

The Myth of Equidistance in Thai Tuning

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INTRODUCTION

WESTERN and Thai Scholars of Thai music generally accept that Thai classical music (*phleng Thai doem*) is based on a seven-tone equidistant tuning system which is sometimes called 7-tet (7-tone equal tempered). According to this theory, Thai tuning is defined by an ideal interval of 171.429 cents. This understanding stems from an encounter in London in 1885 between the noted mathematician Alexander J. Ellis, and a senior Siamese diplomat, Prince Prisdang. Despite persistent doubts about this theory, it has not been seriously questioned and no alternative explanations have been put forward to challenge the assumption that Ellis's theory is accurate and comprehensive.

This article identifies problems with the theory of equidistance and shows that the widespread acceptance of the theory and its ideal interval is misplaced because it is incorrect to say that Thai music is based on the equidistant division of the harmonic octave into seven intervals. I will point out problems with the theory that stem from its formulation. I will draw attention to empirical research that shows instruments are not tuned to 171.429.¹ I will show that tuners do not consider the theoretical interval when tuning, and show that the theory overlooks certain tuning concepts and practices that are central to Thai music. Although I will discuss the mathematical formulations that have been used to describe Thai tuning, the theoretical orientation of this article is primarily informed by concepts that circulate within the discipline of ethnomusicology. These aim to describe and explain the details of musical systems in terms that reflect the concepts and practices of those who perform and listen to the music.

A complex range of musical-cultural factors are associated with Thai tuning and these influence how fixed-pitch instruments are tuned and how non-fixed-instruments are played. To clarify some of these issues I will address the disparate epistemological perspectives that scholars and musicians have on tuning. This includes discussing empirical pitch data derived from a variety of sources, including my own tests, and the views of practicing Thai musicians and tuners. The tests of Thai instruments conducted in the course of this research involved recording each note of each individual instrument at a sampling rate of 16 bit, 44.1 kHz in controlled (quiet) conditions with high resolution recorders (Zoom H4N). The pitch of each instrument was then analyzed with the Sonic Visualiser and Audacity software programs. This process has advantages over collecting pitch data from commercial recordings because extraneous sounds can be eliminated.

Data derived from these tests are complemented by insights from musicians who play the fixed-pitch percussion instruments upon which the theory is based, as well as from those who play non-fixed-pitch instruments. This is complemented by observations

1. *Empirical* is used here in the narrow sense of research based on experimentation rather than in the broader sense of research based on observation and experience.

made of instrument tuners at work and following discussions with a number of them about their tuning objectives and methods. They show that individual tuning preferences of musicians and tuners as well as other extra-musical ideas about tuning are significant factors in shaping the sound of Thai music. This provides an insight into the disjuncture between Western-derived theories and beliefs about Thai tuning and actual musical practice.

This approach inevitably means mixing epistemologies that may be seen as incompatible or in some way problematic. Data from the physical sciences that is expressed in numerical terms may be difficult to square with ethnographic and musicological insights that emphasize historical, cultural, and performance factors, but the absence of an integrated strategy for dealing with all factors involved in Thai tuning is behind the failure of theorists to properly describe and explain the concepts and practices of those who actually play Thai music. A full account of Thai tuning is not possible without considering the views of musicians and tuners because these have a direct bearing on how they tune and play their instruments.

The problems that I will describe can be clarified by dividing them into two broad categories. The first of these relates to the extent to which the theory of equidistance explains the actual (and/or intended) tuning of the fixed-pitch instruments that it purportedly describes. I will argue that evidence does not support equidistance nor is it the intention of tuners to tune to the ideal equidistant interval 171.429. This is in part because, as is well known by Thai musicians, the technologies and practical methods used in tuning Thai percussion instruments do not readily allow for tuning precision.

In addressing how the theory has become so entrenched, I discuss David Morton's (1976) research on tuning that appeared in his influential and widely cited study of Thai music *The Traditional Music of Thailand*. This publication, which includes analysis of Thai fixed-pitch percussion instruments, has played an important role in shaping thinking about Thai music. Given the historical importance of Morton's work, I will discuss what I consider to be its shortcomings. A secondary issue in the first category relates to the proportions of the Thai octave. The theory of equidistance was formulated on the assumption that the Thai octave is a harmonic octave with a ratio of 1:2. I dispute this and point out that tuners of fixed-pitch percussion do not intend for the octave to be a ratio of 1:2.

The second category of problem relates to the limited scope of the theory of equidistance. The theory was formulated following observations made of fixed-pitch percussion instruments that are limited in their intonational scope to seven notes per octave. It did not set out to explicitly account for the practices of string players and singers because they were assumed, as they have been since, to be part of a single canonical tuning system. Thus the established theory does not consider tuning concepts and practices of singers or non-fixed-pitch instruments. Scholars writing about Thai tuning who followed Ellis have either not discussed tuning theory or they have been primarily interested in fixed-pitch percussion instruments and accepted the orthodox explanation, albeit reservedly at times. None have described, explained or proposed an alternative theory for

the tuning concepts and practices of those musicians who do not play fixed-pitch percussion.

Continued acceptance of Ellis's theory means that contemporary orthodox thinking about Thai tuning continues to reflect the intellectual climate of the late nineteenth century under which the theory was formulated and which has persevered as the epistemological prism through which Thai tuning is seen. Intellectual and technological developments have uprooted and displaced nineteenth-century thinking in many areas of musicology; however, Thai tuning is still discussed in empirical terms that presuppose a non-existent standardization that paints a distorted and partial perspective of Thai tuning.

Analysis of frequencies is undoubtedly useful in describing the properties of instruments, but because of the diversity of intervals found in Thai melody and the absence of evidence corroborating 7-tet, a surer way to understand Thai tuning is to consult Thai musicians about their objectives, concepts, and practices rather than relying solely on the results of physical tests.

Echoing Schneider's (1991, 297) warning that basing an "explanation on an assumption is no proof," I argue that the persistent belief that Thai music is equidistant rests upon the incorrect assumption that the description given by certain historically influential scholars is both comprehensive and accurate, and that it describes all Thai instrument families and ensemble types. I will argue that neither the measurable diversity of fixed-pitch instruments described by empirical research nor the diversity of tuning concepts and practices found amongst other Thai musicians can be explained within the scope of the theory of equidistance. There is a range of other reasons why misunderstandings about Thai tuning have not persisted.

Because the notionally 7-tet tuning system is not based on the harmonic series, it has complex harmonic properties that make the fixed-pitch percussion instruments that are said to be tuned according to this theory difficult to tune. Thus, the aural complexity of the sound of Thai music is in itself an obstacle to understanding its tuning properties (Somchai T. 1973, 53). According to my sources, there has also been a historical lack of familiarity among Western and Thai scholars with the musical concepts involved in Thai music and the terms that are used by Thai musicians to describe them. This has led to a misunderstanding of the importance of the musical concepts of *thang* and *samnieng* (discussed below) in influencing melodic qualities and tuning. The established practice in Thai musical culture of intentionally withholding information (*huang wicha*) or of providing false and misleading information to those who are considered outsiders has led to uncertainty and the proliferation of falsities about Thai music (Fuller 1983, 153; Gaston 2012, pers. comm.; Myers-Moro 1993, 117–19).² Difficulty in gaining access to instruments has limited opportunities for further testing, analysis, and theorizing. Collectively, these factors have constrained the development of a more accurate understanding of tuning and the role of intonation within the Thai melodic system.

2. According to Gaston, it is for this reason that David Morton's primary informant Montri Tramote may not have always been entirely truthful or forthcoming (Gaston, pers. comm., 9 September 2012).

There are unresolved questions related to the tuning concepts and practices of Thai singers and players of non-fixed pitch instruments who because of the nature of their instruments have the capacity for intonational flexibility (see Jarun and Kittiphong 2013). Whilst a better understanding of their practice will provide a more complete explanation of how Thai musicians understand intonation and how Thai music sounds, this article focuses primarily on shortcomings with the theory of equidistance as it relates to the percussion instruments it was intended to describe.

ELLIS AND THE HISTORY OF 7-TET

Alexander J. Ellis published his theory of Thai tuning in an appendix to his landmark article “On the Musical Scales of Various Nations,” which appeared in the prestigious *Journal of the Society of Arts* in 1885. He was unable to make conclusive statements about Thai tuning in the original article because the *ranat ek* (soprano xylophone) at the South Kensington Museum upon which he based his initial observations was in poor condition.

Ellis and his assistant Mr. Alfred Hipkins, a piano tuner who, according to Ellis (1885a, 485), had a “remarkable power of discriminating small intervals between tones of very different qualities,” were able to offer a more detailed assessment of Thai tuning when they were granted permission to test the tuning of a set of Thai instruments that had been sent from the Thai court for display at the 1885 London Inventions Exhibition. Access to the instruments was facilitated by Prince Prisdang, who accompanied the instruments. Prisdang was acting in his capacity as the “Siamese Envoy Extraordinaire and Minister Plenipotentiary for Paris, Berlin, Vienna, and the other capitals of Europe” (Ellis 1885b, 1105), but he was also a cousin of the then King Chulalongkorn (Rama V) and grandson of Rama III King Nangklao (ruled from 1824–51) and thus a royal of rank and importance.

Ellis and Hipkins evaluated and discussed the tuning of a *ranat ek*, a *ranat ek lek* (soprano metallophone), a *sor sam sai* (three-string chordophone), and a “tak’hay” (*jakhe*, Thai zither). They were advised by Prince Prisdang that “the intention was to make all the intervals from note to note identically the same” (Ellis 1885b, 1105). Hipkins tested this statement through his own aural observations, following which Ellis concluded that dividing the octave by the number of tones within it would “give the above division of the octave into seven equal intervals each containing 171.43 cents (logarithm.043004)” (1885b, 1105). Ellis’s statement marks the first occasion that the theory of equidistance was formally proposed as a definitive description of Thai tuning. As a result of this interaction, the “correct” Thai interval was explicitly specified as 171.43 cents by a Western scientist. Thus, the widespread and largely unchallenged belief that Thai tuning is both equidistant and standardized stems from this encounter. It has since become orthodoxy and scholars discussing Thai tuning routinely describe its interval as 171.429 cents.³

3. This is an irrational number that is the product of dividing the number of cents in an octave (1200) by 7, which is the number of intervals in the Thai octave. It is routinely written as 171.429. The geometric algorithm for seven-tone equal tempered tuning is the seventh root of 2, $2^{1/7}$, or $2^{(1/7)}$.

Ellis had additional instruments at his disposal, but he emphasized the tuning of the *ranat*, which he used as a reference. In his comments about the three-stringed *sor sam sai* (which he called the Saw Tai), he noted the disparity between the “Thai fourth which is intentionally sharp” and the open strings “of the *sor sam sai* [which] gave slightly flat Fourths” (Ellis 1885b, 1104). Although he observed this difference, he did not offer an explanation of why the fourth intervals were 32.5 and 63.3 cents respectively below the hypothesized Thai fourth.⁴ He made no mention of any comments the string player may have made of the disparity between the “Thai” fourths and those the player performed, nor did he comment on any notes other than the open strings of the *sor sam sai*.

In the first of his 1885 articles, Ellis (1885a, 526) stated that there was nothing “natural” about tuning systems. He considered them “diverse, artificial and capricious.” However, despite his rejection of the assumption that tuning systems are ideally related to the harmonic series and thus in some way natural, he apparently believed that this did not apply to the octave interval. He claimed that “in no system of temperament will it be possible to interfere with the octave, the only unisonant concord” (1863, 406), and that “there is no harmonic interval but the Octave” (1895, 556). Without a reason to suspect that the Thai octave was not a ratio of 1:2, he assumed it was and thus formulated his theory with this ratio in mind. With Ellis’s imprimatur, the Thai octave has henceforth been presumed to be a ratio of 1:2, despite the existence of significant evidence that contradicts this assumption.

Ellis’s attempt to explain Thai tuning in mathematical terms reflects the prevailing intellectual climate of scientific materialism that had become established as the defining worldview of modernity in late nineteenth-century Europe (see Whitehead 1925, 22). The idea that Thai tuning can be understood solely in empirical terms can be traced to this attitude towards the study of music. This attitude has since been largely rejected in ethnomusicology because it overlooks indigenous explanatory models and other theoretical frameworks that may attribute musical characteristics to cultural and historical factors in favor of those that can be described in mathematical terms.⁵

HISTORY OF THAI TUNING THEORY AND DISCOURSE

In addition to becoming established in European musicological thought, the theory of equidistance had made its way to Thailand by the early twentieth century.⁶ It was entrenched there by the middle of the twentieth century, by which time the Thai interval was routinely described as equidistant comprising 171.429 or 171.43 cents (Phra Chen 1951, 4; Morton 1970, 10).

4. Based on the values given in Ellis (1885b, 1104).

5. See Rice (2010, 100–34) for a discussion of ethnomusicological theory.

6. In his *Siam: A Handbook of Practical, Commercial, and Political Information*, British colonial advisor Walter Armstrong Graham (1913, 459) stated that “the Siamese gamut consists of seven equal intervals each of which is exactly $1\frac{5}{7}$ semitones, which division renders the chromatic scale impossible and prevents the satisfactory rendering of European music on Siamese instruments.” This implies that a mathematical explanation of Thai tuning was circulating in Thailand by the second decade of the twentieth century.

While it is common to discuss tuning in terms of scales, the concept of a musical “scale,” as it is routinely understood by Western musicians and musicologists, has harmonic implications that are not relevant to traditional Thai music. The term has no direct equivalent in Thai music (Myers-Moro 1993, 85) and the concept is not part of traditional Thai musical thought that underpins *phleng Thai doem*. Although it is closer to Thai musical practice to understand musical pitch in relation to the entire suite of factors that influence melody (Lerkiat 2012, pers. comm.), the range of idiomatic and instrumental factors that influence Thai melody (discussed below) are typically overlooked in discussions about tuning and it is discussed in terms that conceptually reduce melody and tuning to a single theoretical scale.

Describing the Thai tuning system as an equidistant scale has enabled a direct comparison between Thai and Western scales and the employment of Western-derived explanatory methods and terms to explain Thai tuning.⁷ Thus the standard explanation is that both Western (12-tet) and Thai tuning systems are equidistant; the Western scale comprises twelve equidistant notes and the theoretical Thai scale comprises seven. Because of the different theoretical processes of dividing the octave from which these scales are (supposedly) derived, the pitches and intervals of these scales are uniformly dissimilar and share no common notes (Morton 1976, 27; Somchai T. 1973, 6). An important distinction between Thai and Western equidistance is that Western equidistance is based on mathematical calculations that were devised to optimize harmonic functionality, whereas Thai equidistance is the product of the human ear with its preferences and vagaries.

The Thai scale’s intervallic properties, for which there is no apparent or accepted acoustic or psychological justification, mean that it cannot be explained in reference to these principles as is done to explain tuning systems that are based on the harmonic series (Polansky et al. 2009; Stumpf 1901). The absence of a credible historical record (Miller and Jarernchai 1994, 1–2; Schneider 2001, 490) leaves a gap that is filled with stories of uncertain historical accuracy. These stories are part of a web of colorful anecdotes about Thai music that are important in Thai musical life and its study. While it is not possible to verify these stories, they illustrate the importance of myth in shaping beliefs about Thai music. These beliefs, which are reinforced through the oral mode of knowledge transmission and the authority of the teacher in Thai pedagogy influence how musicians understand their history. Even though the theory of equidistance is an idea that was developed in Europe in the late nineteenth century and imported into Thai musical thought, the belief that 7-tet accurately describes traditional Thai musical practice has been important in shaping ideas about Thai music and how it should sound in Thailand and elsewhere.

The disparities between Western and Thai tuning systems have to a large extent defined the relationship between these musical systems. It was in the context of the compatibility of their musical elements that the influential German-born Western musician and long-time resident of Thailand Phra Chen Duriyanga (1948, 24) argued that

7. The term “scale” in this context refers to the array of consecutive bars and gongs of the fixed-pitch percussion instruments.

“under no circumstances can Western instruments be mixed up with the Siamese, since the scale-steps of the two systems of music are different.”⁸

The uptake of the European-derived explanation of Thai tuning in Thailand may be linked to the absence of Thai historical records and the historical Thai tendency to attach prestige to the products of supposedly Western thought (Pasuk and Baker 2009, 47–80; Peleggi 2008; Thongchai 2000, 529). This practice, which began in the mid-nineteenth century, gained momentum in the 1930s, when Western ideas and practices were used in politically fabricated attempts by the Phibunsongkhram government to modernize or “civilize” Thailand (Harrison and Jackson 2010, 65–66; Thongchai 2000, 530).⁹ Whatever the impetus, it has for many years been common practice for Western and Thai scholars alike to describe Thai tuning in the unyielding terms of mathematics rather than in terms that match the flexible nature of Thai melody.

The resurgence in popularity of Thai music following the fall of Phibunsongkhram in 1957 and its establishment in the university system brought a surge of interest in its study. In 1973, Somchai Thayanyong published an extensive study of the tuning of Thai instruments with the aim of understanding Thai tuning from a “scientific point of view” (Somchai T. 1973). This study, which included hundreds of instruments, found that although “Thai musicians try to tune to the equal interval scale. No instrument was tuned to anywhere near the equal tempered scale.”¹⁰ He further stated that “none of [sic] Thai instruments was tuned to equal tempered scale” (58). In 1998, an anonymous study of Thai tuning was commissioned by the Royal Thai Palace to ostensibly clarify tuning practice and explore the possibility of standardizing Thai tuning, thus enabling musicians to play in ensembles other than their own (Dusadee 2003, 25; Myers-Moro 1993, 31).¹¹ According to its author, who is now widely known to have been highly regarded musician Boonchuay Sawadt, this study proved “that the system of pitches used in Thai music is made up of seven notes divided by equal intervals within an octave” (Boonchuay 1999).¹² Whereas Somchai (1973) attempted to investigate and explain the properties of Thai tuning, Boonchuay (1999) accepted the validity of the theorized interval (171.429 cents), which he used to construct an ideal meta-scale that covered the combined ranges of all Thai instruments, even though his own data are unconvincing. Despite their different attitudes toward the theory itself, they both adopted quantitative methods of determining pitch relations and described tuning in mathematical terms.

In contrast to studies that were solely concerned with the physical characteristics of tuning, Thai musician and scholar Anant Narkkong’s (2003) study on tuning gave an insider’s perspective into Thai tuning that considered Thai musical history, practice, and

8. Western tuning is the European derived 12-tet system with a relatively standard reference frequency of 440 Hz for the note A4.

9. For example, see the twelve government edicts (*ratthaniyom*) developed during the period 1939–1942 by the government of Prime Minister Phibunsongkhram (see Pasuk and Baker 2009, 132.)

10. This comment appears in the Abstract, which is not numbered.

11. Thai tuning is not standardized, and ensembles belonging to different schools and institutions use different registers.

12. This comment appears in the Abstract, which is not numbered.

thought.¹³ Anant (2003, 445) acknowledged that many musicians accept the belief that Thai tuning is equidistant, but he also pointed out that tuning diversity is fundamental to Thai musical practice.

Previous analytical approaches to Thai tuning have lacked the capacity to comprehensively account for the intonational complexities of Thai tuning. This, combined with an absence of documentary evidence that could clarify its origins, has left room for speculation about its origins and nature. It is thus not surprising that the Thai tuning system has been a continual source of interest for ethnomusicologists and other scholars. Indeed, no discussion of Thai music seems complete without some acknowledgment of its tuning system. Scholars and musicians have written about it from a musicological perspective (see Burns 1999, 247; Bussakorn 1997, iv; Dusadee 2003, 23–32; Hughes 1992, 23; Miller 2008, 140–41; 1998, 260–61; Miller and Sam-Ang Sam 1995, 237–38; Morton 1976, 27; 1970, 4–5; Myers-Moro 1993, 31; 1988, 53; Panya 1999, 64; Silkstone 1993, 85; Tanese-Ito 1988, 112; Worayot 1998) while others have discussed it in terms related primarily to its physical properties (Abraham and von Hornbostel 1994, 450; Boonchuay 1999; Ellis 1885b; Kittiphong et al. 2004; Pheerasut et al. 2013; Phra Chen 1948, 57; Sarawut 2002; Sethares 2005, 303; Somchai T. 1973; Strumolo 2007, 3; Sugree 2003; Sugree et al. 1997).

Although the theory of equidistance is firmly entrenched in Western scholarly thought and in some areas of Thai musical thought, its legitimacy is assumed on the basis of belief in its authority rather than demonstrated on empirically verifiable grounds or conferred through intersubjective consensus among musicians.¹⁴ Some scholars, such as Boonchuay, have presented equidistance as a clearly articulated, definitive mathematical formulation that when applied, results in optimal Thai tuning. Alternatively, others endorse equidistance as the correct description of Thai tuning because this is widely accepted as the official explanation and as such has historical legitimacy. According to this belief, the sound of Thai music is inalienably linked to its equidistant tuning system. This makes the tuning system an important part of the Thai musical tradition and its history (Tanyatip 2012, pers. comm.).

Widely held beliefs about Thai tuning stem primarily from ideas related to the fixed-pitch percussion of the *piphat* ensemble upon which Ellis based his observations and theory, primarily the *ranat ek*, and *ranat ek lek*.¹⁵ In Morton's (1974, 90) discussion of Thai vocal music, he described what he termed the "traditional style" in which the singer is accompanied by the hand cymbals and drum. This is a description of vocal practice in *piphat* settings, which differs from other ensemble performances in which the singer is accompanied by a non-fixed pitched instrument.

13. This was part of the "Sonic Orders" research project, which was supported by the ASEAN Committee on Culture and Information.

14. Theory in this sense means the "production of generalizations about musical structure in the abstract" (Solis 2012, 530). I argue that there is no consensus about its validity among Thai musicians and that the theory is incorrect.

15. The standard *piphat* (*mai khaeng*) ensemble is made up of tuned and untuned percussion and a *pi* (Thai oboe). The tuned percussion instruments are also part of the *mahori* ensemble, but they have a supporting role in that ensemble. They are not part of string ensembles.

Piphat performs the highest repertoire (called *naphat*) in the most historically prestigious cultural events, such as the *wai khru* (teacher honoring) ceremony, the *khon* masked theatre, and royal ceremonies. This was the ensemble for which the music was transcribed when the Thai Manuscript Committee set about archiving Thai music from 1930 to 1942 (Panya 1999, 7). Through its associations with these cultural events and repertoire, *piphat* has an unambiguously elevated social position. For some musicians, this high social status has created what they perceive to be a *piphat*-centric view of Thai music, of which the equidistant tuning theory is a part. Thus, justifications for the belief that equidistant tuning is the sole correct Thai tuning system are partly based on an interpretation of Thai history that places *piphat* above other musical forms (Anant 2012, pers. comm.; Lerkiat 2012, pers. comm.; Worayot 2012, pers. comm.) Some musicians have claimed that the *piphat*-centric nature of Thai musical discourse has discouraged discussion and recognition of the factors that influence the tuning practice of non-*piphat* musicians. This is seen as an obstacle to institutional acceptance of alternative concepts and practices of tuning intonation (Anant 2012, pers. comm.; Dusadee 2003, 27; Lerkiat 2012, pers. comm.; Worayot 2012, pers. comm.).

UNCERTAIN ORIGINS OF THAI EQUIDISTANCE

Morton (1976, 226) speculated that Thai equidistance may be the result of mixing the Chinese tuning system, which is based on principles similar to just intonation, with the non-equidistant tuning system of the Khmer and possibly Mon musical systems.¹⁶ This would have led to “confusion” out of which a single equidistant system arose.

Musicians give varying accounts of the development of the tuning system. Two highly accomplished Thai string players explain their views on the historical development of Thai tuning that contradict the orthodox concept of equidistance. Highly regarded *sor* player Lerkiat Mahavinjchaimontri, who works at the Fine Arts Department (Krom Silapakorn) and is a member of the Fong Naam and Korphai ensembles, believes the Thai scale may have evolved as a result of Thai musicians in the Ayutthaya period (1350–1767) transposing primarily pentatonic vocal melodies to modes of the fourth and fifth degree on one hand, and their attempts to play them on the intonational inflexibility of the (pentatonic) fixed-pitch percussion on the other.¹⁷

According to this explanation, when vocalists changed register (mode/*thang*) during performance, they sang notes outside of the pentatonic mode in which they began. Adjacent notes of the pentatonic mode are separated by intervals of major seconds and minor thirds which makes them relatively easy to sing, but combining the pentatonic modes of the first, fourth, and fifth degrees results in a heptatonic mode that includes the smaller interval of a semitone. This created a problem because there was no theory of how to deal with this smaller interval that now existed between the third and fourth scale degrees, and the seventh and upper octave degrees (of the tonic mode) of the resulting

16. The practice of determining the tuning of musical instruments by simple ratios is believed to be more than 2000 years old in China (see McLachlan et al. 2013; DeWoskin 1987).

17. This refers to the pentatonic mode that comprises scale degrees 1-2-3-5-6.

heptatonic mode. According to Lerkiat (2012, pers. comm.), the solution was to make all intervals on the *ranat* the same size, thus creating Thai equidistance.

By contrast, Lerkiat's teacher, Worayot Suksaichon, who was formerly a member of Fong Naam and its precursor, the celebrated Siamese Music Ensemble (known in Thai as *Ketkhong damrong sin*), stated that before 7-tet became established, Thai fixed-pitch percussion instruments were probably tuned to a seven-note scale made up of tones and semitones similar to that of the *khaen*.¹⁸ He believes that equidistance became established in the Ayutthaya period following an incident in which a member of the Thai nobility ordered the removal of large and small intervals that made up the presumably diatonic tuning of the ensemble because it was tuned to a key outside of his singing range. As diatonically tuned percussion instruments are incapable of transposing, he ordered that all intervals be the same, thereby allowing the ensemble to play in any key (Worayot 2013, pers. comm.)

As with other undocumented stories about Thai music, these cannot be verified. However this does not reduce their importance because these and other stories influence how musicians tune and play their instruments. The legitimacy of such beliefs or the extent to which they influence musical behavior is not determined by the extent to which they can be historically validated. Thus, ideas that would be considered extra-musical from an analytical perspective cannot be isolated from performance or dismissed as irrelevant because they play a role in shaping music theory and instrumental practice and have a direct bearing on how music sounds. Those who accept that Thai music is equidistant may do so in part because they believe in the truthfulness of the concept of equidistance. This belief may be sustained by the considerable prestige and authority that the theory derives from its association with *piphat*. The lack of empirical evidence that confirms equidistance does not undermine this belief because empirical support is not a consideration. On the other hand, those who reject equidistance may do so because they prefer tuning concepts that are more suited to their instruments or singing practice for which 7-tet does not apply, or because they endorse another set of stories about Thai tuning. These attitudes cannot be explained by existing quantitative approaches to Thai tuning.

Despite the general acceptance of the theory of equidistance, there has been persistent academic uneasiness about it. It is a curious anomaly of Thai tuning that although it is regarded as equidistant and said to be defined by the interval of 171.429, which reflects optimal tuning practice, it is acknowledged that instruments are not actually tuned to this value. This idiosyncrasy is accepted as part of Thai music. Dusadee (2003, 23) called Thai tuning "functionally rather than acoustically equidistant." Morton (1976, 29) stated that while it is the intention of musicians is to achieve equidistance, it is "often imperfectly realized on instruments of fixed pitch." Sorrell, referencing George Orwell, stated that some intervals are "more equal than others" (quoted in Fong Naam 1991, 3). Myers-Moro (1993, 31) stated that "the Thai octave is divided into seven tones ideally—

18. *Khaen* is the bamboo mouth organ that originated in Laos.

though in practice rarely—an equal distance apart.” As recently as 2008, Terry Miller (2008, 140) stated that “controversy swirls around the problem of Thai tunings, specifically whether the tones of the Thai system are equidistant or not.” Kittiphong, Rudeerat, and Sarawut (2004, 1) measured the fundamental frequencies of a metal *ranat* and Thai flute (*klui phiang aw*) and, as with Somchai Thayarnyong (1973), found that “the pitch-intervals of Thai scale are not constant as the previous hypothesis of Morton’s.” These studies, as with all others, found no statistical evidence to support equidistance, and for reasons outlined here, it is unlikely that future studies will.

MISPERCEPTIONS OF THAI TUNING

The absence of evidence of precise equidistant tuning in fixed-pitch percussion has led scholars to speculate about this intonational diversity. Morton (1976, 28) attributed it to a range of factors including poor skill, mistakes made by tuners, faulty instruments, a “rough and ready approach to precise tuning,” and a general “decline” in the tradition. While these factors can lead to poorly tuned instruments, it is incorrect to attribute the intonational diversity that routinely occurs in Thai music to out-of-tune or otherwise intonationally suboptimal instruments.

While the method of tuning the *ranat* and *khawng wong* (by attaching a mixture of lead shavings and wax to retard vibrations) does not practically allow for them to be precisely tuned to the theoretically ideal interval, their lack of agreement with the theory does not necessarily make them out of tune by Thai standards. This is because they are tuned according to a traditional ear-based practice rather than to the specifications laid out in the theory of equidistance, which is not a consideration for most Thai tuners, many of whom are unaware of its existence.

However, attempts to rationalize the intonational diversity that routinely occurs in Thai music imply a belief that Thai tuning “should” match the theory, and that diversity of intervals falls outside of proper practice and requires explanation. This may be because the standardized tuning of Western music, in which harmonic practices depend upon precision and uniformity, is mistakenly assumed to be a universal concept.¹⁹ Attempts to explain Thai intonational diversity are predicated on the idea that equidistance is a requirement for songs to be played in any of the seven modes of the Thai musical system. However this is not a defining factor because modulation is generally limited to the fourth and fifth scale degrees, and Thai songs are played in a limited number of modes and some are rarely, if ever, used.²⁰ According to Panya (1999, 65), some modes “simply do not sound right” because of personal preferences in tuning. Thus it would be highly unusual for a single instrument or ensemble to perform a song in all seven modes. The observation that

19. It is well known that Western singers and players of non-fixed-pitch instruments also deviate from equidistance, but this often occurs as a result of musicians attempting to optimize harmonic effect, a practice which has no parallel in *phleng Thai doem*.

20. Morton (1976) uses the term “metabole” to describe the practice of modal transposition that occurs when a piece shifts tonal center. As with other terms used by Morton (1976), this is not used by Thai musicians, many of whom reject it.

some modes are more suitable than others indicates a difference between modes that is impossible in an equidistant tuning system.

Thai musical performances have a diverse intonational quality that is not comparable to anything found in conventional 12-tet-based Western musical practice, which is underpinned by harmonic uniformity. Intonational diversity occurs in the intervallic relations on individual instruments and between instruments within an ensemble. This diversity is normal and is not perceived by listeners or practitioners to be the result of poor musicianship or the result of aberrant musical practice in need of amelioration. It also exists between the pitch levels (entire registers) of traditional Thai music houses (*ban*) and music institutions that have historically differentiated themselves through their overall pitch register (*thang*).²¹ This plays an important role in the identity of an ensemble and is a marker of historical lineage and institutional affiliation.²² Despite the aforementioned attempt to explore the possibilities for standardizing Thai tuning, the tuning diversity found on fixed- and non-fixed-pitch instruments and singers is a normal part of Thai music and its elimination through standardization is not considered a desirable goal because this would cause a narrowing of musical scope and significant loss of tradition.

Thai tuning diversity has been theorized in relation to a concept called *phian chalia* (Lasit 2012, pers. comm.; Lerkiat 2012, pers. comm.) This term combines a term for “out of tune” with the term for average distortion. It translates to “average out-of-tuneness.” According to this idea, Thai tuning should be understood by considering fixed-pitch instruments separately from the non-fixed because they have different references for the theoretical concept of “out of tune.” For the fixed-pitch percussion instruments, *phian chalia* relates to deviations from the theoretical 7-tet system. These deviations occur as a result of limitations inherent in the tuning method (described below) and the preferences and skill of the tuner. Thus the seven-tone scale heard on the *ranat* and *khawng wong* is the product of what Lasit (2012) described as an ear-based detuning system.

On the other hand, *phian chalia*, as it relates to non-fixed-pitch instruments, relates to deviations that these players make from the natural harmonic series in the course of producing a Thai sound. Lasit and Lerkiat consider both Western 12-tet and Thai 7-tet to be examples of *phian chalia* because both of these tuning systems are understood to involve a process of detuning or out-of-tuneness in relation to what they consider to be the meta-principles that underpin their tuning (12-tet and 7-tet respectively). This is entirely in keeping with Thai musical practice as Thai music has no need for the precision required by harmonic music.

Some musicians, especially string players, argue that it is futile to attempt to explain intonational diversity solely in reference to equidistance because the theoretical interval is

21. The lowest pitch registers, such as that of *Ban Pattayakoson*, are considered the oldest. The overall tuning of ensembles is believed to have risen in pitch because of a historical tendency for ensembles to match that of the Fine Arts Department. This usage of the term *thang* relates to overall pitch register.

22. This is mentioned in passing by Myers-Moro (1993, 106) and by Prasarn, Anant, Lerkiat, Bussakorn, and Gaston in discussions with the author. It is considered common knowledge among Thai musicians.

an academic fabrication that has no bearing on musical practice. For these musicians, any attempt to understand intonational variations must also consider factors that influence intonation of string playing. These include the instrumental idiom (*thang khrueng*), the stylistic idiom in which the performer trained (*thang*), the accent in which the song is performed (*samnieng*), the ensemble in which a song is performed, and the skill and preference of the individual player. For them, it is not possible to understand the diversity inherent in Thai tuning without considering these factors. Seven-tone equal temperament cannot account for intonational diversity because these factors were not considered when the theory was formulated.

The tendency to explain tuning diversity in the context of equidistance is interpreted by some Thai musicians as an indication of the extent to which Thai music and its tuning is misunderstood. This is often attributed to the influence of Morton's work and the perception that it attempted to explain Thai tuning practice from a Western perspective that did not consider the full range of factors relevant to Thai performance. Morton's legacy in Thai musical circles remains slightly controversial. Wong (1999, 53) described the irritation Thai musicians felt towards Morton's use of the term "metabole." In my discussion with Thai musicians, it was clear that his work is respected for its historically ground-breaking importance, but some consider his understanding of Thai music rudimentary and occasionally flawed. Doubt over the work of Morton and others has resulted in an attitude of dismissiveness on the part of some Thai musicians towards Western scholarship because they feel that it has failed to realize that intonational diversity is a normal and valued characteristic of Thai music with a distinctive aesthetic function and quality. They attribute this to an insistence on explaining Thai tuning from a Western analytical perspective in Western terms (Anant 2012, pers. comm.; Gaston 2012, pers. comm.; Lerkiat 2012, pers. comm.)

The belief that Thai music is misrepresented is not unfounded. For example, in his book *Tuning, Timbre, Spectrum, Scale*, Sethares (2005, 304) states that "the *pong lang* is a wooden xylophone-like instrument from Northeast Thailand. Like the boat-shaped *renat*, it is tuned to (approximately) 7-tet." This is incorrect. The *pong lang* belongs to the Isan musical system from the Northeast of Thailand, and as with all Isan instruments, its tuning is based on the heptatonic tuning of the *khaen* (Miller 2008, 173), which is tuned to simple integer ratios. It is part of an entirely different musical-cultural system and its tuning is unrelated to that found in the Thai classical music he was discussing.

TUNING OF PERCUSSION AND THE OCTAVE

The second issue in the first category of problems relates to the Thai octave. The theory of Thai equidistance is predicated on a harmonic octave because it has simply been assumed that the Thai octave is a ratio of 1:2. However, many tuners do not intend to tune the octave to a ratio of 1:2, but aim for a marginally larger interval. The diversity found in the tuning of Thai fixed-pitch percussion, including variations in the octave, can be partly explained by the limitations imposed by the materials and methods used in tuning these instruments. The tuning of Thai percussion instruments involves attaching or removing a mixture of beeswax and fine lead particles called *tagua* to the underside of each end of the

wooden (bamboo for *ranat thum* and Thai hardwood for *ranat ek*) *ranat* bars, and to the inside of the concave section of the raised bosses of the gongs. The addition or removal of *tagua* adds or reduces mass, which lowers or raises the pitch. When tuning the *ranat* or *khawng wong*, the tuner matches the pitch of a bar or gong to a specific note played on a *khlui* (Thai flute) or to a bar on a *ranat lek* (Anant 2003, 446). Successive bars or gongs are then tuned by ear to the correct pitch according to the tuner's personal concept of tuning (Figure 1).

This entire process has traditionally been done by an experienced musician who tunes solely by ear (Anant 2003, 452). While there are tacit limits to permissible intonational diversity, it is accepted that reliance on the human ear inevitably leads to variations of tuning amongst instruments and ensembles and tuners are known to make small "personal adjustments to the equidistance" (Panya 1999, 65).²³

The *khlui* and *ranat lek* are used as references because their pitch is set when they are manufactured and does not change unless they are physically altered in some way.²⁴ This can be done by changing the bore size or repositioning the holes of the *khlui*, or filing or grinding all of the bars of the *ranat lek*, but these are extreme measures that indicate a transformation in the entire tuning register of an ensemble. This does not happen lightly and is not part of the normal tuning process.

The large octave interval can be tuned in two ways. The first six successive intervals, ascending or descending, may be tuned to a size that corresponds to the tuner's concept of



Figure 1. Renowned master tuner *Khru Sivasit Nilsawan* and *Adjarn Kumkorm Pornprasit* preparing *tagua* with a hair dryer. (Photo by John Garzoli.)

23. Electronic tuners are also occasionally used nowadays.

24. They are also used to ensure consistency of tuning register of all instruments belonging to a *ban* or institution.

the Thai interval, and the seventh and final interval is made slightly wider. Alternatively, the tuner may simply approximate the expanded octave interval by ear and adjust the other intervals according to their preference. In each case the tuner aims to tune the octave interval (above or below the note from which tuning commences) larger than the harmonic octave by about 10 cents. The extent to which tuners increase the size of this interval varies with the skill and preference of the tuners (Anant 2012, pers. comm.; Bussakorn 2012, pers. comm.; Prasarn 2012, pers. comm.) Perhaps wary of what they perceive to be a tendency by Western scholars to conflate the intentions of tuners with precise mathematical values, the tuners and musicians with whom I discussed this practice stated the 10 cents value was an approximation only; and, as with other aspects of Thai tuning, the slightly expanded octave is considered an aspirational target and not a precisely measured process (Bussakorn 2012, pers. comm.)

Prasarn Wongwirojruk, who is a member of the Thai classical and fusion music ensembles Fong Naam and Korphai, is a recognized tuner of percussion instruments and has studied the theory of Thai tuning. Most of the ensembles he tunes are calibrated to the register (*thang*) of celebrated musician Luang Pradit Phairoh or that of Krom Silapakorn (Fine Arts Department).²⁵ He generally tunes by ear but occasionally uses an electronic tuner to tune to the theoretical 7-tet. Although the theoretical interval of 171.43 is a factor in his practice, his tuning is not equidistant. He aims to tune the first six intervals, ascending and descending from the starting pitch, to his concept of equidistance. The octave is tuned to a slightly larger interval, which is commonly thought to be about 10 cents larger than the other intervals. Prasarn's use of the theoretical interval is not typical and other tuners I spoke with were unaware of the existence of the theory and the numerical value of the interval. Tuners aim for a quality of sound that satisfies their own judgment. It is not a priority or considered a realistic goal to attempt to tune to a specific numerical value. In my discussions with highly regarded tuners Sivasit Nilsawan (2012, pers. comm.) and Chalor Jaicheun (2012, pers. comm.), they were insistent that tuning be done by ear because it is the skill, experience, and preference of the tuner that determines the tuning quality of an ensemble. Both of these individuals were dismissive of the theory of equidistance.

The common practice of stretching one of the octave intervals per octave has implications for the theory of equidistance and the ideal interval of 171.429 because the cents system, which is a means of indicating the geometric proportions of a ratio, is based on an octave ratio of 1:2. However, because Thai percussion instruments are intended to be tuned to a larger interval, the equal division of the expanded Thai octave (approximately 1210 cents) does not result in a theoretical interval of 171.429 cents but rather a theoretical interval of 172.857. This is obviously a very small difference, in fact it is imperceptible, but if mathematical principles are to be employed in the description of Thai tuning, then they must be based on correct values.

25. *Thang* in this sense means pitch register. The *thang* of Luang Pradit Phairoh and Krom Silapakorn are part of what is known as the *fang* Phra Nakhon. They are not regarded as the same but they share a familial relationship. They are distinguished from music schools of the Thonburi area of Bangkok called *fang* Thon (Thonburi shore/riverbank), whose pitch register is older and therefore lower.

MORTON'S TESTING

Morton's (1976) widely cited book *The Traditional Music of Thailand* constituted the largest study of Thai tuning of its time. His work on tuning has stood out as one of his major contributions and has become an important reference for scholars who discuss Thai music and tuning. Despite widespread acceptance of this work, Morton's methodology has not been evaluated. Fuller (1979, 340) was critical of it and claimed to have found at least "50 errors of cents and averaging figures," but he did not provide details of these errors. My results indicate that with one exception, Morton's arithmetic was without substantial errors.²⁶ I will concentrate on what I consider to be flaws in Morton's methodology. These include concerns about the reliability of the testing equipment, the lack of consistency in the number of instrument samples, and the practice of using averages to describe frequencies and their intervallic relations as a method of analyzing Thai tuning practice and explaining tuning theory.

Morton's pitch data were collected from five sets of fixed-pitch percussion instruments that belonged to the Department of Fine Arts (Krom Silapakorn), the Publicity Department (Krom Pracha Samphan), the University of Agriculture, an unnamed Thai television station, and the Phakavali Institute of Dance and Music.²⁷ These instruments were tested in Thailand with a monochord. The Phakavali instruments and a set of instruments that Morton had purchased in Bangkok were tested again in the USA with a Stoboconn when the instruments were transported there in 1962.

Morton (1976, 25) acknowledged that both the monochord and the Stoboconn produced inaccuracies and noted that when the monochord was compared to the Stoboconn, "it was found that pitches produced on the monochord deviated from those produced on the Stoboconn by about 10 cents over the entire range, not always on the same side of the pitch, or consistently from one test to another." He also acknowledged that the accuracy of data generated using the monochord is directly proportionate to the ability of the ear to hear correctly, and that "the device is easily affected by climatic conditions" (25). Morton included the monochord data in his master tuning chart in Appendix B to allow for comparison but he stated that they were less accurate than the Stoboconn data. The monochord data were not included within other sections of his analysis.²⁸

Morton's process of determining the intervallic properties of the Thai scale involved two steps. He first collected raw pitch data in hertz from each note of each instrument. Frequencies (Hz) of the corresponding notes from all of the instruments were averaged to create a reference frequency. In this way, he attempted to represent the notes of all instruments with a single numerical value by calculating the mean frequency of

26. The average of the highest note of the *khawng wong lek* in Table A, Appendix B of Morton (1976, 233) is incorrectly indicated as 2446; the correct value is 2429.3.

27. Phakavali was the traditional Thai musical theater company that was established by the family of Thai musician Luang Pradit Pairon. It performed dramatic arts involving music, dance, and storytelling.

28. The Stoboconn data were taken from readings of four instruments that were measured during 1961 and 1962.

corresponding notes on each instrument. With the exception of instruments in Tables A, B, and C of Appendix B, the frequencies indicated for the gongs and bars in his tables are not measurements of individual gongs or bars but are the mean value of numerous gongs and bars (Morton 1976, 233–35).

Morton's next step was to use these averages to calculate average intervals (cents). The values given for the intervals are also the product of calculating the mean, in this case, of multiple intervals taken from the multiple instrument types. By this process he was satisfied that the Thai tuning is idealistically equidistant and that "in tune" instruments are reasonably close to equidistant, which he henceforth considered the "theoretically correct" tuning (Morton 1976, 27). This is a questionable conclusion to draw in light of his raw data from *ranat lek*, *ranat thum*, *khawng wong yai*, and *kong wong lek* in Table A, which show disparities of up to 80 cents below and 40 cents above the theoretical interval in the lower register of the *ranat thum* (233).

The data upon which Morton (1976, 233) based his analysis and part of his conclusions were collected in Thailand from monochord readings of nine *ranat thum*, fourteen *ranat ek*, six *khawng wong yai*, and four *khawng wong lek*. These readings were then combined with another data set taken from instruments that were used in a performance given by the Phakavali ensemble. He also collected another set of data that were derived from three sets of Stroboconn readings of the Phakavali instruments taken in America in 1961 and 1962.

Because of the overlapping ranges of the instruments he measured, there is an unavoidable lack of uniformity in the number of corresponding gongs or bars that can be averaged at each pitch level. Some notes are present on all instruments while others are present only in the upper or lower register of one instrument type. For example, the bars and gongs that produce frequencies of approximately 600 Hz and 665 Hz are shared across all thirty-seven individual instruments measured with the monochord and all ten measured with the Stroboconn. Thus the mean (average) values of these frequencies are derived from instrument samples of thirty-seven (*ranat* bars) and ten (gongs). However, the register of the *khawng wong lek* is higher than the other instruments. It has seven gongs that range from 1362 to 2464 Hz that exceed the highest notes of the *khawng wong yai* and *ranat lek*.²⁹ Therefore, the averages of the higher notes in Morton's tables (Appendix B) are taken solely from the *khawng wong lek*.

A problem with this methodology can be illustrated by comparing the mean frequencies of sets of corresponding *ranat* bars and gongs with Morton's combined mean of these sets of intervals. Tables A and B below compare Morton's (1976, 237) average frequencies of the *khawng wong lek* and the *ranat ek* to individual pitch data he collected from each instrument (before they were combined and their averages calculated). These tables show the intervallic relations of the *ranat* and *khawng wong yai* to clarify the extent to which averaging intervals distorts the data.

Table A shows that the interval between the nineteenth and twentieth *ranat* bars is 176 cents (column 3). Table B shows that the corresponding frequencies are at gongs six

29. These values are Morton's monochord averages presented in Morton's (1976, 233) Appendix B.

and seven (also 176 due to averaging). This value indicates a close match with the ideal theoretical interval. However, when the instruments are considered in isolation, i.e., as they would be heard (an impossible task given that this datum is already the mean of multiple instruments), a different picture emerges.

The nineteenth and twentieth *ranat* bars in Table A have frequencies of 998 Hz and 1098 Hz respectively (column 2). This is an interval of 165.3 cents (column 4), which is 6.1 cents smaller than the theoretical interval. The sixth and seventh gongs, which are the corresponding pitches on the *khawng wong lek* shown in Table B, are 994 Hz and 1106 Hz, respectively (column 2), an interval of 184.8 cents (column 4), which is 13.4 cents larger than the prescribed 171.429.

<i>Ranat</i> <i>ek</i> bar number	Morton's Stroboconn readings (Hz)	Morton's average interval (cents)	Actual interval ³⁰ (cents)
21	1220		
20	1098	178	182.4
19	998	176	165.3
18	896	187	186.7
17	818	160	157.7
16	740	167	173.5
15	672	175	166.9
14	604	177	184.7

Table A. Interval between individual *ranat* bars compared to Morton's averages. Table based on data from Morton's (1976, 237) Table E.

<i>Khawng</i> <i>wong lek</i> gong number	Morton's Stroboconn readings (Hz)	Morton's average interval (cents)	Actual interval (cents)
8	1224		
7	1106	178	175.5
6	994	176	184.8
5	894	187	183.6
4	812	160	166.6
3	738	167	165.4
2	664	175	182.9
1	602	177	169.7

Table B. Interval between individual gongs compared to Morton's averages. Table based on data from Morton's (1976, 237) Table E.

30. This value is the average of the single instrument types before the data from the *ranat* bars and *khawng wong yai* gongs were combined and averaged.

The process of calculating the mean frequency of these separate sets of instruments obscures the difference that exists between them and gives the false impression that the interval between these notes is 176 cents when in fact there is a difference of 19.5 cents between these two (sets of) instruments. The *ranat* interval is 6.1 cents smaller than the theoretical 171.429 and the gong interval is 13.4 cents larger. Cents is an analytic term that is not continuous with human perception so the extent to which this disparity affects how music is interpreted cannot be known from this data alone, but disparities between instruments should not be obscured by the analytic processes that are intended to elucidate their relations. In this case, however, such relations are theoretical conjecture because the averaged data are a statistical fabrication that does not correspond to the sound that the instruments make or to any sounds they may be intended to make.

In summary, Morton's work is flawed because his hypothesis incorrectly presupposes that the Thai octave is a ratio of 1:2, the technology he used to collect raw pitch data was, by his own admission, susceptible to environmental and human influence that raise questions about their reliability, and there is methodological inconsistency in his instrument sample numbers. However, even if these problems were overcome, the data would still be of questionable use because using averages derived from multiple instruments is not a proper way to understand tuning systems. Morton's methodology presupposes that averages derived from multiple instruments and multiple unrelated sets of instruments can produce meaningful data about these instruments from which a general tuning theory can be deduced. I dispute this and argue that in order to represent the specific characteristics of a musical instrument, each individual note must be represented in hertz and each individual interval in cents, thereby enabling meaningful comparison between the notes on a single instrument, between notes on different instruments, between notes on different sets of instruments, and between instruments and theoretical models.

The process of creating averages obscures the actual differences that exist between instruments and disregards what the ear perceives when listening to individual instruments. The idiosyncratic tuning characteristics of individual instruments can only be understood by considering their intervallic qualities in isolation, which is not possible when they are averaged. Attempting to derive or corroborate a tuning theory from the mean of multiple instruments misrepresents the way the instruments actually sound. Therefore Morton's theoretical intervals are not indicative of any of the instruments that he tested and have no meaningful relationship to any sound that the individual instruments actually produced because the actual variations between instruments are lost as a result of averaging. The various sets of frequency data that have been published in the abovementioned studies indicate that the tuning of individual fixed-pitch percussion instruments vary widely. In the case of Morton's work, discovering the extent of this variation is made impossible because the frequencies of multiple instruments are given as averages.

RESULTS OF PITCH TESTS

To place Morton's data in perspective, I have collected and analyzed pitch data from multiple fixed-pitch percussion instruments. The instruments tested were from

Chulalongkorn University and other recognized music institutions. They were in use and considered in tune by the musicians who use them when they were recorded. Raw pitch data were conducted using a Zoom H4N digital recorder. Output WAV files were analyzed using Audacity and Audio Visualizer software programs, which provide fundamental frequencies in hertz. Cents calculations were done in a spreadsheet. These technologies helped eliminate the methodological problems described by Morton. Table C summarizes the results of tests of the instruments from Krom Pracha Samphan (the Public Relations Department), Chulalongkorn University, *Ban Sivasit Nilsawan*, and *Ban Pattayakoson*.

These data indicate variations from the theoretical interval of 171.429 in the instruments tested. Intervals shown in columns 4 and 5 are those that are closest to 7-tet. Intervals in columns 2 and 3 are the furthest. The greatest deviation from 7-tet is seen in

Instruments tested (1)	2	3	4	5
Chulalongkorn University instruments	cents	cents	cents	cents
<i>khawng wong yai</i> #1	17.4	-29.1	0.7	-1.0
<i>khawng wong yai</i> #2	25.9	-23.8	0.8	-1.6
<i>khawng wong yai</i> #3	14.6	-11.3	0.2	-0.1
<i>khawng wong yai</i> #4	11.2	-23.6	1.8	-2.9
<i>ranat thum</i> #1	69.7	-47.3	11.3	-3.8
<i>ranat thum</i> #2	28.5	-23.2	1.3	-1.0
<i>ranat thum</i> #3	25.4	-11.2	0.9	-4.7
<i>ranat ek</i> #1	20.0	-12.8	1.1	-0.7
<i>ranat ek</i> #2	27.0	-23.9	1.8	-0.7
<i>ranat ek</i> #3	51.3	-45.8	0.2	-0.1
Sivasit Nilsawan instruments				
<i>ranat ek</i>	33.6	-20.8	0.1	-0.5
<i>ranat ek</i>	15.1	-14.8	0.1	-0.1
<i>ranat ek lek</i>	24.1	-13.9	0.2	-1.1
<i>ranat thum</i>	42.8	-22.3	0.9	-3.0
<i>ranat thum lek</i>	19.8	-9.5	0.0	-0.4
<i>khawng wong yai</i> #1	15.5	-10.2	1.6	-0.8
<i>khawng wong yai</i> #2	15.3	-16.3	0.2	-1.2
<i>khawng wong lek</i>	18.7	-8.1	0.5	-1.1
Pattayakoson instruments				
<i>ranat ek</i>	26.8	-23	1.4	-4.5
<i>khawng wong yai</i>	27.2	-19.4	2.0	0.0
<i>ranat thum</i>	55.3	-23.4	1.1	-2.1
Krom Phracha Samphan instruments				
<i>ranat ek lek</i>	32	-27.7	1.1	-0.4
<i>ranat ek</i>	30.8	-35.2	0.1	-3.3

Table C. Frequencies of selected Thai instruments from four music institutions. For each instrument, the table reports the intervals that are furthest from and closest to the theorized interval of 171.429 cents, with columns labeled as follows: 1. instrument type; 2. furthest interval above 171.429 cents; 3. furthest interval below 171.429 cents; 4. nearest interval above 171.429 cents; 5. nearest interval below 171.429 cents.

the *Ranat thum* #1 from Chulalongkorn University (69.7 cents), the Pattayakoson *ranat thum* (55.3 cents), and the *ranat thum* of Sivasit Nilsawan (42.8 cents). Each of these intervals deviates from the theoretical interval by more than 40 cents. These data are in line with previous research showing that Thai percussion instruments are not tuned to 7-tet. The 7-tet theory implies that the diversity of intervals found on these instruments is the result of them being “out of tune.” As these instruments were in use at the time of testing, this is clearly not the case. The inability of the theory to account for this diversity means that it cannot explain tuning that Thai users consider correct.

THE LIMITED SCOPE OF 7-TET

The inability of the theory to explain the intonational diversity of Thai fixed-pitch instruments raises doubts regarding its suitability to fulfill the task for which it was conceived. However, an even greater problem lies with the theory’s limited scope. Ellis and Morton provide only a partial explanation of Thai tuning because their tests were restricted to the *khawng wong yai*, *khawng wong lek* (large and small gong circles), *ranat ek* (soprano xylophone), *ranat el lek* (soprano metallophone), *ranat thum* (alto xylophone), and *ranat thum lek* (alto metallophone). Conclusions or theories derived from Ellis and Morton’s work are incomplete because of this omission.

By not distinguishing between instrument types, the tuning of all Thai instruments is conflated. The failure to consider intonational concepts of singers and wind and string instruments separately means that they are viewed through the theoretical prism that was designed for fixed-pitch instruments. Despite this shortcoming, 7-tet has historically been regarded as comprehensive. With the exception of Miller (2008, 141), who acknowledges that “any discussion of equidistance and nonequidistance concerns only certain members of the Thai instrumentarium,” scholars do not generally distinguish between tuning practices of instrument families or ensembles. This may stem from Phra Chen’s (1951, 4) comments that the Thai “diatonic scale” was “characteristic to Siamese music and to all Siamese musical instruments.” Morton (1974, 89–90) describes pitches of a single vocal performance using a device called a Melograph.³¹ In this study, he recognized that some vocal tones were clearly different from the fixed-pitch instrument, but he did not offer a substantial explanation for the differences he observed. In his study of tuning, Boonchuay (1999) did not measure vocalists because, according to Dusadee (2003, 27), he “assumed that vocalists used the same equidistant scale as instrumentalists.”

While the idea does not circulate widely in English, it is common knowledge among Thai musicians that vocalists and string players have a different concept of tuning to that of the percussion of *piphat* (Anant 2012, pers. comm.; Gaston 2012, pers. comm.; Lasit 2012, pers. comm.; Lerkiat 2012, pers. comm.; Pornpradit 2012, pers. comm.; Prasarn 2012, pers. comm.) This distinction is the basis for Jarun and Kittiphong’s (2013) study of variations in the way Thai flute players interpret Thai melodies played in different accents (*samnieng*).

31. This device was developed by ethnomusicologist Charles Seeger. See Moore (1974).

While players of fixed-pitch percussion have no control over pitch and are not required to attend to subtle intonational detail during performance, those who sing or play non-fixed-pitch instruments have considerable discretionary powers and high levels of control over intonation. Consequently there is a disparity in the attitudes toward tuning and intonation between singers and players of non-fixed-pitch instruments who are associated with *khrueng sai* and *mahori* ensembles, and those who play in the fixed-pitch percussion-based *piphat* because their experience of intonation and the production of melody is fundamentally different (Anant 2012, pers. comm.; Lerkiat 2012, pers. comm.; Worayot 2012, pers. comm.)

Apart from Dusadee's (2003) discussion, little has been made of the intonational practices of singers and string players other than for their intonational diversity to be regarded as ornamental variations of 7-tet rather than part of structurally different systems. Panya (1999, 64) states that the intonational diversity of string players gives the "appearance of additional pitches" but that these are "not actually part of the system." Miller (2008, 140–41) observed that some instruments "make use of intonations between those of the fixed-pitch instruments, and these are difficult to accommodate in any system. Indeed, the gliding commonly played on these suggests a continuum of sound, rather than a series of specific levels of pitch." The tendency to consider this intonational difference as ornamental has obviated the need to theorize alternative tuning systems.

It is true that intonational variation is outside of the orthodox theoretical system but it is not accurate to describe it as purely ornamental. String players and vocalists with whom I discussed tuning approach melody and intonation entirely differently from how tuning is rendered on fixed-pitch percussion. For these musicians, intonational diversity cannot be explained as the product of embellishment because these sounds are not variations of 7-tet but are instead characteristic of an alternative Thai tuning system that should be understood on its own terms.

There are a number of factors that influence the production of melody and intonation of non-fixed-pitch instruments. As stated above, the *samnieng* of a composition or performance requires that string players shape the melodic quality to match a particular musical style. The *thang* of a music school or house, and the individual preference and skill of the performer also influence the melodic quality of string playing and singing (Anant 2012, pers. comm.; Gaston 2012, pers. comm.) The extent to which these factors shape intonation depends upon the ensemble type and the role and proportion of fixed- and non-fixed-pitch instruments. When playing with fixed-pitch percussion (*piphat*, *mahori*), string players usually match their intonation to the *khawng wong* and *ranat*, but when playing with a string ensemble (*khrueng sai*) that does not contain fixed-pitch percussion or as soloists, they do not need to consider the inflexible nature of the percussion and tailor their intonation to suit the melodic context (Anant 2012, pers. comm.; Dusadee 2003, 29–32).

Former Fong Naam member, singer, *jakhe* player, and scholar Dusadee Swangviboonpong (2003, 27) claims that while singers prefer other tunings, equidistance has been imposed on them by authorities and consequently they are "mirroring an

establishment viewpoint.” The convention of all instruments matching *piphat* tuning gives insight into the influence of culture on Thai intonation. For Dusadee (2003, 27), the practice of non-fixed-pitch musicians aligning their intonation with fixed-pitch instruments does not occur voluntarily but is “imposed” on singers who are pressured into “fitting in” with the tuning practices of *piphat*. A more assertive stance has been taken by Worayot, who has been a prominent figure in advocating for the recognition of alternative concepts of Thai intonation. His 1998 Thai-language publication on string tuning, the *Theory of Thai Musical Sound* (ทฤษฎีเสียงดนตรีไทย), and outspoken views on tuning have made him a controversial figure in Thai musical circles (Anant 2012, pers. comm.; Lerkiat 2012, pers. comm.) He and a number of his students, including Lerkiat, have challenged the legitimacy of 7-tet and questioned its legitimacy as the sole model of Thai tuning on the grounds that they do not use it when playing Thai music.

CONCLUSION

The contention that Thai music is based on an equidistant tuning system should be abandoned because equidistance as specified by the accepted theory of Thai tuning (7-tet) does not exist in Thai music. Although Ellis’s theory of 7-tet prescribes an ideal interval of 171.429, this is not found on actual instruments, and in the course of this study, no tuners endorsed nor adopted the theory in practice. The theoretical formulation incorrectly assumes an octave of 1:2, and the theory overlooks singers and string players. Unsurprisingly, given these conditions, the theory of equidistance has not been supported by empirical research, which has consistently found no evidence of it.

Belief in equidistance has been sustained by the incorrect assumption that Ellis’s theory was accurate and comprehensive. It became entrenched in Thai thinking through the work of the Western music specialist Phra Chen Duriyanga, who had limited knowledge of Thai music, and strengthened in Western ethnomusicological thought through David Morton. Despite its prevalence, the theory is questionable because it was formulated under conditions that did not consider the full range of Thai instruments. It is also suspect because it was based on a reductionist epistemological framework that overlooked factors that are important in the performance of Thai music. Thus, the Western-originating idea of Thai equidistance became a quasi-theoretical orthodoxy despite its various shortcomings. In the process, scientific materialism and early Western ethnomusicology collided with the historical impetus within Thai society to “modernize,” creating a false orthodoxy that was both incorrect and incomplete.

Discussions of Thai tuning often invoke two contradictory positions. On one hand it is presumed, without good evidence, that the theory of 7-tet, which comprises a single interval size of 171.429, is the most correct way to understand Thai tuning. On the other hand, scholars accept that intonational diversity is part of Thai music. These positions are fundamentally incompatible. Despite not being supported by empirical evidence, the theory creates confusion by implying that the “correctly” tuned Thai instrument should be tuned to the ideal interval. This gives two false impressions: first, it creates the illusion that when tested, Thai instruments are routinely out of tune; and second, it implies that, were

an instrument found to be tuned to precisely 7-tet, it would represent a superior expression of Thai tuning to those that are not so tuned. This is incorrect because the idea of standardized tuning is not part of the Thai musical tradition and Thai musicians do not require this of their instruments. On the contrary, as testing on serviceable instruments has shown, intonational diversity is routinely accepted as the norm.

The intonational diversity that routinely occurs in Thai music exists for a variety of reasons, most of which are not found in standardized Western musical forms. Thus, Thai tuning should be understood in relation to the music-cultural conditions of Thai instruments and their use rather than in terms appropriate for Western musical analysis.

The theoretical shortcomings in Morton's methodology raise questions about its continued use as a reference for Thai tuning, but pointing out methodological problems merely demonstrates that Thai tuning has been misrepresented and is consequently misunderstood. It does not resolve the problem of how to arrive at a comprehensive description of Thai tuning. Discussions with expert musicians and analysis of empirical data show that intonational diversity in instruments that are considered to be acceptably in tune (by those who tune and play them) cannot be explained by 7-tet. My and other empirical tests show that the interval of 171.429 bears little relationship to the reality of tuning of Thai instruments. As the supposed ideal interval is not normally a consideration when fixed-pitch percussion instruments are tuned, it may at best be considered a loosely approximate analytic expression that may be useful in explaining some aspects of Thai tuning theory, rather than a canonical theoretical benchmark to which tuners aim. This is consistent with Panya's (1999, 64) view that because Thai music is not based on "an a priori, articulated theoretical system," it is not possible to reduce it to a set of "rules" and thus cannot be understood in quantitative terms.

However, the greatest flaw in the theory of equidistance is that it covers only the fixed-pitch percussion instruments. Equidistance by definition excludes variation in interval sizes. Thus the theory of equidistance applies to only those instruments that are incapable of altering tuning. The intonational diversity practiced by singers and string players is clearly not part of the Thai equidistant system and the theory provides no insight into these intonational concepts.

Scholars have proposed equidistance and then stuck to it even though empirical evidence refutes it, and many Thai musicians either do not consider it or explicitly reject it, especially those who do not play fixed-pitch instruments. So long as the notion of equidistance is believed to be comprehensive and inclusive of all Thai instruments and singers, Thai tuning will remain misunderstood. The gaps in understanding of Thai tuning can only be filled when the intonational concepts and practices of instrumentalists who do not play fixed-pitch percussion and singers are recognized. Rather than attempt to explain Thai tuning in mathematical terms, I have argued that it is more helpful and closer to Thai musical practice to understand it as a broadly defined concept and practice that comprises two main categories. On the one hand there are percussion instruments that have seven fixed notes in a stretched octave. The tuning of these instruments may be thought of as idiosyncratic versions of approximate equidistance. On the other hand, singers and non-

fixed-pitch instruments are not constrained by such limitations and their practice involves producing notes that are part of alternative, although often not explicitly theorized, intonational concepts and practices. The tuning of these instruments is in the hands of the performer, where it is influenced by a range of factors including the instrumental and stylistic idiom (*thang*), musical accent (*samnieng*), and skill and preference of individual musicians. This concept of tuning cannot be explained by the orthodox theory and should be understood in terms that reflect its features rather than those designed to explain other instrument families.

Thus, loosely approximate and highly idiosyncratic versions equidistance of fixed-pitch percussion should be considered as but one of a number of competing beliefs about Thai tuning, each of which is based on its own musical and historical insights and supported with its own justifications. Seven-tone equal temperament and the widely cited interval of 171.429 cents should be abandoned because they imply that Thai tuning can be meaningfully understood in terms of standardization and uniformity. But without evidence of this and in the face of musical performances by Thai master musicians who tune in other ways, the equidistant theory should be jettisoned because it misrepresents the reality of how both fixed-pitch and non-fixed-pitch instruments are tuned and played.

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REFERENCES

- Abraham, Otto, and Erich M. von Hornbostel. 1994. “Suggested Methods for the Transcription of Exotic Music.” Translated by George and Eve List. *Ethnomusicology* 38(3): 425–56.
- Anant Narkkong. 2003. “Sonic Orders in the Musics of Thailand.” In *Sonic Orders in ASEAN Musics: A Field and Laboratory Study of Musical Cultures and Systems in Southeast Asia*, edited by Joe Peters, 442–54. Singapore: ASEAN Committee on Culture and Information.
- Boonchuay Sawadt. 1999. *ความถี่ของเสียงดนตรีไทย* [The Sound Frequency of Notes Used in the Thai Musical Scale]. Bangkok: Reurnkaew Karnphim.

- Burns, Edward M. 1999. "Intervals, Scales, and Tuning." In *The Psychology of Music*, edited by Diana Deutsch, 2nd edition, 215–64. San Diego: Academic Press.
- Bussakorn Sumrongthong. 1997. "Melodic Organization and Improvisation in Thai Music with Special Reference to the Thaang Ranad Eek." PhD diss., University of York.
- DeWoskin, Kenneth J. 1987. "Comment on 'The Bronze Chime Bells of the Marquis of Zeng: Babylonian Biophysics in Ancient China' by E. G. McClain." *Journal of Social and Biological Structures* 10(4): 329–41.
- Dusadee Swangviboonpong. 2003. *Thai Classical Singing: Its History, Musical Characteristics, and Transmission*. Aldershot: Ashgate.
- Ellis, Alexander J. 1863. "On the Temperament of Musical Instruments with Fixed Tones." *Proceedings of the Royal Society of London* 13: 404–22.
- . 1885a. "On the Musical Scales of Various Nations." *Journal of the Society of Arts* 33: 485–527.
- . 1885b. "On the Musical Scales of Various Nations: Appendix." *Journal of the Society of Arts* 33: 1102–07.
- . 1895. Additions by the translator to *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, by Hermann Helmholtz, 430–556. Translated by Alexander J. Ellis. 3rd ed. London: Longmans, Green, and Company.
- Fong Naam. 1991. Liner notes from *The Sleeping Angel: Thai Classical Music*. Nimbus Records NI5319, compact disc.
- Fuller, Paul. 1979. Review of *The Traditional Music of Thailand*, by David Morton. *Ethnomusicology* 23(2): 339–43.
- . 1983. "Thai Music 1968–1981." *Yearbook for Traditional Music* 15 (East Asian Musics): 152–55.
- Graham, Walter Armstrong. 1913. *Siam: A Handbook of Practical, Commercial, and Political Information*. 2nd ed. Chicago: F.G. Browne.
- Harrison, Rachel V., and Peter A. Jackson. 2010. *The Ambiguous Allure of the West: Traces of the Colonial in Thailand*. Hong Kong: Hong Kong University Press.
- Hughes, David W. 1992. "Thai Music in Java, Javanese Music in Thailand: Two Case Studies." *British Journal of Ethnomusicology* 1(1): 17–30.
- Jarun Kanchanapradit, and Kittiphong Meesawat. 2013. "Subjective Measurement of Thai Traditional Musical Scales." In *Music and Technologies*, edited by Darius Kučinskas and Stephen Davismoon, 37–48. Newcastle upon Tyne: Cambridge Scholars.

- Kittiphong Attakitmongcol, Rudeerat Chinvejitvanich, and Sarawut Sujitjorn. 2004. "Characterization of Traditional Thai Musical Scale." Paper presented at the 5th WSEAS International Conference on Acoustics and Music: Theory and Applications, Venice, Italy, November 15–17, 2004.
- McLachlan, Neil, David Marco, Maria Light, and Sarah Wilson. 2013. "Consonance and Pitch." *Journal of Experimental Psychology: General* 142(4): 1142–58.
- Miller, Terry E. 1998. "Thailand." In *The Garland Encyclopedia of World Music: Volume 4: Southeast Asia*, edited by Terry E. Miller and Sean Williams, 217–334. New York: Routledge.
- . 2008. "Thailand." In *The Garland Handbook of Southeast Asian Music*, edited by Terry E. Miller and Sean Williams, 121–82. New York: Routledge.
- Miller, Terry E., and Jarernchai Chonpairot. 1994. "A History of Siamese Music Reconstructed from Western Documents, 1505–1932." *Crossroads: An Interdisciplinary Journal of Southeast Asian Studies* 8(2): 1–192.
- Miller, Terry E., and Sam-Ang Sam. 1995. "The Classical Musics of Cambodia and Thailand: A Study of Distinctions." *Ethnomusicology* 39(2): 229–34.
- Moore, Michael. 1974. "The Seeger Melogram Model C." *Selected Reports in Ethnomusicology* 2(1): 2–13.
- Morton, David. 1970. "Thai Traditional Music: Hot-House Plant or Sturdy Stock." *Journal of the Siam Society* 58(2): 1–44.
- . 1974. "Vocal Tones in Traditional Thai Music." *Selected Reports in Ethnomusicology* 2(1): 89–99.
- . 1976. *The Traditional Music of Thailand*. London: University of California Press.
- Myers-Moro, Pamela A. 1988. "Thai Music and Musicians in Contemporary Bangkok: An Ethnography." PhD diss., University of California, Berkeley.
- . 1993. *Thai Music and Musicians in Contemporary Bangkok*. Berkeley: Center for South and Southeast Asia Studies, University of California at Berkeley.
- Panya Roongruang. 1999. "Thai Classical Music and Its Movement from Oral to Written Transmission, 1930–1942: Historical Context, Method, and Legacy of the Thai Music Manuscript Project." PhD diss., Kent State University.
- Pasuk Phongpaichit, and Chris Baker. 2009. *A History of Thailand*. Melbourne: Cambridge University Press.
- Peleggi, Maurizio. 2008. "Refashioning Civilization: Dress and Bodily Practice in Thai Nation-Building." In *The Politics of Dress in Asia and the Americas*, edited by Roces Mina and Edwards Louise, 65–80. Eastbourne: Sussex Academic Press.

- Pheerasut Boonmatham, Sunee Pongpinigpinyo, and Tasawan Soonklang. 2013. "Musical-Scale Characteristics for Traditional Thai Music Genre Classification." Paper presented at the International Computer Science and Engineering Conference, Nakorn Pathom, Thailand, September 4–6, 2013.
- Phra Chen Duriyanga. 1948. *Siamese Music: In Theory and Practice as Compared with That of the West and a Description of the Piphat Band*. Bangkok: Department of Fine Arts.
- . 1951. "A Talk on the Technic of Siamese Music in Relation to Western Music." Newsletter. *African Music Society* 1(4): 2–8.
- Polansky, Larry, Daniel Rockmore, Micah K. Johnson, Douglas Repetto, and Wei Pan. 2009. "A Mathematical Model for Optimal Tuning Systems." *Perspectives of New Music* 47(1): 69–110.
- Sarawut Sujitjorn. 2002. *การวิเคราะห์เสียงดนตรีไทย* [Analysis of the Thai Music Sound]. Nakhon Ratchasima: Suranari University of Technology.
- Schneider, Albrecht. 1991. "Psychological Theory and Comparative Musicology." In *Comparative Musicology and Anthropology of Music*, edited by Bruno Nettl and Philip Bohlman, 293–317. Chicago: The University of Chicago Press.
- . 2001. "Sound, Pitch, and Scale: From 'Tone Measurements' to Sonological Analysis in Ethnomusicology." *Ethnomusicology* 45(3): 489–519.
- Sethares, William A. 2005. *Tuning, Timbre, Spectrum, Scale*. New York: Springer Verlag.
- Silkstone, Francis. 1993. "Learning Thai Classical Music: Memorisation and Improvisation." PhD diss., University of London.
- Solis, Gabriel. 2012. "Thoughts on an Interdiscipline: Music Theory, Analysis, and Social Theory in Ethnomusicology." *Ethnomusicology* 56(3): 530–54.
- Somchai Rassami. 2014. การศึกษาการปรับระดับเสียงและการแบ่งระยะเสียงในช่วงทบของดนตรีไทยระบบแบ่งเท่า [The Study of Thai Musical Sounds and the Octave Division]. *BSRU Music Journal* Jan–Dec: 22–33.
- Somchai Thayarnyong. 1973. *Harmonics of Thai Music*. Bangkok: Chulalongkorn University.
- Strumolo, Will. 2007. "Relating Spectrum and Tuning of the Classical Thai Renat Ek." New York University. http://www.lifesci.sussex.ac.uk/home/Chris_Darwin/PerMuSo/pdfs/RelatingSpectrumAndTuningOfTheClassicalThaiRenatEk.pdf. Accessed November 11, 2011.
- Stumpf, Carl. 1901. "Tonsystem und Musik der Siamesen." *Beiträge zur Akustik und Musikwissenschaft* 3: 69–138.
- Sugree Charoensook. 2003. *เสียงและระบบเสียงดนตรีไทย* [Pitch Systems of Thai Music]. Bangkok: Mahidol University.

- Sugree Charoensook, Sangad Pookhaothong, James Upton, Anak Charanyananda, Sakchai Hirunrux, and Sanong Klangphrasri. 1997. *Research for Standard Pitch and Scale of Thai Music*. Bangkok: Mahidol University.
- Rice, Timothy. 2010. "Ethnomusicological Theory." *Yearbook for Traditional Music* 42: 100–34.
- Tanese-Ito, Yoko. 1988. "The Relationship between Speech-Tones and Vocal Melody in Thai Court Song." *Musica Asiatica* 5: 108–39.
- Thongchai Winichakul. 2000. "The Quest for 'Siwilai': A Geographical Discourse of Civilizational Thinking in the Late Nineteenth and Early Twentieth-Century Siam." *The Journal of Asian Studies* 59(3): 528–49.
- Whitehead, Alfred North. 1925. *Science and the Modern World*. Cambridge: Cambridge University Press.
- Wong, Deborah. 1999. "Ethnomusicology in Thailand: The Cultural Politics of Redefinition and Reclamation." *Tongyang umak* 21: 39–76.
- Worayot Suksaichon. 1998. *ทฤษฎีเสียงดนตรีไทย* [Theory of Thai Musical Sound]. Bangkok: Hongpap Suwan.

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