehistoric Europe that continued into the Bronze Age and beyond (Feinman and Neitzel 2019; Mittnik et al. 2019).

For future studies, we look westward, to sites in central Myanmar, where the origin of state-level societies—including the Pyu city-states, the earliest in non-Sinicized MSEA (e.g. excluding northern Vietnam) and Bagan, the great rival of Angkor in Cambodia (9th-13th c. AD)—are being newly investigated. These origins can be witnessed at sites predating the Pyu city-states of the 1st-9th c. AD, such as the UNESCO-listed site of Halin in central Myanmar, from early Neolithic (c. 2000-1000 BC) to Bronze Age (c. 1000-500 BC), Iron Age (c. 500 BC to -200 AD) deposits.

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Figure captions

Figure 1. Map of the sites in Table 1.

Figure 2. Bivariate plots of zC versus zSr in tooth enamel samples from Khok Phanom Di (KPD) phases II – III (**left**) versus later KPD phases IV-VI (**right**). The inset of each plot shows density distribution of zSr values. One outlier is not shown for KPD IV-VI.

Figure 3. Boxplot of zSr for three sites with only Sr isotopes measured (Table 1): Con Co Ngua (CCN), Man Bac (MB) and Oakaie 1 (OAK). The bar in each box shows the median; lower and upper hinges correspond to the first and third quartiles. One outlier is not shown (MB male, $zSr = 4.9$).

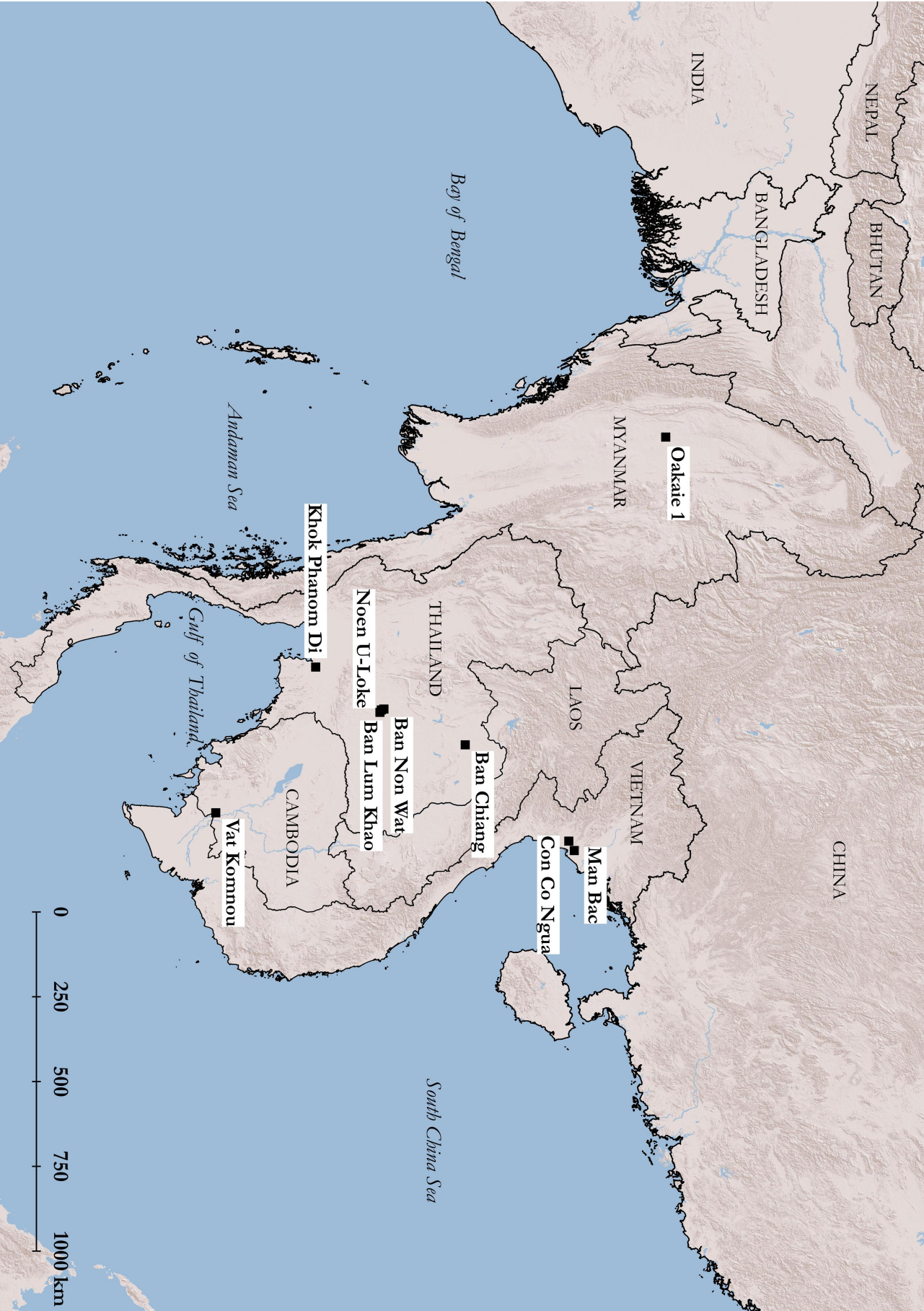
Figure 4. Bivariate plots showing tooth enamel results from Vat Komnou (VK) in terms of (**left**) zC versus zSr , and (**right**) the ratios of zO/zC versus zSr/zC . The inset of the plot on the left shows density distribution of zSr values. One outlier not shown from ratios plot on the right.

Figure 5. Bivariate plots of zC versus zSr in tooth enamel samples from (**left**) Ban Chiang (BC) phases II – IV, versus (**right**) later BC phases V-VI. The inset of each plot shows density distribution of zSr values. Two outliers are not shown for the early phases and one outlier is not shown from the later phases.

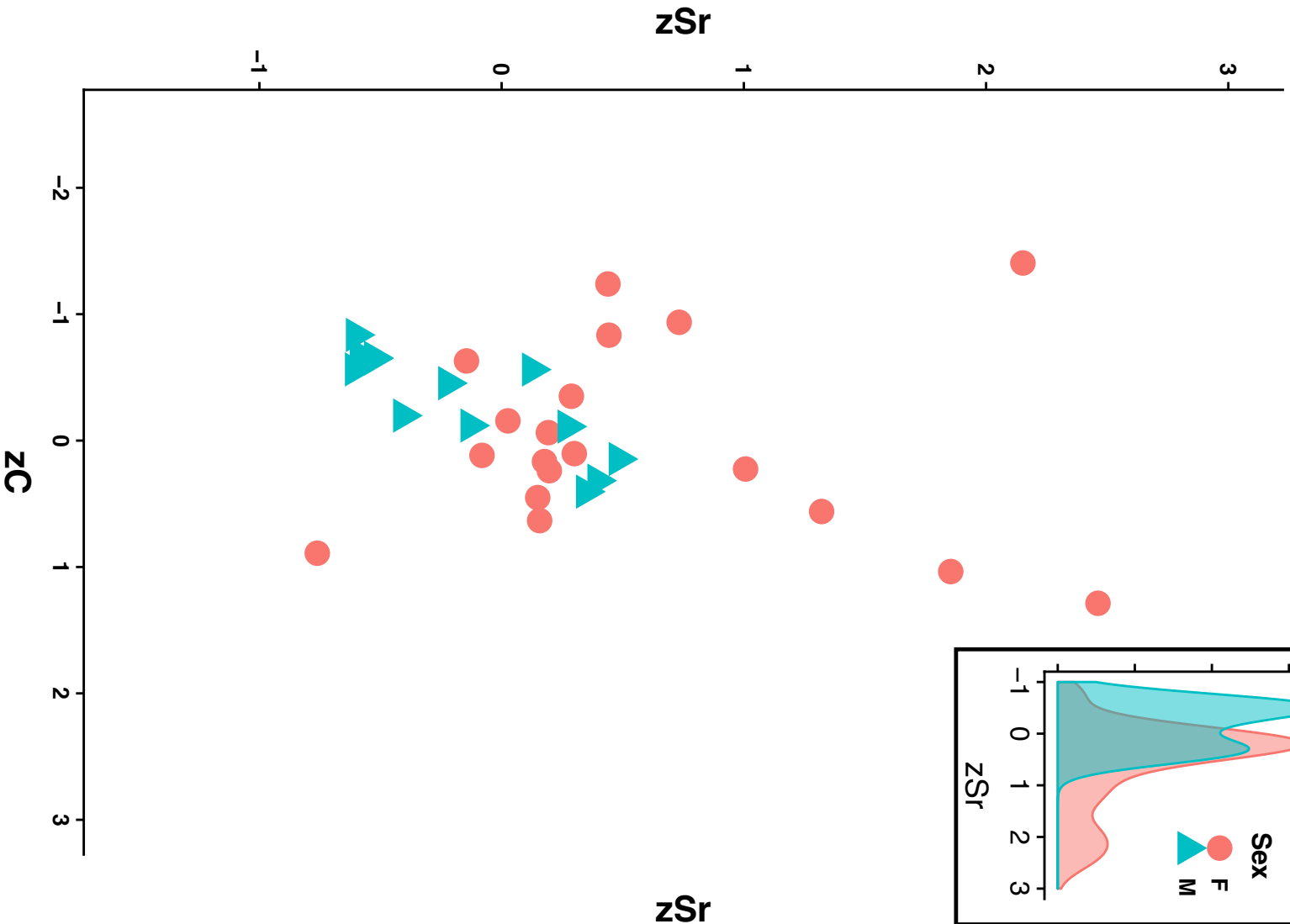
Figure 6. Bivariate plots of zC versus zSr in tooth enamel samples from (**left**) Noen-U-Loke (NUL), and at (**right**) Ban Lum Khao (BLK). The inset of each plot shows density distribution of zSr values. Two outliers are not shown for BLK.

Figure 7. Bivariate plots of zC versus zSr in tooth enamel samples from Ban Non Wat (BNW). The four panels show the different chronological phases, from Neolithic to Early Bronze Age (EBA), Late Bronze Age (LBA) and Iron Age (IA). The inset of each plot shows density distribution of zSr values.

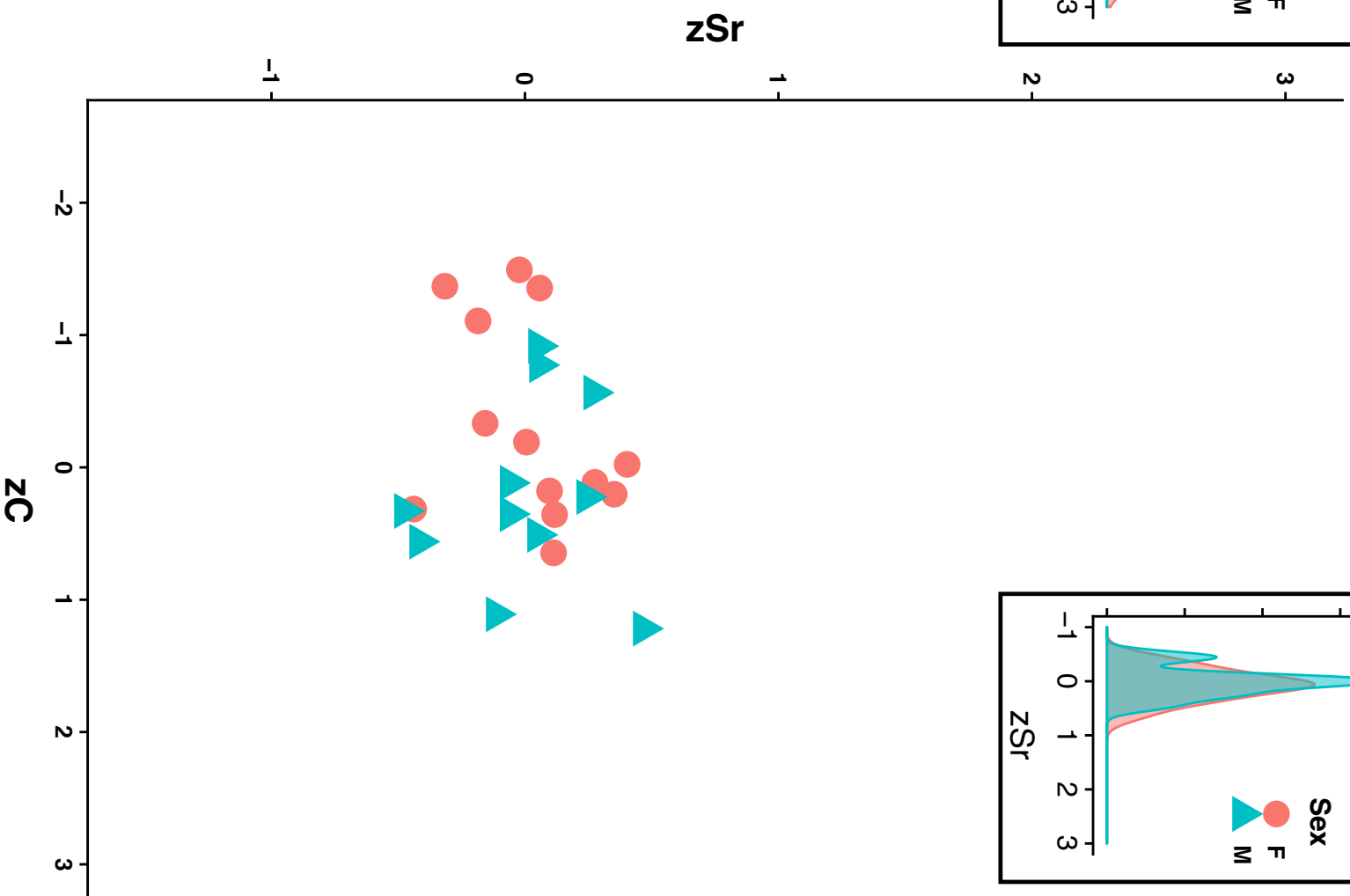
Figure 8. Bivariate plots of zC versus zSr for (left) pooled samples from hypothesized matrilineal sites versus (right) all other samples in Table 1. The hypothesized matrilineal sites are Vat Komnou, Man Bac, KPD phases IV-VI and Ban Chiang phases V-VI. Ellipses represent 95% confidence for each sex. The inset of each plot shows density distribution of zSr values.

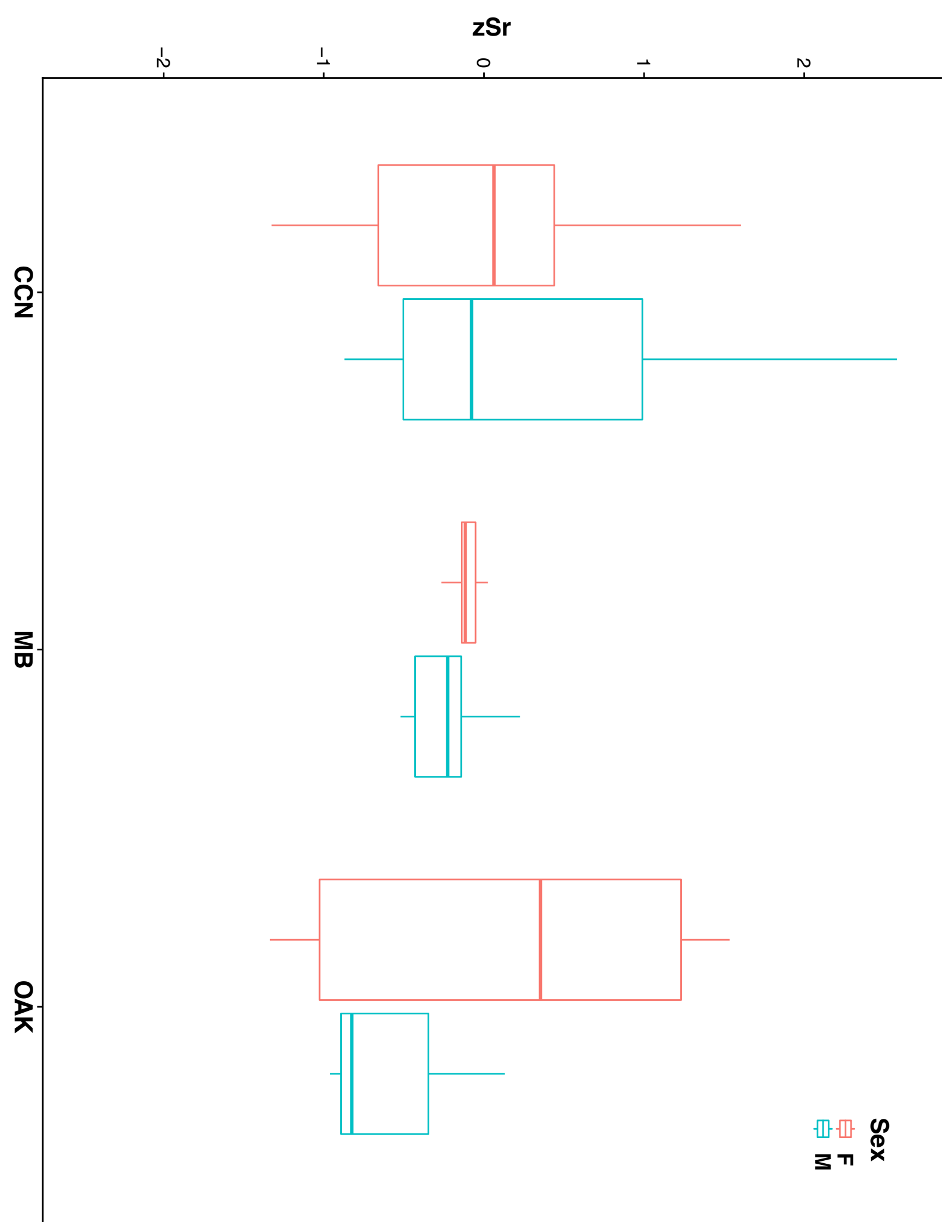


KPD II-III

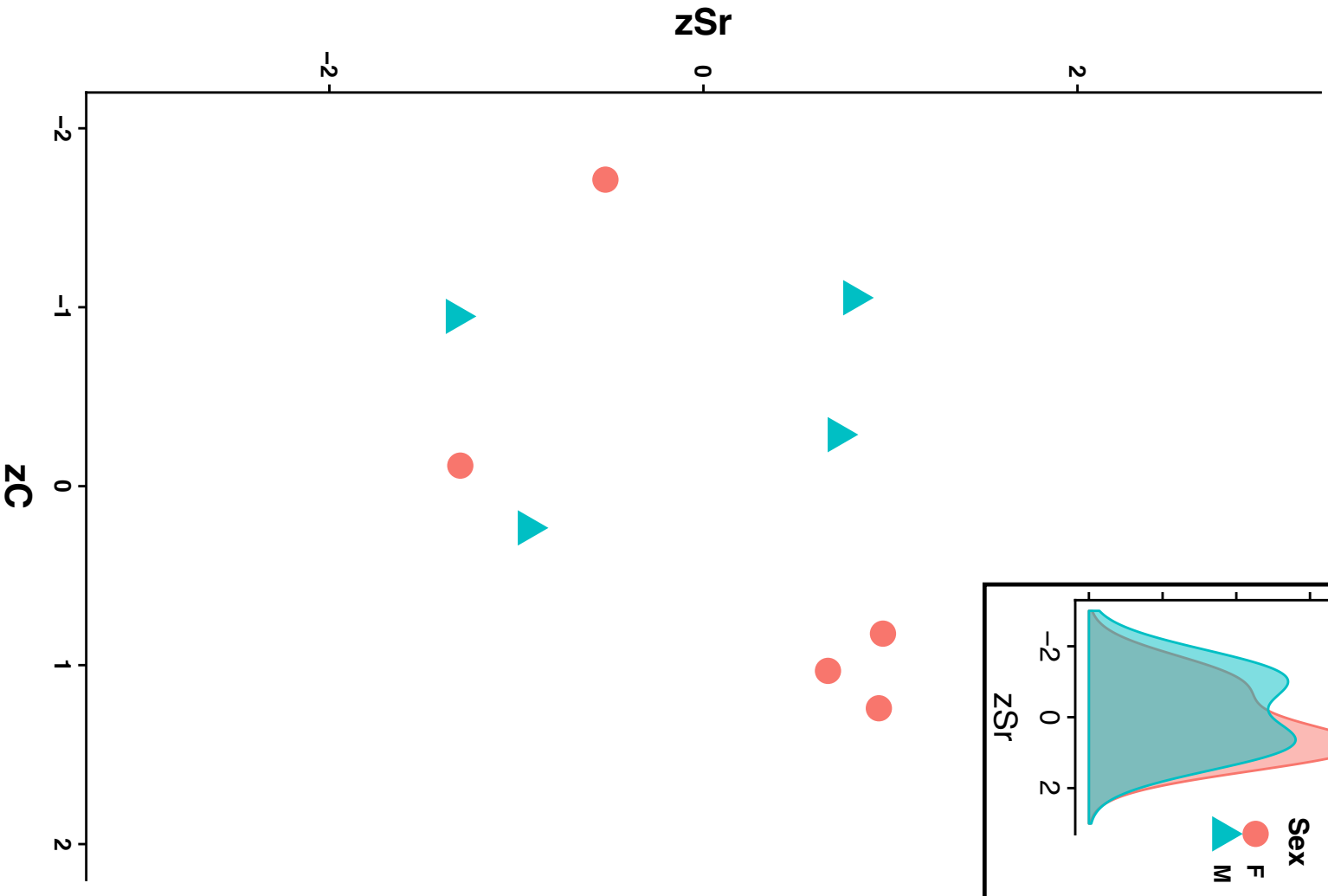


KPD IV-VI

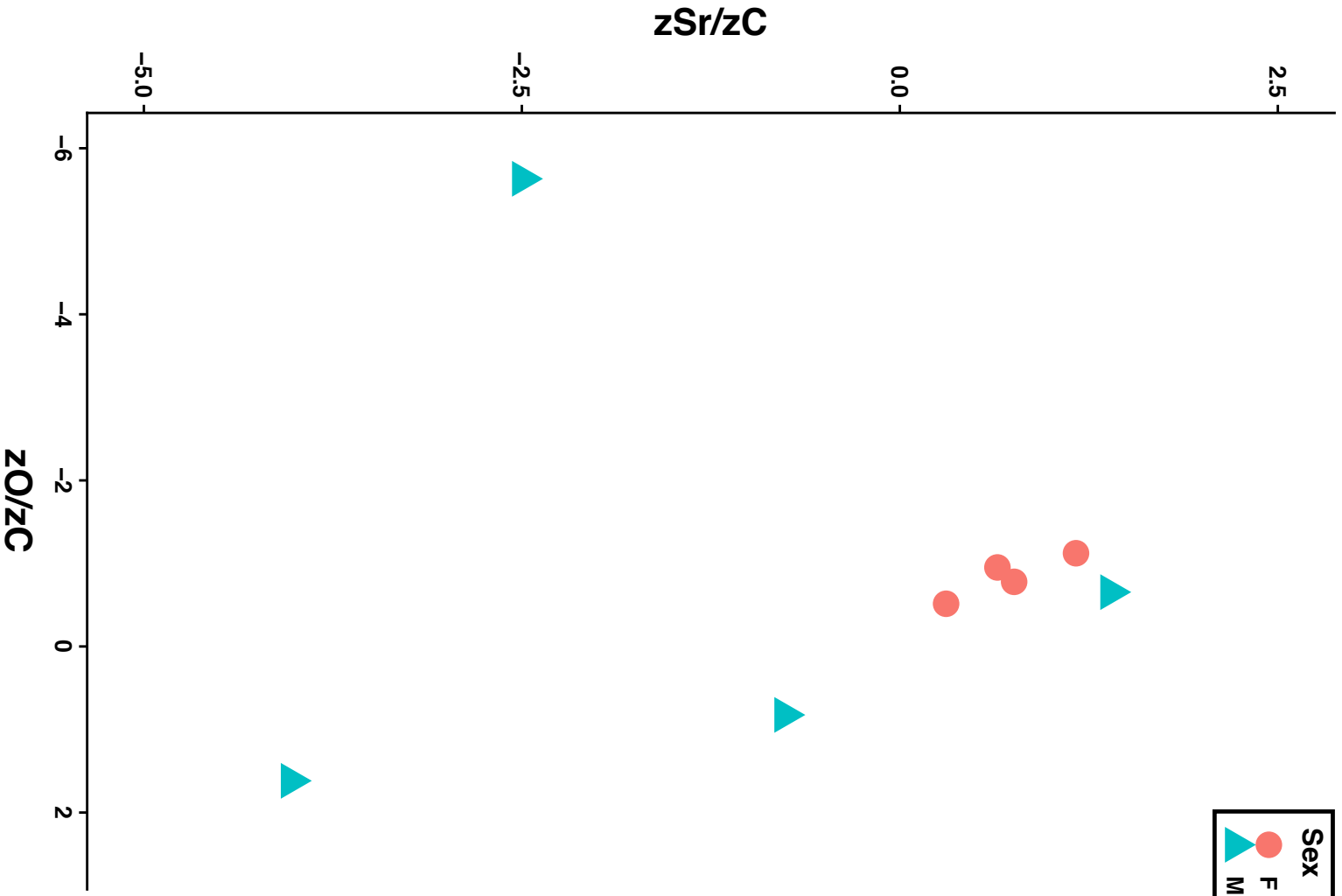




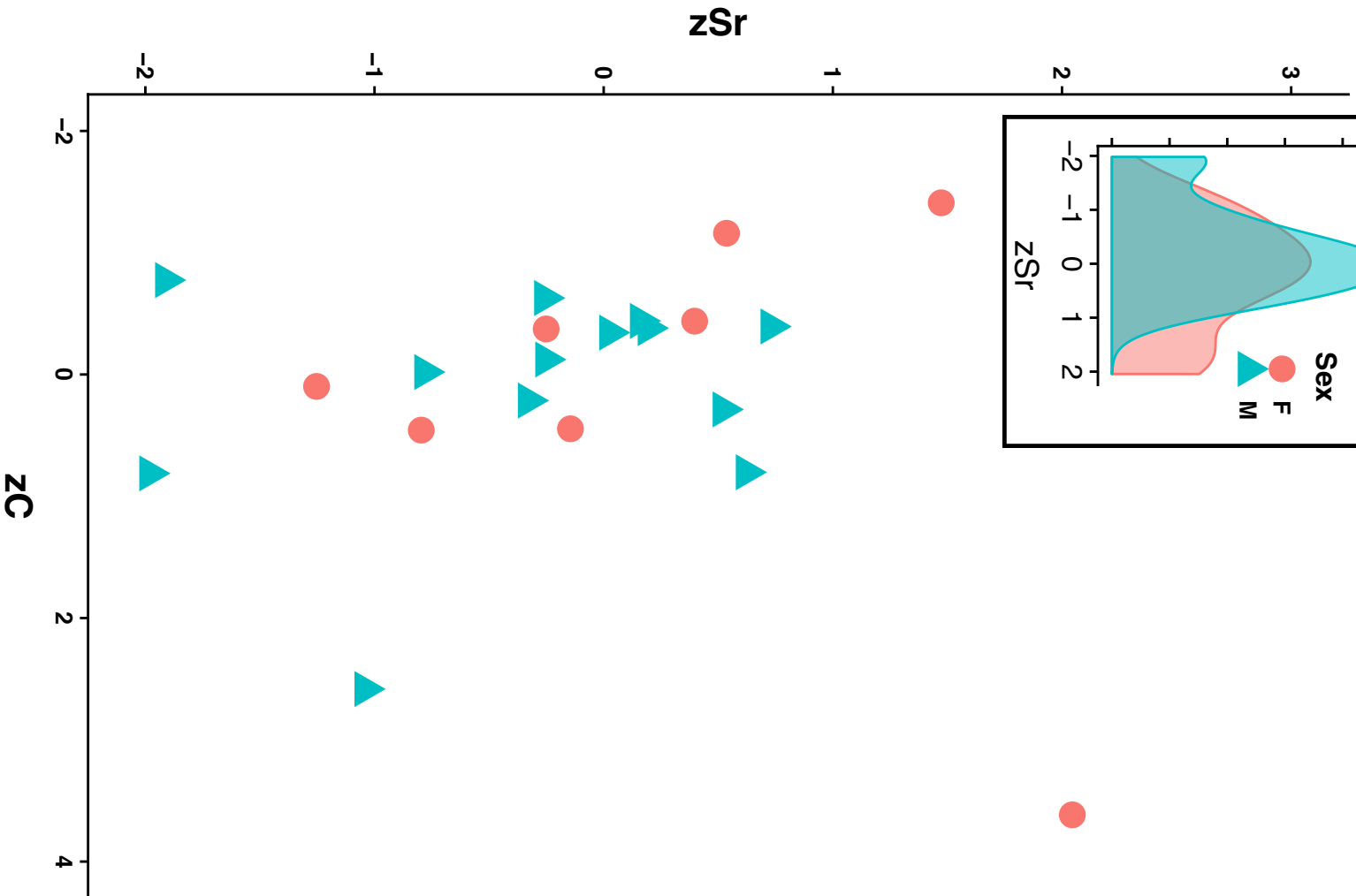
Vat Komnou



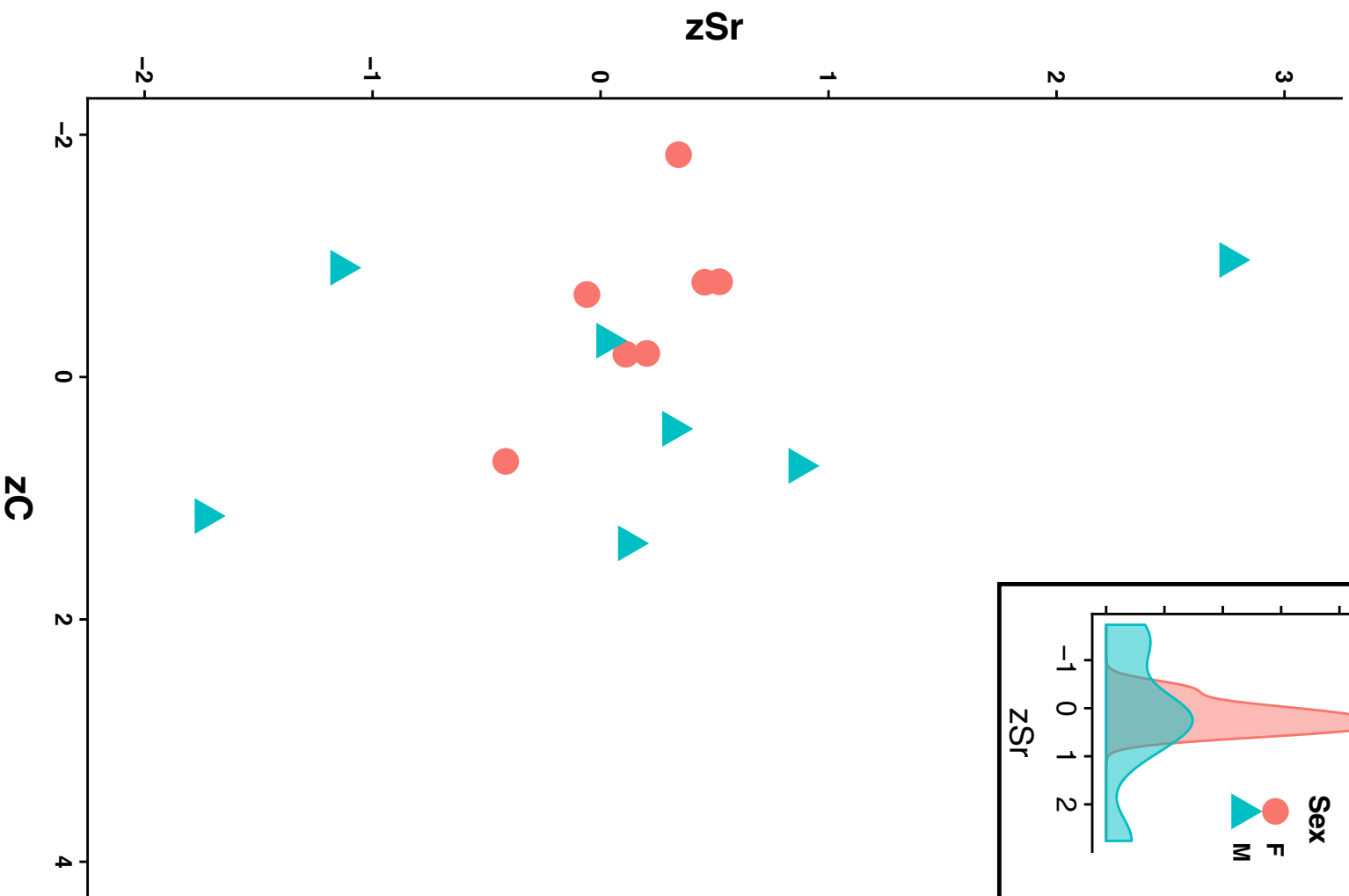
Vat Komnou, ratios



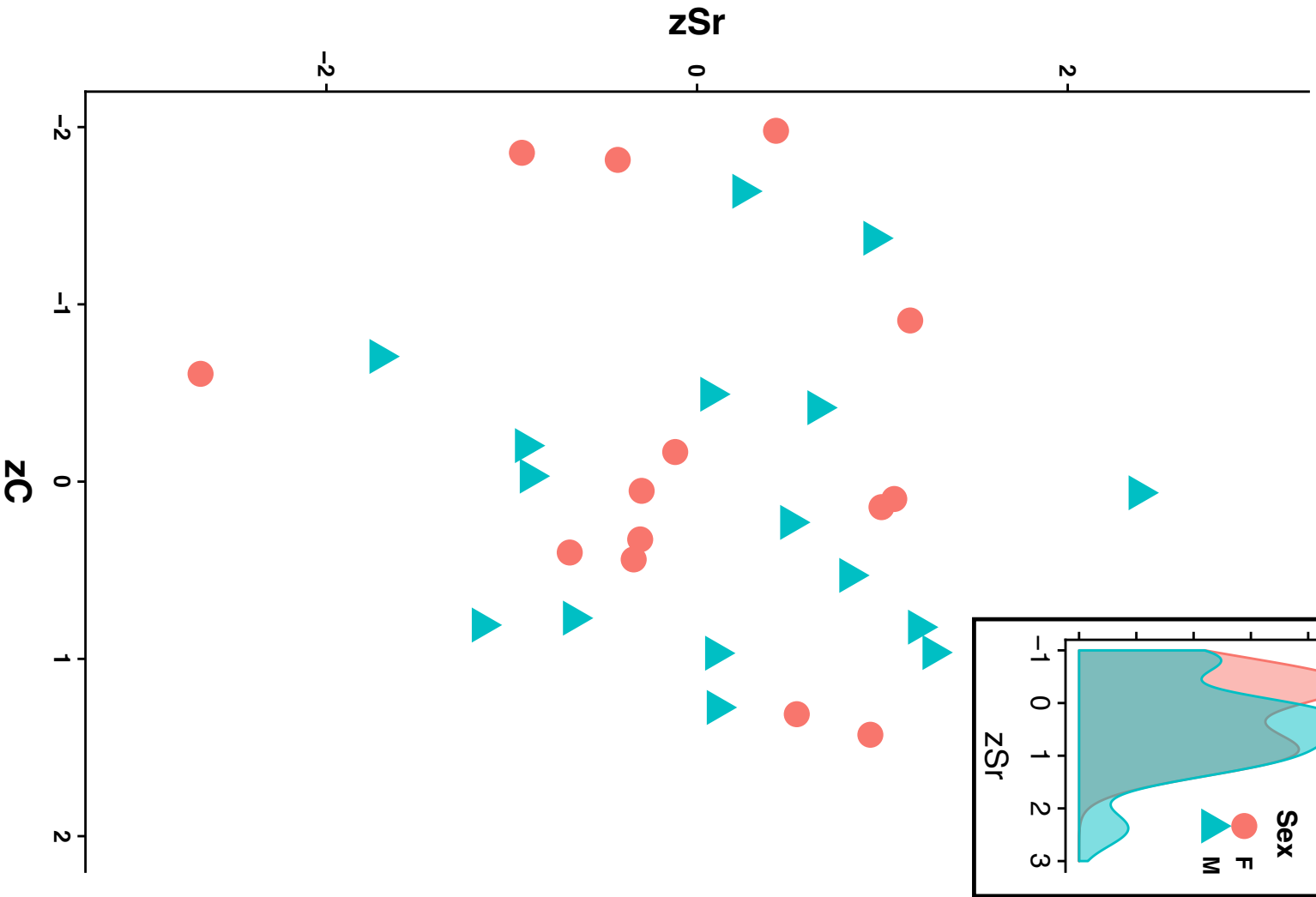
Ban Chiang: EP I-IV



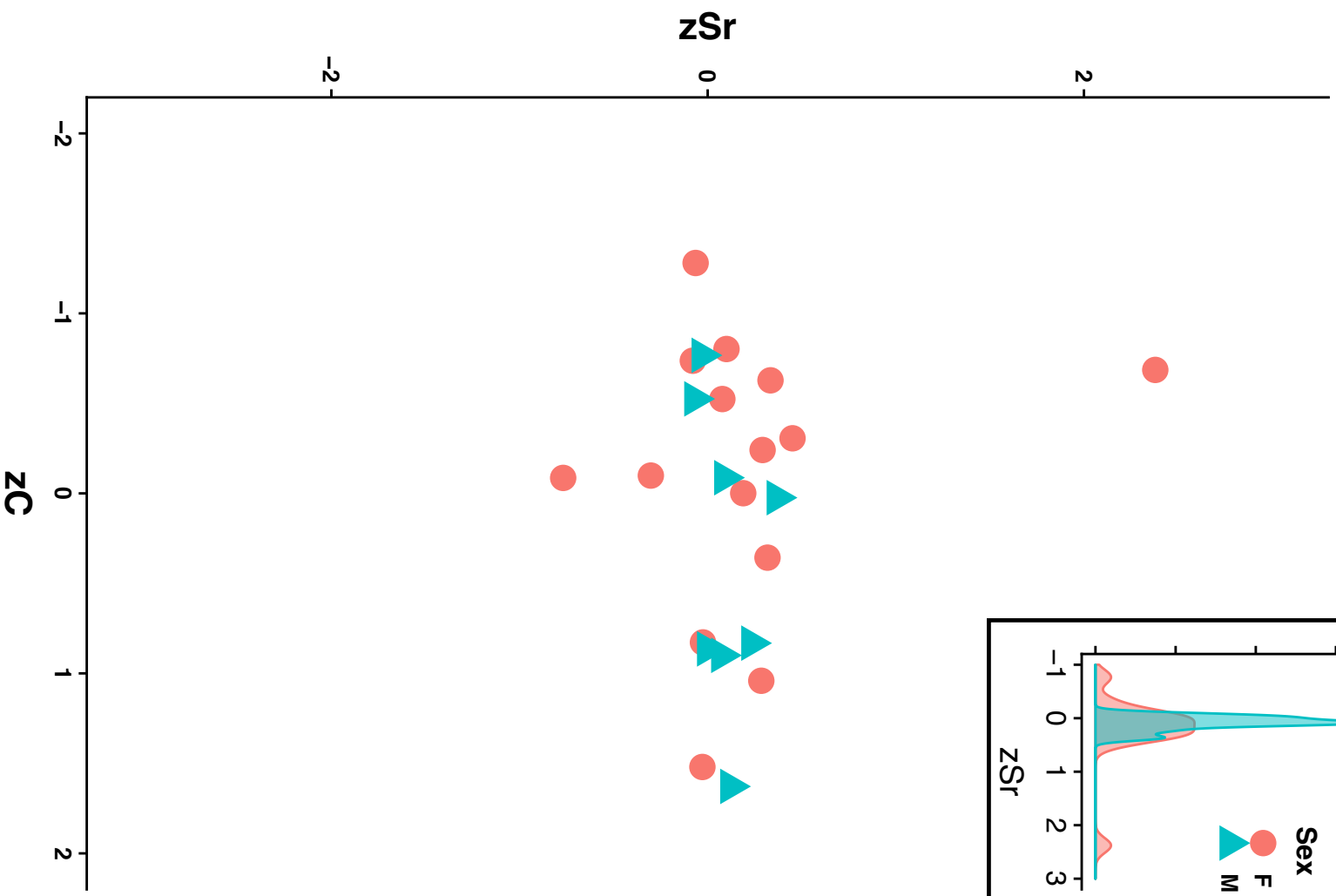
EP V-VI



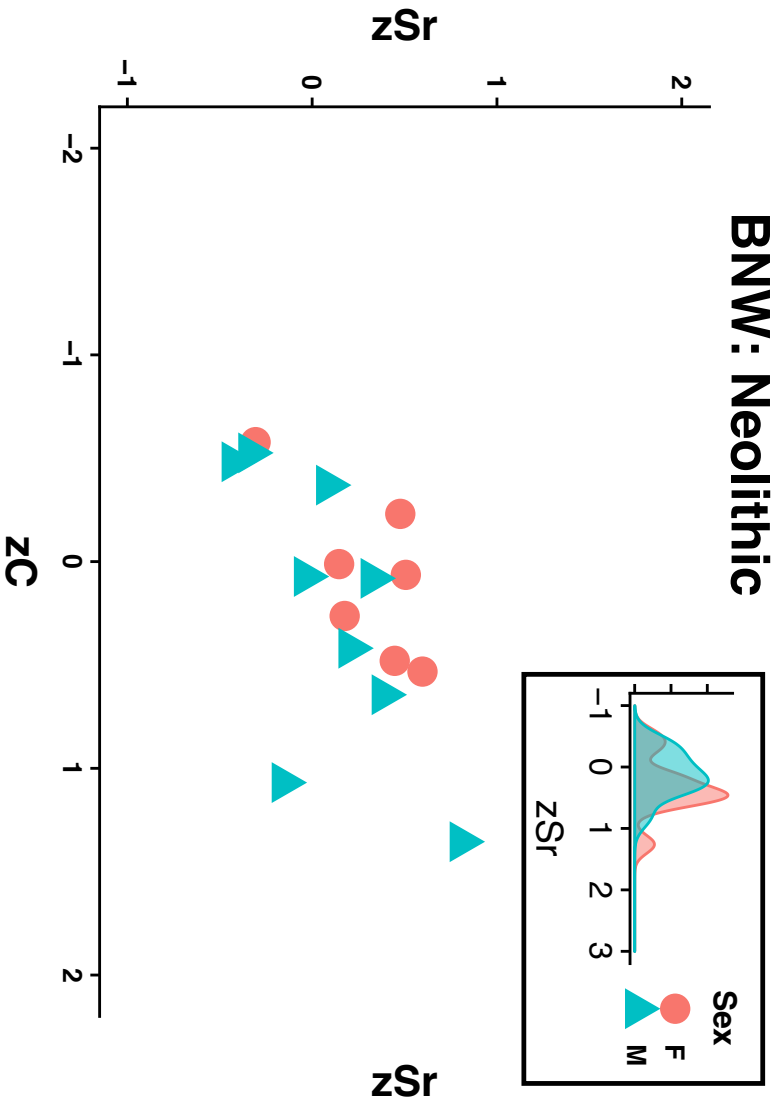
Noen U Loke



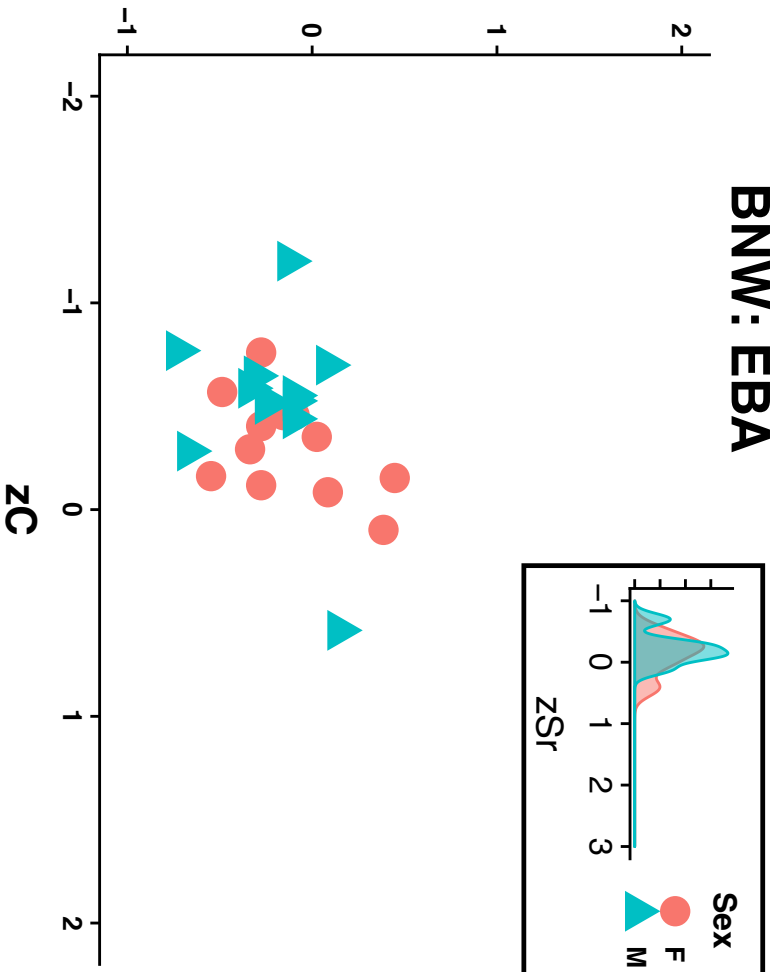
Ban Lum Khao



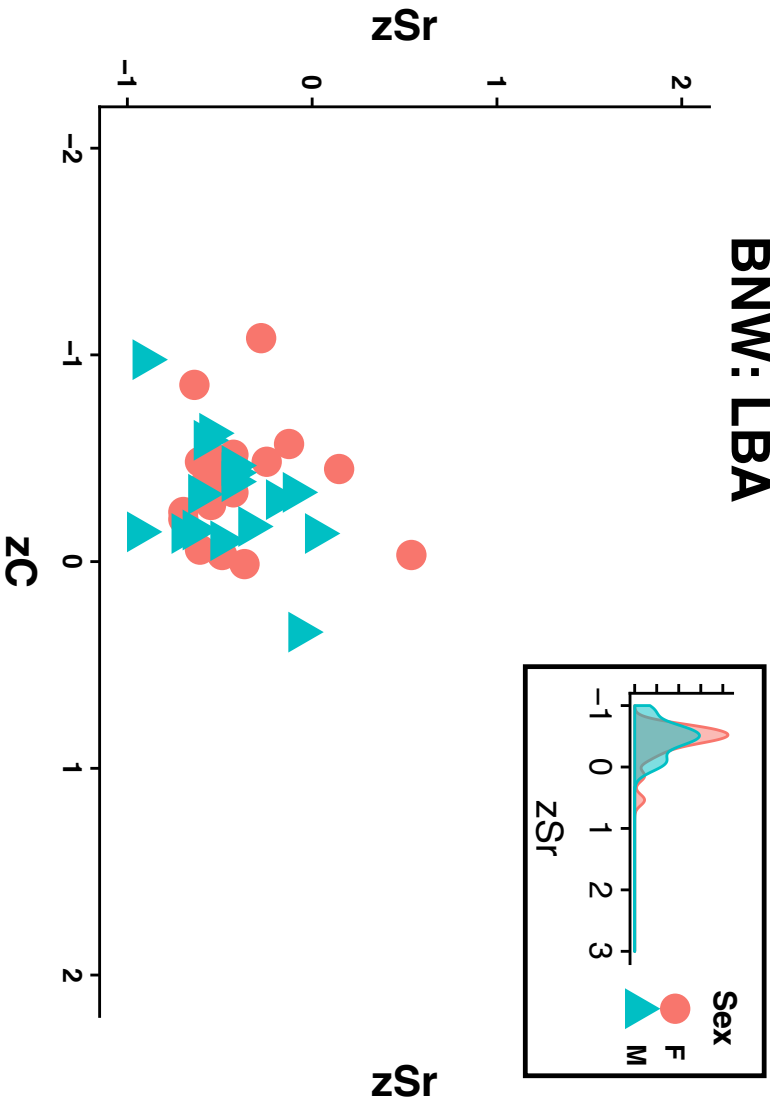
BNW: Neolithic



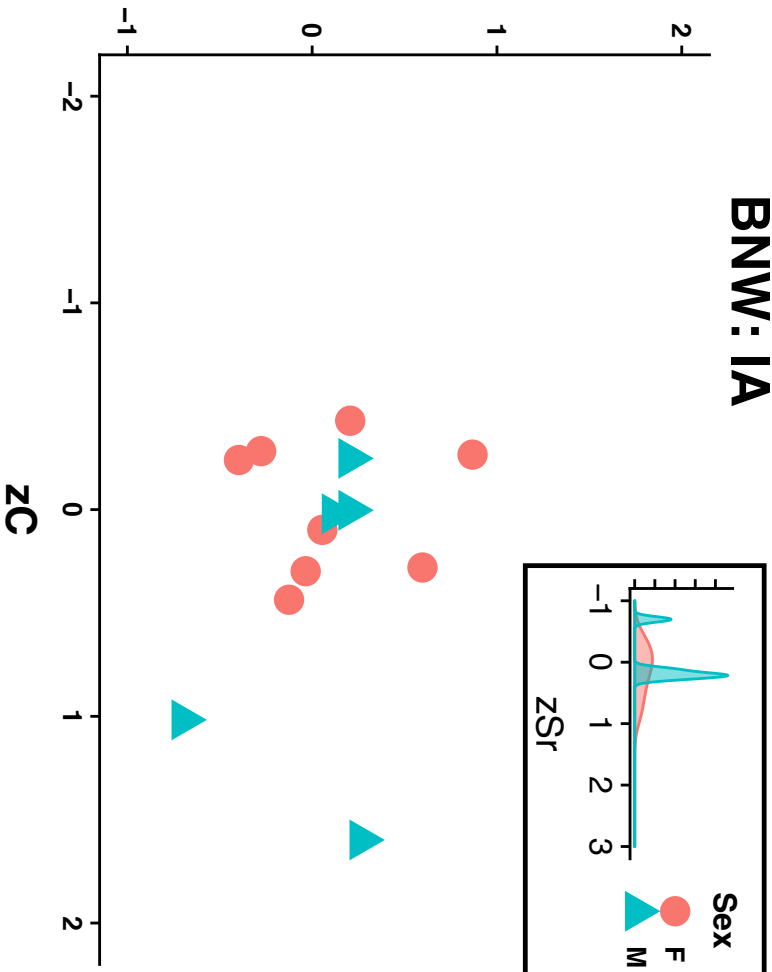
BNW: EBA



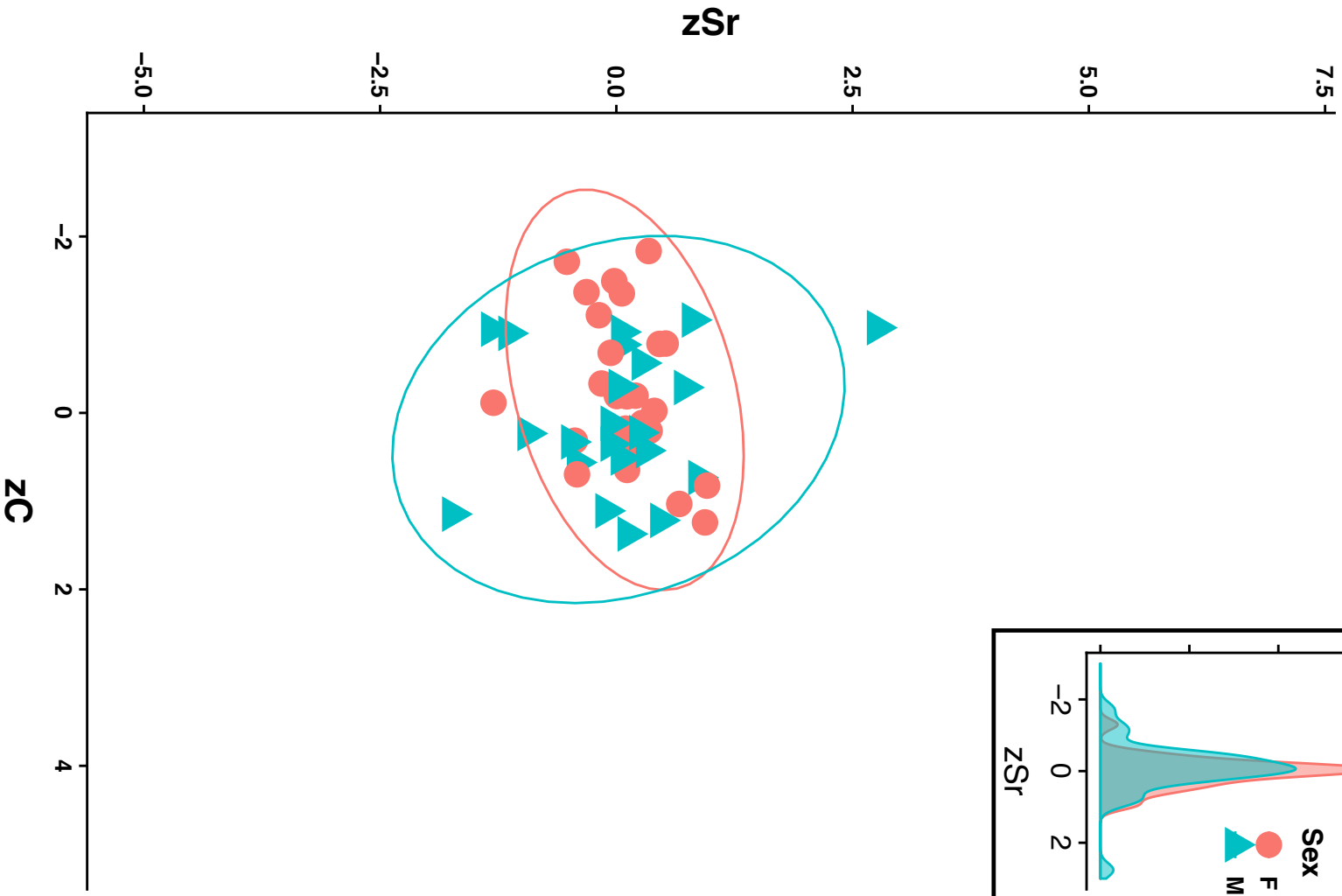
BNW: LBA



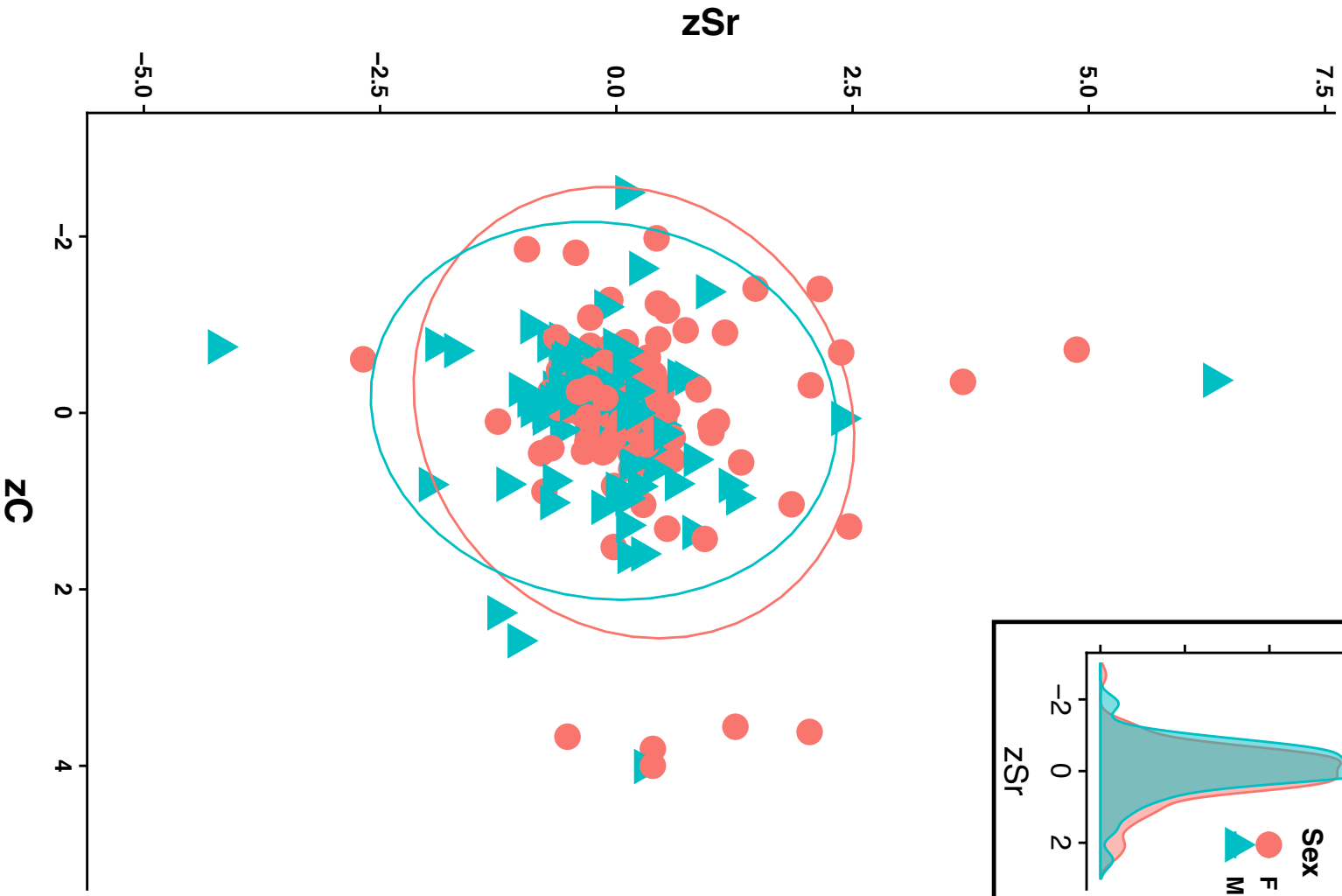
BNW: IA



Matrilocal?



Other sites



Conflict of Interest and Authorship Conformation

Submission to *Archaeological Research in Asia*:

“Kinship and migration in prehistoric Mainland Southeast Asia: An overview of isotopic evidence”

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