

# OUR Journal

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## Welcome

### Kelsey Ward\*, Environmental Science

Welcome to the fourth volume of *OUR Journal*! It is hard to believe that this issue is also my last as editor-in-chief. I have learned so much during my period of involvement with the *Oregon Undergraduate Research Journal*; it has been my first foray into academic editing and publishing, an opportunity to learn about fantastic research happening in many disciplines across campus, and above all, an incredible leadership building experience and a chance to work with similarly motivated, driven, compassionate, and hard-working undergraduates.

I want to particularly recognize the work of two of our senior editors, Alex Fus and Vishesh Khanna, who have been on the editorial board since the journal's inception. They provide excellent mentorship to the new editors and truly exemplify what it means to lead by example. Vishesh, amidst a busy spring of medical school visits and decisions, managed to still Skype into meetings when he had to be absent, worked tirelessly on his editing and figure-layout duties, and is a tireless, enthusiastic advocate for undergraduate research and the journal. He is an accomplished researcher himself, earning the highest level of honors, passing with distinction, on his thesis for the Clark Honors College titled "Sources of Genotoxicity in a Zebrafish Model of Fanconi Anemia." Alex is a premier editor, interested in pursuing a career in publishing, which she will surely excel at. Authors who receive her feedback through the double blind peer review and copy editing process are lucky to have her thorough, thoughtful, and probing suggestions. Like Vishesh, she is a tireless advocate for the journal, fully embracing social media and all forms of outreach and publicity. Thank you Alex and Vishesh! You have left your permanent mark on *OUR Journal*.

The publication of this journal truly would not be possible without the support of many dedicated individuals. First, the editorial board, Alex, Vishesh, Meredith, Zeph, Charlotte, Lauren, and Mari, participated in the entire process of publication with smiles on their faces. I am so appreciative of the kind atmosphere and camaraderie of the editorial board. The faculty advisors, Dr. Barbara Jenkins and Dr. Kevin Hatfield, gracefully advise the journal's trajectory. It was a pleasure to meet Lee Rumbarger, who wrote the faculty editorial to this issue, this spring and participate in facilitated dialogue about how faculty can support undergraduates in their research endeavors. Finally, this issue would not have been published without the tremendous support provided by the University of Oregon Libraries, especially Deb Carver, Karen Estlund and John Russell. Thank you!



## Editorial: “Beyond the ‘Task at Hand’: Finding Purpose and Voice in Academic Writing”

Lee Rumbarger\*, Director of the Teaching Effectiveness Program

The Teaching Effectiveness Program is twenty-five years old this academic year; I’m its new director—only the second in its history. TEP supports the University’s teachers “across rank and discipline, building an imaginative, resourceful, and connected campus-wide teaching culture,” according to our mission statement. To do this work, TEP, in my view, needs to have regular conversations with students. What defines a UO education in their view? What distinguishes a great general education course from one that, every moment of every class, feels like a “requirement?” What were the most important things they learned here? When did they transition from feeling like students to feeling like writers, scholars, researchers, artists, and teachers in their own right?

Recently, the editorial board of the *Oregon Undergraduate Research Journal* took the time to talk with me about these issues. I asked what they look for in papers they opt to publish and what kinds of teaching practices have been most influential to them as writers. Their answers tell us something not only about the work that fills the pages to come, but also about the promise of a UO education. The editors seek writing that pushes past the “task at hand”—one assignment for one reader for one course; instead, the editors consider the best writers those who attempt to say why their work matters to a discipline, to a segment of society, to a wider “we,” or even to the writer personally. One of the editors—a humanist—mentioned that she read a biology paper expecting to be a bit bored, but found herself hooked: “It wasn’t just ‘here’s what I found’... it was a wonderful argument about why this matters.”

They praised student writers who ask themselves, “Why am I learning this? Is there an expansiveness to this issue that I can explore?” And they praised professors who challenge students by saying, “Here’s what we’ve learned—what do *you* want to do with it?”

The group emphasized that theirs is a teaching journal—every writer gets two full sets of comments from editors, one in a similar field, one in a completely different one: a practice the board is proud of and to which they’re committed. Much of that feedback is about pushing students to articulate the “so what?” latent in their work—encouraging them to explore the implications of their topics and have confidence that they can make claims that matter

The board members struck me as impressive peer teachers with a clear lesson for student writers: have courage; pursue your intellectual interests; claim them as meaningful; and share them with others, whose interest and curiosity you have the power to ignite in turn. I hope that

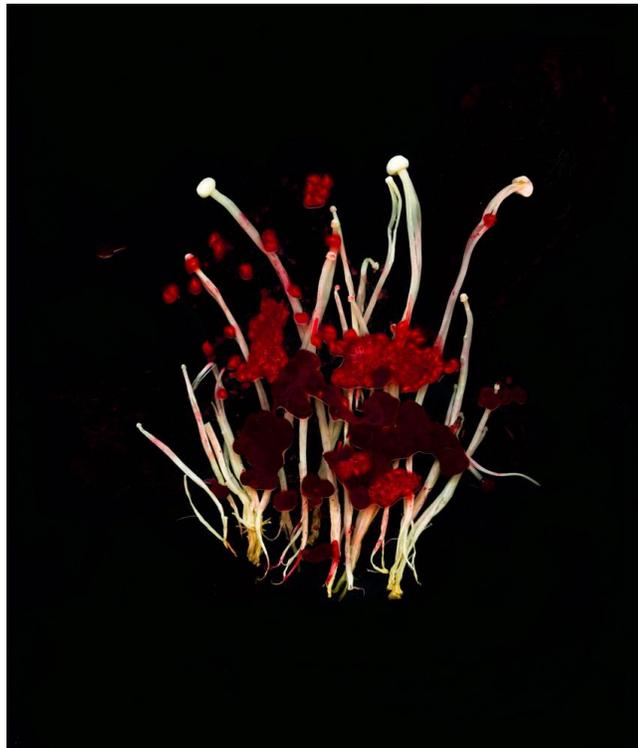
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every UO undergraduate can point to a piece of work that fulfills that promise—the examples here, and the work of peer editors to bring them before us, give us a glimpse of the best of UO's teaching and learning culture.



## Artist Statement: “*Flammulina velutipes*”

Cara Pfund\*, Department of Art



My earlier work focused on the idea of humans and nature, in the juxtaposition of the two, as well as the human exploration of nature. I worked with 35mm black and white film, until the past year when I began to explore digital photography. The digital medium opened my work to new possibilities as well as a change in artistic direction.

In my recent work, including *Flammulina velutipes*, I experimented with scanner art. The medium is unique because it can create a flat, high resolution, and detailed image very different from a digital camera. For this project I placed fruits and vegetables on the bed of a scanner to create an abstract form. Through the scanning techniques and the abstract combination of the natural materials, I produced an unfamiliar and unnatural image, devoid of any obvious link to the original form. I chose to use natural objects in reference to the early photographic methods developed by Henry Fox Talbot and shown in his book *The Pencil of Nature*.

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## Bernice Pauahi Pākī and Charles Reed Bishop: A Marriage of Imperialism and Intimacy in Nineteenth-Century Hawai‘i

Quinn Akina\*, History

### ABSTRACT

In 1850 at the age of eighteen, Princess Bernice Pauahi Pākī challenged dynastic resistance when she terminated an arranged marriage to her royal cousin in favor of a marriage to New England merchant Charles Reed Bishop. The marriage of a Native Hawaiian princess and an American foreigner at a time when interracial sexuality was heavily policed offers a rare opportunity to examine nineteenth-century attitudes toward interracial marriage in colonial environments. When understood within the context of imperialism, the Bishop marriage emerges as an intimate and ambiguous zone of empire. In considering the role of personal interests in private relationships and investigating how these ambitions manifested within Pauahi and Bishop’s marital relationship, this study ultimately argues that personal interests, both political and romantic, informed the couple’s marriage.

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Hawai‘i was a vulnerable kingdom during the nineteenth century’s era of Manifest Destiny. As a commercial acquisition and ideal location for American settlement, the Hawaiian Islands were an object of expansionist lust. According to historian Amy Greenberg, aggressive expansionism that unfolded in the Pacific came as the result of a vision of Manifest Destiny that celebrated white supremacy.<sup>1</sup> Scholars of American history have already established links between white supremacy and the policing of interracial sexuality, which reached its zenith during the nineteenth century.<sup>2</sup> It was not atypical for proponents of racial purity, for example, to forbid intermarriage on the basis of natural law. Such a racialized convergence of ideas about religion, culture, and biology simultaneously justified and challenged American imperialism in the Pacific. As a result of its paradoxical applications, this logic at once strengthened and undermined interethnic marriages between white men who settled in Hawai‘i and local women of color.

Americans were not the only people to monitor sexual and marital relationships on the basis of race. On the contrary, the desire to maintain social and genealogical purity also resulted in ethnic and intra-status endogamy among Native Hawaiians.<sup>3</sup> This impulse was particularly strong within the *ali‘i* (royal) class, whose members continued to marry first- and second-degree

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relatives despite the abolition of incestuous marriage following the introduction of Christianity by American missionaries in 1820. In 1834, for example, King Kamehameha III married his full sister. Four years later, two closely-related branches of the ruling family arranged a marriage between their infant son, Lot Kapuāiwa, and Lot Kapuāiwa's newborn cousin, Bernice Pauahi Pākī, demonstrating that the practical logic of endogamous marriage prevailed (albeit to a lesser degree) even after the abolition of incest.

The Kapuāiwa betrothal of 1839 symbolized familial expectations for a joint accession to the throne and hope for the kingdom's future security. These wishes were disappointed in 1850 when Pauahi married Charles Reed Bishop. Theirs was a union that defied popular anti-amalgamation sentiment as the first marriage between a daughter of the Kamehameha dynasty and an American foreigner. As such, the Bishop marriage offers a unique window into nineteenth-century attitudes toward interethnic marriage in cross-cultural contact zones. Moreover, such an alliance between two so unequally ranked individuals in this historic situation raises important questions about structures of dominance and individual agency: At what moments and to what degree did each partner exercise interpersonal dominance in the relationship? In this example of what critical race theorist Ann Stoler calls a "tender tie," we must also consider whether power struggles and mutual love were compatible.<sup>4</sup>

This study seeks to answer these critical questions by placing the Bishop marriage within a comprehensive framework that considers both imperialism and intimacy. To that end, this investigation takes a chronological approach to detailing the circumstances leading up to the Bishop marriage, including the birth of Pauahi in 1831 and the formative decade (1840-1850) during which she and Kapuāiwa attended The Chief's Children's School. Finally, the Bishop marriage is considered under historian Deborah Moreno's model of intercultural marriage to ultimately conclude that the Bishops' mutual love was constituted by and of colonial power brokering.

Given the numerous persons and complicated relationships this investigation takes under examination, it may be best to briefly identify each at the outset. At the center of this historical narrative is the Native Hawaiian princess, Bernice Pauahi Pākī Bishop. Her biological parents were High Chief Abner Pākī and Princess Laura Kōnia. Pauahi's *hānai* (adoptive) parents were Royal Governor Mataio Kekūanā'oa and Queen Regent Elizabeth Kīna'u. Pauahi counted five siblings between both families, including Kekūanā'oa and Kīna'u's biological son, Lot Kapuāiwa, and Pākī and Kōnia's *hānai* daughter, Kamaka'eha. Aside from Bishop, two other Americans by the names of Amos and Juliette Cooke also play a central role in this narrative. Sent to the islands by the American Board of Commissioners for Foreign Missions (ABCFM), the husband-and-wife pair taught at The Chief's Children's School and was the only set of Pauahi's guardians to encourage her relationship with Bishop.

Pauahi was born in Pākī and Kōnia's home, 'Aikupika, on the morning of December 19, 1831. Less than a week later, she was delivered into the custody of Kekūanā'oa and Kīna'u in the prevailing tradition of *hānai* (a practice comparable to informal open adoption among family and close friends). Unification of families was the most significant outcome of informal

adoption, though a complex web of kinship was already in place even before the princess' birth. For example, Kōnia was the sister of Kekūanā'oa's second wife, Kalanipauahi, and also the niece of his third wife, Kīna'u. As one strand in this intricate web of interrelatedness and alliance, Pauahi's adoption was therefore a symbolic reaffirmation of affinity between the two royal branches of Hawai'i's ruling family.

In addition to the physical exchange of a child, the erasure of distinctions between biological and adoptive ties was crucial to this fusion of families. While this practice may have been "perfectly natural" to the Native Hawaiian community, American settlers regarded it as "a most unnatural system and a grievous outrage upon maternal instincts."<sup>5</sup> Nevertheless, because state policy forbade any legal modifications of this tradition, foreigners were forced to accept the legitimacy of *hānai* kinship—and by extension, a looser family structure that was at odds with the contemporary American concept of the nuclear family. Americans' acquiescence is exemplified by the fact that no one distinguished between biological and adoptive ties.<sup>6</sup>

Just as the *ali'i* strengthened family connections by blurring the division between biological and adoptive relationships, they further cemented these bonds by arranging marriages between their offspring. Although the exact date is unknown, Pauahi and Kapuāiwa were engaged sometime before Kīna'u's death in 1839.<sup>7</sup> There were at least two incentives to orchestrate such unions. First, marriage among the chiefs was an important matter of state policy. The prince and princess both ranked high in the succession of potential heirs eligible for the throne. A joint claim via marriage could strengthen both families' claim to monarchical power. Secondly, an attempt to revive traditional marriage practices may be another rationale, since *hānai* sibling marriage echoed earlier days when "brothers and sisters in the reigning families sometimes married each other in order to have children of the highest possible rank."<sup>8</sup> Provided that Pauahi and Kapuāiwa ascended the throne together and produced an heir, an undisturbed transfer of power was guaranteed. In light of these possibilities, their betrothal was cause for celebration in the Native Hawaiian community.

Native Hawaiians anticipated the engagement in part because of its traditional *hānai* roots. Ironically, it was for the same reason that ABCFM missionaries denounced the proposed marriage as an abomination to God. Recalling that neither natives nor foreigners differentiated between biological and adoptive ties helps to explain why evangelicals viewed marriage between *hānai* siblings as incestuous. Beyond those considerations, the arrangement was perceived as a personal affront to ABCFM, who had claimed earlier that their missionary activity had resulted in a "universality of change... unexampled in the history of Christianity."<sup>9</sup> Having been orchestrated by royals who were already confirmed members of the church, the arranged marriage suggested that conversion did not automatically eliminate long-established traditions of Native Hawaiian marriage or necessarily engender Christian values in new converts. Thus, the betrothal raised troubling questions about the past, present, and future successes of ABCFM's mission in the Hawaiian Islands: If the *ali'i* were only half-heartedly committed to the new religion, how could Christianity hope to spread into the masses? Would Native Hawaiian "minds ever be freed from utter darkness, their hearts... from the influence of depraved passion, and their lives... [from] gross vices"?<sup>10</sup> While it is clear that both natives and foreigners accepted the

legitimacy of the *hānai* relationship, it is equally apparent that these cultural groups' differing principles gave way to a polarized understanding of the tradition's functions and implications. Such contradictory perceptions of native customs explain these conflicting reactions to both the Kapuāiwa engagement and ultimately, the Bishop marriage.

Thus far, *hānai* has been discussed in broad strokes as a cultural practice. Yet it would be a grave oversight for any comprehensive historical study to ignore how this social system affected relationships on the individual level. For example, Pauahi spent the first eight years of her life as the only daughter in Kekūanā'oa and Kīna'u's household in what was surely a formative experience. While the princess' private thoughts on her adoption are unknown, the memoir of Kamaka'eha, the daughter adopted by Pauahi's biological parents, makes it possible to imagine how young royals experienced *hānai*:

I knew no other father or mother than my foster-parents, no other sister than Bernice. I used to climb up on the knees of Pākī... and he caressed me as a father would his child; while on the contrary, when I met my own parents, it was with perhaps more of interest, yet always with the demeanor I would have shown to any strangers who noticed me. My own father and mother had other children... the most of them being adopted into other chiefs' families; and although I knew that these were my own brothers and sisters, yet we met throughout my younger life as though we had not known our common parentage.<sup>11</sup>

Not all chieftains' children were as content as Kamaka'eha. Rather, Kapuāiwa believed that *hānai* "deprived [him] of the love of a mother, and ... [made him into] a stranger in the house of [his] adoption."<sup>12</sup> While Kamaka'eha's and Kapuāiwa's accounts demonstrate personal variations in adoption experiences, what is clearly apparent from both recollections is that *hānai* children recognized their alienation from their biological families. Physical and emotional estrangement was a natural consequence of the *hānai* social system that affected all involved. Indeed, Pauahi's detachment from her biological family may account for her willingness to marry against their wishes.

As Pauahi's biological parents, Pākī and Kōnia never recovered from their separation from their natural daughter. Throughout their lives, they remained "very desirous of" and dedicated to her reunion<sup>13</sup> such that when the Queen Regent suddenly died from a paralytic affection in April of 1839, Pākī quickly moved to regain custody of Pauahi. As eager as Pākī and his wife were to reclaim their natural daughter, her foster father Kekūanā'oa was equally adamant about keeping the "promising child of whom he and the other chiefs had become very proud."<sup>14</sup> Pākī proved the more determined of the two and Pauahi returned to live in 'Aikupika sometime between April and June of the same year.<sup>15</sup> The family's reunion, while successful, was also short-lived. By the most generous scholarly estimates, the princess spent only two months at 'Aikupika before she left to attend The Chief's Children's School. From the time students enrolled in this boarding school until they either reached their majority or entered into marriage, students remained on campus and were "allowed to return to their homes [only] during vacation time, as well as for an occasional Sunday during the term."<sup>16</sup> School records

indicate that Pauahi rarely visited either her biological or her *hānai* parents. In fact, her only absence between 1840 and 1850 occurred during the week of March 1, 1842, when she left the island to recover from pleurisy, a lung condition. Except for these sporadic and brief trips home, Pauahi therefore spent little time in the company of her Native Hawaiian families. Losing their daughter a second time—and for such a long duration—appears to have devastated Pākī and Kōnia, both of whom ultimately came to regard the institution and its directors, including the Cookes, as competitors for Pauahi’s affection and obedience. The royal pair was so jealous of the Cookes’ possession of their natural daughter that they initially refused to send their *hānai* daughter, Kamaka’eha, to school. Thus, Pākī and Kōnia’s thwarted desire to claim Pauahi’s childhood, adolescence, and early adulthood may explain their hostility toward those they perceived as rivals for her heart.

American Protestant missionaries, particularly Amos and Juliette Cooke, were some of the first rivals for the princess’ heart. A careful study of the couple’s role in acculturating Pauahi to American ideologies is critical to understanding her later preference for an interethnic marriage. The Cookes and their twelve ABCFM companions arrived in Honolulu Harbor on April 9, 1837.<sup>17</sup> Theirs was not only the largest company of missionaries commissioned up to that point, but also the first to include teachers. Educators, the ABCFM Prudential Committee believed, would best fill the “vacuum in the nation’s civil and religious affairs” occasioned by the abandonment of polytheism in the early 1820s.<sup>18</sup> Teachers’ overt purpose as tools “employed in the propagation of the gospel”<sup>19</sup> was clear: the Cookes would teach their Native Hawaiian pupils “industry by the aid of art, science, and piety,”<sup>20</sup> as well as help their new Christian brethren “establish institutions, civil and literary, for the improvement and happiness of a people now barbarous and wretched.”<sup>21</sup> The arrival of ABCFM missionaries in the islands promised to become a harbinger of change for the kingdom.

So it was that Native Hawaiian education underwent significant changes in the early decades of the nineteenth century. In 1809, King Kamehameha II ordered missionaries to instruct his chiefs and certain favored commoners in English literacy so that Native Hawaiians would have the “mystical abilities of foreigners to transact by means of paper and script.”<sup>22</sup> Missionaries happily complied, since conversion efforts required communication in a shared language. As a result, from the 1810s to mid-1830s, Native Hawaiian adults made up “the great part of pupils.”<sup>23</sup> King Kamehameha II’s successor, Kamehameha III, expanded the monopoly his brother had placed on learning and literacy by making education compulsory in 1835 for all children over four years of age, including Pauahi.

The Crown was particularly concerned with educational opportunities for royal offspring. In 1839, King Kamehameha III ordered the construction of The Chief’s Children’s School for “persons whose claims to the throne were acknowledged” by the Constitution of the Kingdom of Hawai’i.<sup>24</sup> The *ali’i* petitioned Amos Cooke to offer his services as a teacher, since they believed it was he who could best “teach wisdom and righteousness” to their children.<sup>25</sup> Cooke accepted the nomination, stipulating that the chiefs “build a school house, sustain him in his authority over the scholars, and support the Sabbath.”<sup>26</sup> This collaborative effort to establish The Chief’s Children’s School was one of the many measures advancing the formal education of natives.

Amos and Juliette Cooke officially opened their boarding school on May 5, 1840, enrolling pupils Alexander Liholiho, Bernice Pauahi, James Kaliokalani, Lot Kapuāiwa, Moses Kekūāiwa, and William Kīna‘u. Over the course of twenty-one years, ten more students gained admittance. As befitting the royal background of its students, the institution’s motto was “*Aupuni Na‘auao*” (“Wise Government”).<sup>27</sup> According to ABCFM, wise government required that the Cookes frame their Native Hawaiian school after American-Protestant educational models. Consequently, “the government of the school [was] paternal in its influence.”<sup>28</sup> School days for Pauahi and her peers thus consisted of a series of highly structured and ritualized exercises in prayer, English composition, mathematics, geography, and drawing.

The Cookes attempted to exert—and sometimes gained—a Westernizing influence over their pupils. Amos and Juliette perceived their project of acculturation to be most successful with Pauahi, whose behavior and intellectual endowments were above reproach. Juliette’s letter to her sister describes the fifteen-year-old princess as follows:

Bernice is a most lovely girl—lovely in feature, form, and disposition... She reads to me every day [for] an hour. She is very fond of reading, likes history, and is very well versed in it for a girl of her age—she plays and sings well, paints prettily, works well, makes her own dresses... I wish you could know her, you would love her.<sup>29</sup>

By the age of sixteen, Pauahi’s role in the school had evolved from student to appointed librarian and even assistant teacher. In this last position, she was “devoted to domestic economy and teaching younger girls pianoforte and singing.”<sup>30</sup> The nature of the princess’s educational accomplishments hint at her strong Western leaning. Gorham Gilman, a visiting Bostonian merchant, saw in Pauahi the successful Americanization of a Native Hawaiian. “Miss Bernice Pauahi,” Gilman complimented, “has always been more under foreign influence than most other pupils. She is now a young lady [who] combines a well cultivated mind with much grace of person... She would win golden opinions in any circle.”<sup>31</sup> He attributed her formation of character to Juliette Cooke, whom “the female pupils seem to be strongly attached... [and] who possessing a well-balanced, well regulated mind, with much tact and discretion... has succeeded in a rich degree in imparting a portion of these happy traits to some of her pupils.”<sup>32</sup> The parallel that Gilman draws between Juliette’s instruction and the princess’s development is significant not only because it testifies to the crucial role the female missionary played as an agent of Manifest Destiny and domesticity,<sup>33</sup> but also because it provides a framework for understanding Pauahi’s marital choice as a consequence of the Cookes’ successful conversion. Pauahi’s assertion of personal agency in selecting a love match appears to have been subsumed (at least partially) under the cultural influence of her exposure to missionaries, who viewed interethnic marriage as a means to “transplant and engraft the liberal policy of [American] institutions upon old heathen despotisms.”<sup>34</sup>

Under the supervision of the Cookes at The Chief’s Children’s School, the princess socialized with both Native Hawaiian and American suitors. As boarders, Pauahi and Kapuāiwa had plenty of time and opportunity to gain an intimate knowledge of one another’s character and so

evaluate the suitability of their arrangement. Which of the prince's character traits might the princess have admired or criticized, and how might her judgment of Kapuāiwa compare to her estimation of Bishop?

The Cooke journals record the personal development of the young man who would later become King Kamehameha V. Kapuāiwa was a gifted flutist at the court of the king. His civic involvement ranged from translating articles for a local Hawaiian newspaper to participating in parliamentary sessions. In terms of musical and community interests, Kapuāiwa shared much in common with Pauahi, who was a noted pianist and translator for the same Hawaiian newspaper, *'Ele'ele Hawai'i*. There, however, the couple's similarities appear to end.

More often than not, Kapuāiwa seems to have conducted himself in ways unbecoming of his rank, upbringing, and future bride. Intemperance was one of his more serious offences. By the 1840s, missionaries and natives began to associate intemperance with beastliness. Royal Governor Kuakini captured this new idea in a speech he gave, saying: "To *horses, cattle, and hogs*, you may sell rum; but to *real men* you must not on these shores."<sup>35</sup> Kuakini's speech articulates a connection between temperance and a form of manhood marked by abstinence that was then gaining hegemonic strength both in the United States and Hawai'i during the nineteenth century. Whereas Bishop, who was elected as the Vice President of the Oahu Temperance Society in 1848, well epitomized this emerging type of straight-laced Protestant-influenced masculinity, Kapuāiwa exercised an older form of manhood that recalled earlier days when chiefs were "habitually addicted to the grossest intemperance [and when Hawai'i was a] nation of drunkards."<sup>36</sup> In August of 1845, neighboring missionaries witnessed Kapuāiwa and his two brothers purchasing and consuming wine—activities which were in clear violation of both school and government prohibitions against the sale and consumption of alcohol. When confronted by Amos, the brothers "appear[ed] much disposed to conceal each other's guilt."<sup>37</sup> Indeed, Amos was never able to break the brothers' alliance or curb their defiances, and in fact, struggled to establish authority over his male charges from the school's very beginning. In 1839, he wrote: "Today punished Alexander & Moses replied *he keiki a ke ali'i 'oia nei* [he was a child of the Chief]. I replied *I was King of the school*."<sup>38</sup> Thus, there was clearly a jockeying for supremacy in The Chief's Children's School that pitted foreign teachers against native children. As evidenced by his continued intemperance, Kapuāiwa had the upper-hand over Amos by the time he reached adolescence, and as such, it seems he may not have been as receptive to the Cookes' acculturation efforts as was Pauahi.

Scholars cannot know exactly what the comparatively well-behaved Pauahi thought about Kapuāiwa's behavior. She, like Amos and Juliette, probably perceived his rebellions to be a rejection of the Cookes and their American Protestant ideals. The prince's resistance may have repelled the princess, especially if she interpreted his actions as a critique of Americanized royals like herself. In this way, the young royals' contrasting reactions to Westernization help to explain not only Kapuāiwa's compliance with Pauahi's wish to call off their arranged marriage, but also her eventual choice of an American husband.

The Cooke journal entry on March 14, 1849 is the first of any source to mention Bishop in connection with Pauahi. Their courtship was typical of those in the nineteenth-century, consisting of “calls received, walks taken, visits exchanged... [and] communication through writing.”<sup>39</sup> In a letter dated August 30, 1849, Amos captured a sense of the romance between Pauahi and Bishop when he wrote:

Juliette and Bernice are engaged in sewing and Mr. Bishop is reading to them from the “Life of Hannah More.” Probably you are aware that Miss Bernice has a beau who calls almost every evening and probably will till they find a home of their own... Mr. Bishop has called again and commenced his reading, but, alas, it is broken in upon for I hear the voice of a Mr. Hitchcock, formerly Editor of the “*Polynesian*.” ... For all who call, Bernice is obliged to grind out a few tunes on the Aeolian attachment as an accompaniment to her singing. It is getting to be an old story, especially to her, except when Mr. B. is present. It is very apparent that her thoughts and affections are centering in him, and well they may, for he is in every way worthy of her heart and hand. I hope and pray that it may turn out to be a match made in heaven, and that heaven’s blessing may ever attend them, both in this world and in that which is to come.<sup>40</sup>

Although it is risky to speculate about the emotional quality of any private relationship, it is reasonable to believe that love fueled the couple’s union. Certainly, some attachment existed between the two given that they overcame serious objections to both their courtship and marriage.

In September of 1849, the princess took measures to end her arranged marriage with Kapuāiwa. She “had a frank talk with Governor Kekūanā‘oa about his desire that she marry Lot. She told him she did not like Lot.”<sup>41</sup> A week later, Kekūanā‘oa, Pākī, and Kōnia sought to negotiate a public announcement of the engagement with an understanding that the marriage would occur upon Kapuāiwa’s “return from France. They wished her to decide at once without seeing him & without his saying to her whether or not he loves her.”<sup>42</sup> The princess reacted by writing a note to her betrothed:

She told him the wishes of their parents & said she would consent in accordance with their commands but she knew it would make her always unhappy for he did not love her, nor did she love him. After this, she wrote to the Governor & said if they wished her buried in a coffin, she would submit to their authority. That she would as soon have them bury her as to promise to marry Lot.<sup>43</sup>

Pauahi’s challenge to the established order and reluctant, almost rebellious submission highlights emerging tensions between patriarchy and individualism. Her strategy was ineffective with her royal parents, who declared, “she was deceiving herself.”<sup>44</sup> Interracial marriage scholar Deborah Moreno theorizes that in order for a native elite woman to marry against the initial desires of her family, she first needed to acquire the alliance of her mother; working together, the mother-daughter pair then needed to convince the woman’s father of the groom’s suitability.<sup>45</sup> Pauahi, however, failed to accomplish either of the objectives Moreno outlines.

Although ineffective with the elder generation of *ali'i*, Pauahi's appeal to emotional intimacy and personal compatibility worked on Kapuāiwa. After receiving the aforementioned letter, the prince "wrote saying he exonerated her from all her promises in her youth, that he would not be the means of rendering her unhappy, that he knew he was unworthy of her, but that there was one who was worthy, even the one she loved & he hoped she would be happy with him."<sup>46</sup> Having been raised during the Victorian era when romantic expression was idealized, perhaps Kapuāiwa felt obligated to release a fiancée who claimed she did not love him.<sup>47</sup> An equally (if not more) likely explanation for his easy capitulation is that he had no wish to marry a woman who appeared captivated by the culture for which he held little esteem. Support for this argument comes from the fact that he twice proposed marriage to Emma Rooke, a scholar at The Chief's Children's School whose anti-American and pro-British sentiments were well known.<sup>48</sup> In any case, the prince made clear his awareness of and encouragement for the relationship between Pauahi and Bishop in his letter. In this way, Pauahi's strategic discourse and broken engagement attests to the possibility for feminine agency against a backdrop of patriarchal pressure.

On November 1, 1849, Amos noted that there was still "much opposition with [Pauahi's] parents and native friends" toward her relationship with Bishop.<sup>49</sup> So strongly opposed were Pākī and Kōnia to Bishop's suit that they threatened to disown her, informing Pauahi that she "must look to Mr. and Mrs. Cooke for all her *pono* [care]."<sup>50</sup> A week after she read her parents' disapproving letter, Pauahi wrote to Bishop "in such a manner as to release him if he wished."<sup>51</sup> Bishop responded the same night, appearing at The Chief's Children's School where he convincingly promised his continued suit and devotion. In this sense, Pauahi's actions appear to be part of classic nineteenth-century courtship performance. Karen Lystra, a social historian who studies marriages of the Victorian era, observes that wooing featured at least one dramatic emotional crisis by the woman as a test to gauge her partner's emotional commitment. According to Lystra, Pauahi did not need to "create a major or minor crises" for she had the "life material" of her family's opposition as an "obstacle in the pathway of love," which Bishop needed "to overcome [by] actions or words of reassurance."<sup>52</sup> If viewed in this light, Pauahi and Bishop were actors performing a highly ritualized and well-established script. That is not to say, however, that the couple did not benefit from the testing of their romantic bond, since the structured nature of courtship and its internal mechanisms tended to ensure "a strong emotional identification between men and women [that] was vital to the privatized, autonomous, and sentimental choice of a lifetime partner."<sup>53</sup>

Bishop, too, appears to have manipulated romantic conventions in his performance of courtship rituals. The New York native's "emigrating fever" during his early adulthood years makes it possible to imagine that political gain was a strong motive in his courtship of Pauahi.<sup>54</sup> In the early 1840s, Bishop and his friend, William L. Lee, were in their mid-twenties and "neither was satisfied with his outlook. They felt the stir of the westward movement and saw no signs of large opportunities in the staid old communities in which they lived."<sup>55</sup> Serious economic depressions precipitated by the Panic of 1837 and the collapse of the United States Bank of Pennsylvania cast long shadows over their future employment prospects in the East. Moreover, young bachelors in American cities faced dismal marriage prospects, outnumbering

unattached women by a substantial margin.<sup>56</sup> The opening of the Western-Pacific frontier offered Bishop and Lee not only a space for them to use their “Law books and surveyor’s compass,” but also opportunities for finding a wife (whether white or non-white).<sup>57</sup> Because hegemonic ideology understood marriage as a relationship between a dominant man and subservient woman, marriage between a white American male and a female of color, such as Pauahi, “did not upset the American concepts of racial hierarchy that held all colored individuals as naturally inferior.”<sup>58</sup> In fact, many nineteenth-century Americans viewed sexual amalgamation as an “integral part of the colonial experience [that] disable[d] native society.”<sup>59</sup> ABCFM missionary Laura Judd, for instance, supported Bishop’s suit, believing that “those who intermarry should surely bring the civil and social blessings of the fatherland to the one of their adoption.”<sup>60</sup> For Bishop, marriage to Pauahi represented a fulfillment of Manifest Destiny that promised landed wealth, domestic and sexual services, as well as valuable membership in the native community.<sup>61</sup>

Deborah Moreno, a researcher studying intercultural marriages between foreign traders and propertied California women during California’s Mexican period (1822-1846), argues that while interethnic marriages such as the Bishop’s may have appeared romantic on the surface, they were actually calculated maneuvers to form mutually beneficial alliances. Although her geographical scope differs from this study’s concern with Hawaiian royal romantic alliances, Moreno’s thesis is useful for comparative purposes. She profiles the typical foreign husband as having: 1) previously resided along the eastern seaboard; 2) apprenticed around the age of fourteen under a whaler, trade ship, or merchant; 3) acquired citizenship in his adopted country; and 4) gained socio-political power via land and commercial investments.<sup>62</sup> Her historic profiling fits Bishop almost perfectly. Bishop was born in Glen Falls, New York on January 25, 1822. At the age of fourteen, he apprenticed under a mercantilist from whom he learned clerking and bookkeeping. Between the time of his arrival in Honolulu on October 12, 1846 and his naturalization on February 27, 1849, Bishop gained socio-political power as secretary to the Minister of the Interior and United States Consul, co-founder of the Lihue Sugar Plantation, and Collector Generalship of Customs. Although marriage to Pauahi did not seat Bishop upon the throne as predicted by *The Sandy Hill Herald*,<sup>63</sup> it did afford Bishop greater visibility and political power in the form of lifetime membership in the House of Nobles, chairmanship of the Legislative Finance Committee, and presidency on the Board of Education. Whether he acknowledged it or not, marriage to Pauahi was a politically advantageous alliance for Bishop.

A romantic union with Bishop may have been a carefully calculated political maneuver on Pauahi’s part as well. Ever since Western contact, the Native Hawaiian population had been in rapid decline, falling from approximately 300,000 in 1778 to 82,035 in 1850.<sup>64</sup> When Pauahi and Bishop first met in 1849, a series of measles, whooping cough, dysentery, and influenza epidemics had just ravaged the islands, claiming an estimated 10,000 lives (more than one-tenth of the population) within a span of four months.<sup>65</sup> In addition to worrying about the health of her subjects, Pauahi was also concerned with political affairs. In 1841, 1846, and 1847, she attended legislative sessions that left her well-aware that American interests, both strategic and

economic, were becoming harder for the government to resist.<sup>66</sup> A diplomatic marriage to Bishop would allow Pauahi to gain advantage for her country via a connection to an increasingly valuable and threatening outside presence. Her appeal to romantic love may have been a necessary one for her to invoke in order to achieve a strategic alliance that would help her to protect her kingdom in the Western-Pacific crossroads.

Power struggles and emotion were subtle but powerful tensions in the couple's relationship. In selecting Bishop for a husband, Pauahi ultimately limited her ability to control relations between Hawai'i and the United States, for she renounced the throne twice in the name of her marriage. The first was when she ended her engagement to Kapuāiwa, who assumed the throne as Kamehameha V on November 30, 1863. The second occasion, in 1872, is related in a letter by John Dominis:

King Kamehameha V turned to Mrs. Bishop, who was sitting at his bedside and declared: "I wish you to take my place, to by my successor" She replied, "no, no, not me; don't think of me, I do not need it." The king said, "I do not wish you to think I do this from motives of friendship, but I think it best for my people and my nation." Mrs. Bishop said, "oh no do not think of me, there are others; there is your sister, it is hers by right" The king answered, "she is not fitted for the position." "But we will all help her; I, my husband, your ministers; we will all kokua [help] and advise her." The king replied, "no, she would not answer." Mrs. Bishop then said, "There is the Queen, Emma; she has been a Queen once, and is therefore fitted for the position." The king said, "She was merely Queen by courtesy, having been the wife of a king."<sup>67</sup>

Pauahi allegedly faced pressure from Americans to seek the throne "due to her pro-American sympathies ... but would not accept the throne, even if offered, because she desired to protect her marriage."<sup>68</sup> In order for Pauahi to have been a "serious contender for the throne... at least two conditions had to exist: the first was husbandly approval and the second was an assurance of support by a majority of the legislators. Neither of those conditions obtained."<sup>69</sup>

Bishop did not want the throne for his wife. His reluctance may have stemmed from his belief that Kalākaua, as a male, was the best contender. In this sense, gender emerges as the main issue at stake, and Bishop's denial appears to be a selfish design to protect patriarchal power. It is likewise telling that when Emma posted a proclamation naming herself as successor and denouncing Kalākaua, his supporters wrote above her poster: *'A'ole mākou makemake e 'ike I ka palekoki e ho'okomo ana I ka lowewawae* ("We do not wish to see the petticoat putting on breaches").<sup>70</sup> While Kapuāiwa may have been willing to place Pauahi on the throne regardless of her sex, most nineteenth-century Native Hawaiians and Americans were not ready to legitimate female political authority. Pauahi herself appears to have been reluctant to move outside of the Protestant family structure wherein which husbands demanded wifely fidelity and submissiveness. One recorded event between husband and wife is revealing of this dynamic: "Every chief in the country," Bishop wrote, "was opposed to [cessation of Pearl Harbor to the United States] and only the fact that I was committed to it, kept my own good wife from so expressing herself."<sup>71</sup> In private, the princess was less reserved, informing Bishop that he "ought to have known that the natives would not favor cessation."<sup>72</sup> As evidenced by her privacy in

expressing this opinion, the princess placed her marriage above Native Hawaiian political interests.

Yet Pauahi's marriage to Bishop did not limit her ability to control Native Hawaiian affairs entirely. Her focus on civic engagement rather than political leadership was more in keeping with nineteenth-century gender ideologies, which encouraged female advocacy in the social realm. The princess devoted herself to Native Hawaiian youth, whom she felt needed more opportunities in academia. Thus, in her last will, Pauahi directed Bishop to use her estate to "erect and maintain in the Hawaiian Islands two schools, each for boarding and day scholars, one for boys and one for girls to be known as, and called the Kamehameha Schools... giving preference to Hawaiians of pure or part aboriginal blood."<sup>73</sup> The estate, which included thousands of acres in land, was cash poor. Although Bishop "did not promise to do anything for the Kamehameha Schools out of [his] estate," his interest in Pauahi's plans and her "very generous gifts," motivated him to convey "the life interests given by her will and [add] a considerable amount of [his] own property on O'ahu, Hawai'i, and Moloka'i."<sup>74</sup> His financial resources proved crucial to the establishment of Kamehameha Schools. Even supposing that the Bishop marriage was not hatched for strategic purposes, Pauahi's will and Bishop's execution of her wishes suggests that the match was also one forged by mutual love: what Pauahi bequeathed to Bishop as a sentimental token, he freely relinquished for the benefit of her beloved subjects.

The marriage of a Native Hawaiian princess and an American businessman at a time when Hawai'i was the object of imperialist designs is a pivotal moment in the history of American-Pacific relations. Demonstrating the powerful consequences of cross-cultural contact and the failure of ideologies to command absolute obedience from individuals, the broken Kapu'waiwa betrothal and enduring Bishop marriage defied anti-amalgamation sentiment and long-established traditions of ethnic and intra-status endogamy. In particular, the princess' ability to direct her own marital destiny is a significant instance of women's agency in world history. Unlike most women of her time and culture, Pauahi moved outside of the Native Hawaiian world of her birth and chose to enter into the Western world introduced to her by American evangelical missionaries at The Chief's Children's School. Bishop, too, was no ordinary individual. The New Englander ascended the social ladder, acquired landed wealth, and gained political power with exceptional speed and ingenuity as an American settler in Hawai'i. Together the Bishops navigated conflicting ethnic, religious, class, and gender tensions amidst intricately complicated, power-laden scenarios. Analysis of the historical accounts of their courtship and marriage reveals the convergence and simultaneous operation of power struggles and mutual love. At different times during the course of their marriage, and to various extents, Pauahi and Bishop both balanced their desire to acquire political power with the need to preserve marital harmony. Pauahi's rejection of political activism in the public realm suggests that private marital harmony was more important to the princess than the need to safeguard national independence from imperial advances by the American government. This prioritization ultimately supports the conclusion that this historic and much-contested marriage was, in the end, a love match. However, because political agency was abandoned in the name of love, intimacy here takes on an oppressive quality, which in turn makes the marriage appear more

strategic in nature. And yet, as Bishop's establishment of the Kamehameha Schools in accordance to his royal wife's wishes indicates, political interests did not necessarily or automatically negate emotions. Thus, the historical evidence suggests that while both political and romantic interests informed the Bishop marriage, imperialistic influences were the stronger force insofar as Western-Pacific contexts characterized this historic marriage.

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<sup>1</sup> Amy Greenberg, *Manifest Manhood and the Antebellum American Empire* (United Kingdom: Cambridge University Press, 2005), 232.

<sup>2</sup> Peggy Pascoe, *What Comes Naturally: Miscegenation Law and the Making of Race in America* (Oxford: Oxford University Press, 2009).

<sup>3</sup> Edward Handy and Mary Pukui, *The Polynesian family system in Ka ‘u, Hawai ‘i* (Michigan: Polynesian Society, 1950), 105.

<sup>4</sup> Ann Stoler, *Haunted by Empire: Geographies of Intimacy in North American History* (Durham: Duke University Press, 2006).

<sup>5</sup> Laura Judd, *Honolulu: Sketches of Life: Social, Political, and Religious in the Hawaiian Islands from 1828 to 1861*, (Honolulu, 1928), 57-58.

<sup>6</sup> Liliuokalani, *Hawai‘i’s Story*, (Vermont: C.E. Tuttle Co., 1964), 4.

<sup>7</sup> George Kanahale, *Pauahi: The Kamehameha Legacy*, (Honolulu: Kamehameha Schools Press, 1986), 56.

<sup>8</sup> W.D. Alexander, *A Brief History of the Hawaiian People* (New York: American Book Co., 1899), 32-33.

<sup>9</sup> *Instructions of the Prudential Committee of the American Board of Commissioners for Foreign Missions to the Sandwich Island Missions*, 53.

<sup>10</sup> *Ibid.*, 48.

<sup>11</sup> Liliuokalani, 4.

<sup>12</sup> *Ibid.*, 26.

<sup>13</sup> Mary Krout, *The Memoirs of the Honorable Bernice Pauahi Bishop*, (New York: Knickerbroker Press, 1908), 21.

<sup>14</sup> *Ibid.*

<sup>15</sup> Amos Cooke, in *The Hawaiian Chiefs’ Children’s School: 1839-1850*, comp. Mary Richards (Vermont: Charles Tuttle, 1970).

<sup>16</sup> Liliuokalani, 5.

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<sup>17</sup> Sandwich Islands Mission Meeting Minutes Collection, 1837: 4, Hawaiian Mission Children's Society (hereafter cited as HMCS).

<sup>18</sup> *Ibid.*, 106.

<sup>19</sup> *Ibid.*, 111.

<sup>20</sup> William Tapuga, "Education, Change, and Assimilation in Nineteenth Century Hawai'i," *Pacific Studies* 5 (1981): 57, accessed January 13, 2013.

<sup>21</sup> Hiram Bingham to Calvin Bingham (February 1, 1820), in *Ibid.*, 57.

<sup>22</sup> *Ibid.*, 58.

<sup>23</sup> "Extracts from Minutes of the General Meeting of the Sandwich Islands Mission" (Honolulu: Mission Press, 1839), 19.

<sup>24</sup> Liliuokalani, 5.

<sup>25</sup> "Extracts" (1839), 19.

<sup>26</sup> *Ibid.*

<sup>27</sup> Amos Cooke (October 28, 1840), in Richards, 87.

<sup>28</sup> "Extracts" (1841), 7.

<sup>29</sup> *Ibid.*

<sup>30</sup> Amos Cooke to ABCFM (May 1848), in Richards, 306.

<sup>31</sup> Gorham Gilman (1845), in Krout, 47.

<sup>32</sup> *Ibid.*

<sup>33</sup> *Ibid.*

<sup>34</sup> Judd, 118.

<sup>35</sup> Kuakini, in American Board of Commissioners for Foreign Missions, *Thirty First Annual Report of the American Board of Commissioners for Foreign Missions: September 1840*, (Boston: Crocker and Brewster, 1840), 220.

<sup>36</sup> *Instructions of the Prudential Committee*, 453.

<sup>37</sup> Amos Cooke (December 30, 1845), in Richards, 247.

<sup>38</sup> Amos Cooke (August 13, 1839), in Richards, 34.

<sup>39</sup> Ellen Rothman, *Hands and Hearts: A History of Courtship in America* (New York: Basic Books, Inc., 1984), 105.

<sup>40</sup> Amos Cooke to Unknown (January 28, 1850), in Richards, 342.

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- <sup>41</sup> Amos Cooke (August 30, 1849), in Richards, 334.
- <sup>42</sup> Amos Cooke (September 8, 1849), in Richards, 335.
- <sup>43</sup> Amos Cooke (September 7, 1849), in Richards, 335-336.
- <sup>44</sup> Ibid.
- <sup>45</sup> Deborah Moreno, "Here the Society is United: Respectable Anglos and Intercultural Marriage in Pre-Gold Rush California," *California History* 80, no. 1 (2001): 9.
- <sup>46</sup> Amos Cooke (September 7, 1849), in Richards, 335-336.
- <sup>47</sup> J. Harris, ed., *Society and Culture in the Slave South* (Great Britain: TJ Press, 1992), 192.
- <sup>48</sup> George Kanahale, *Emma: Hawai'i's Remarkable Queen: A Biography*, (Honolulu: Queen Emma Foundation, 1999).
- <sup>49</sup> Amos Cooke (November 9, 1849), in Richards, 331.
- <sup>50</sup> Amos Cooke (June 6, 1850), in Richards, 344.
- <sup>51</sup> Ibid.
- <sup>52</sup> Karen Lystra, *Searching the Heart: Women, Men, and Romantic Love in Nineteenth-Century America* (New York: Oxford University Press, 1989), 151.
- <sup>53</sup> Lystra, 158.
- <sup>54</sup> Ibid.
- <sup>55</sup> Ibid.
- <sup>56</sup> Greenberg, 113.
- <sup>57</sup> Smith, 12.
- <sup>58</sup> Greenberg, 125.
- <sup>59</sup> Hurtado, 6.
- <sup>60</sup> Judd, 118.
- <sup>61</sup> Hurtado, 42.
- <sup>62</sup> Moreno, 4-5.
- <sup>63</sup> "The Husband of a Princess," *Sandy Hill Herald*, quoted in Kent, 39.
- <sup>64</sup> Robert Schmitt, *Demographic Statistics of Hawai'i: 1778-1965* (Honolulu: University of Hawai'i Press, 1968), 41.

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<sup>65</sup> Robert Schmitt and Eleanor Nordyke, "Death in Hawai'i: The Epidemics of 1848-1849," *The Hawaiian Journal of History* 35, (2001): 1.

<sup>66</sup> Merry Wiesner and William Wheeler, *Discovering the Global Past: A Look at the Evidence*, vol. 2, *Since 1400*, rev. ed. (Massachusetts: Cengage Learning, 2007), 7: 209.

<sup>67</sup> John Dominis to Charles Reed Bishop (January 7, 1873), in Kanahale, 265-266.

<sup>68</sup> Emma to Peter Ka'eo, in Kanahale, 277.

<sup>69</sup> Kanahale, 277.

<sup>70</sup> Kanahale, 283.

<sup>71</sup> Charles Reed Bishop to Elisha H. Allen (November 6, 1867), in Kent, 64.

<sup>72</sup> Ibid.

<sup>73</sup> Bernice Pauahi Pākī Bishop (October 31, 1883), Ke Ali'i Bernice Pauahi Pākī Bishop Will and Codicils.

<sup>74</sup> Charles Reed Bishop to S.M. Damon (October 9, 1911), in Kent, 145-146.



# Comparing *Apis Mellifera* and *Bombus spp.* Pollination Efficiencies on Willamette Valley Blueberry Farms

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## ABSTRACT

With global honeybee populations declining there is concern for the reproduction of plants, most notably food crops that rely on biotic pollination. The purpose of this study was to monitor the behavior and population size of bumblebees (*Bombus spp.*) and European honeybees (*Apis mellifera*) on Highbush Blueberry (*Vaccinium corymbosum*) farms in the Willamette Valley of Oregon during the spring of 2012. We used these population and behavior studies to calculate the pollination efficiency rates of each bee species. We hypothesized that despite their smaller populations, bumblebees would pollinate much more efficiently than would the European honeybee. To test this hypothesis we measured the effects of farm size and bloom time on the pollination efficiency of each species. To make our assessments, we observed their floral handling rates (defined as the number of flowers visited per minute by a single bee) and took population samples by walking systematically sampled transects on each farm. Our study indicated that bumblebees played an essential role in the pollination of highbush blueberry plants due to their high pollination efficiency rates. Floral handling rates for bumblebees and honeybees were proportional across our two primary variables, (bloom time and farm size) with honeybees pollinating an average of 3.5 flowers per minute and bumblebees pollinating 11.2 flowers per minute. Across all farms, honeybees outnumbered bumblebees by a ratio of 5.8:1. In light of our findings, we recommend that blueberry farmers in the Willamette Valley take steps to increase native bumblebee populations by developing bumblebee-friendly habitat and forage on their farms.

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## 1. INTRODUCTION

In the last 25 years, scientists have observed sharp declines in global pollinator populations (Pywell et al. 2011). These trends are of great concern because of the importance of pollination as an ecosystem service. Loss of pollinators may contribute to the reduction in plant populations

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that rely on pollinators for reproduction (Potts et al. 2010). Disappearing pollinator populations and decreasing species diversity have been attributed to a combination of anthropogenic influences including habitat loss and fragmentation (Pywell et al. 2011; Pendergrass et al. 2008), increased pesticide use (Pywell et al. 2011; Pendergrass et al. 2008), agricultural intensification, and introduced pathogens (Rao & Stephen 2010). The majority of studies cite the synergistic impact of such factors for the diminishing pollinator population. (Potts et al. 2010).

The implications of this decline are especially important in the agricultural sector. There is no efficient method of agriculture pollination without the use of biotic pollinators, most notably bees. Without natural pollinators, pollination efficiency would plummet, greatly affecting agriculture across the world. Historically, non-native European honeybees have been the most commonly used commercial pollinators (Potts et al. 2010; Vaughan et al. 2007). Domestic honeybee stocks in the United States have declined by almost 59% between 1947 and 2005, making sole reliance on honeybees an uncertain practice (Potts et al. 2010). Honeybee declines have been attributed to a phenomenon called Colony Collapse Disorder (CCD), in which worker bees abruptly disappear. The causes of CCD are not fully understood, but triggers such as Israeli Acute Paralysis Virus (Mader, personal communication 2012), disrupted navigational senses (Boyle 2007), and a new class of insecticide called neonicotinoids (Hopwood et al. 2012) have been studied. With such large reductions in honeybee populations, scientists have proposed that native bees, such as bumblebees in the Willamette Valley, could compensate for lost pollination services (Rao & Stephen 2010).

Bumblebees tend to pollinate in less favorable conditions and earlier in the season, while honeybees stay in their hives until weather improves (Tuell & Isaacs 2010). For this reason, bumblebees are well suited to the Northwest where the prime pollination season for blueberries, tree fruits, and native wildflowers is early spring, often characterized by cold and wet weather. Bumblebees also visit more flowers per minute and forage longer each day than honeybees (Steven et al. 2009). Lastly, bumblebees buzz pollinate. Buzz pollination is a highly efficient method in which the bees grasp the anthers of a flower in their jaws and rapidly vibrate their flight muscles to force out pollen (Vaughn et al. 2007).

To further evaluate the pollination services provided by native bumblebees, we compared population abundance and pollination efficiency of honeybees from managed hives, and native bumblebees at six sites in the Southern Willamette Valley. Our study consisted of two surveys concerning pollination counts and floral handling rates. For the pollination surveys, we recorded the total number of each bee species along transects at each farm. We also observed the floral handling rate of three bumblebees and three honeybees on the same transects. We combined our population counts with the floral handling rate to derive the pollination efficiency rates of each species of bee. Our hypothesis is that, while honeybees pollinate more blueberry flowers than bumblebees overall, it is only because of their immensely larger population. We also hypothesize that bumblebees will have much higher pollination efficiency rates than the European honeybee.

## 2. METHODS

### 2.1. STUDY AREAS

We conducted surveys at six farms located within a 40-kilometer radius of Eugene, Oregon. We classified the farms based on size of blueberry fields. Small farms had less than one hectare (ha) of blueberries (n=3) and large farms had more than one ha (n=3).

#### 2.1.1. SITE DESCRIPTIONS: SMALL FARMS

Farm A is located in southeast Eugene, and is managed through conventional farming techniques. The blueberry field size is 0.8 ha contained within one plot. Farm A rents six honeybee hives to provide supplemental pollination services. There are flowering trees on site, along with clovers and grasses between each row. The neighboring properties are flower farms, including a large field of clover. It is unknown whether or not these neighboring farms have honeybee hives.

Farm B is located in North Eugene less than 150 meters from the Willamette River. The blueberry plots are separated into three age groups (40, 25, and 10 year-old bushes) in a field less than 0.5 ha in size. The separation of plots is unrelated to any pollination factors. While the farm itself does not maintain honeybee hives, the neighboring farm has 50 honeybee hives. Farm B has a variety of ornamental flowers and fruit trees along with 1.6 ha planted with a western pollinator seed mix of clover and grasses.

Farm C is located approximately 40 kilometers east of Eugene. The field is 0.8 ha and contains approximately 1,500 plants. The farm has two hives of honeybees and has been managed by the owners of Farm E (see below) for six years. Farm C also grows other crops, including fruits and a number of flowers.

#### 2.1.2. SITE DESCRIPTIONS: LARGE FARMS

Farm D is a 50-year-old farm located in Northwest Eugene. The farm contains 4,400 highbush blueberry plants split into four plots with a total field size of approximately two ha. The plots are separated into three age groups: 50, 25, and 15 year-old bushes. Farm D does not own honeybee hives, but a nearby farm has 27 hives. Blueberry is the only crop on the farm, the remainder of which is 45 ha of unmanaged hay and pasture. The properties nearby grow grapes (*Vinus vinifera*) and blueberries.

Farm E is located just east of Eugene and has been cultivating blueberries for 60 years. It has four honeybee hives that are maintained year round. The farm contains 2.2 ha of blueberries and grows 80 other crop varieties interspersed between blueberry rows and on nearby properties.

Farm F is located approximately 35 kilometers east of Eugene. This farm has over 6,000 *Vaccinum* plants on 2.8 ha and maintains five honeybee hives. The farm is managed no-spray,

meaning it uses fertilizers but neither herbicides nor pesticides. The farm also utilizes polyethylene fabric for weed control. There are many flowering plants on the property, including rhododendrons (*Rhododendron sp.*) and fruit trees.

## 2.2. FIELD METHODS

We conducted our surveys over three separate spring bloom periods— early, mid, and late bloom—between the months of April and May 2012. We classified early bloom as the time when many branches were flowering, with many buds but little to no fruit developing. We defined mid bloom as the time during which most or all branches had flowers, with many buds and some fruits developing. We described late bloom as the time during which branches had fewer flowers or buds and many developing fruits. We only conducted surveys during optimal weather for pollination activity, with outside temperatures above 15°C, skies partly cloudy to sunny, and wind speed up to but not exceeding 3.5 m/s (Boulay 2012).

We set up transects of 60 m and 30 m at the large and small farms respectively. Using a systematic sampling design, we divided the field into equal sections and randomly chose rows within each section. We flagged the beginning and end of each surveyed row with temporary markers to ensure that we visited the same transects during subsequent monitoring. We chose rows separated by eight meters or more to avoid double counting of pollinators. We flipped a coin to determine if we surveyed the left or right side of the bushes. Regardless of total row length, we stopped at 30 m for small farms and 60 m for large farms. If rows were too short for a full 60 m or 30 m survey, we continued to the same side of the next row while walking in the opposite direction.

Teams of four researchers completed the monitoring surveys. Each team was split into sub teams of two, which focused on either the pollinator population or behavior assessment survey. During behavior assessment surveys, one researcher monitored and identified the bees while the other recorded observations. We walked at a standard pace of three meters per minute. We did not stop the timer to record a dense population of bees pollinating flowers, but slowed down in high-populated areas and quickened the pace in lower populated areas. We used the same transects for both surveys, with a 15minute interval between each survey to minimize bias due to human disturbance. During our surveys, we classified observed pollinators into the categories “bumblebee”, “honeybee” or “other.” One surveyor counted the number observed and relayed that number to the recorder who kept track of both time and pace to avoid any confusion, double counting or problems with pace.

For the behavior survey, we observed an individual pollinator during a one minute observation period and recorded the number of flowers pollinated. We observed three bumblebees and three honeybees along each transect whenever possible. When not possible, we observed more than three of one type of bee, always resulting in six observed pollinators. We used a Xerces identification pocket guide to accurately identify bees. (Evans 2012).

### 2.3. DATA ANALYSIS

Our data was used to analyze the influence of farm size and blueberry bloom time on bee population abundance and behavior. These variables were chosen because they were the most distinguishable and influential factors across our provided sites. Because we observed few types of pollinators other than bumblebees and honeybees, we focused our data analysis on those two species. Transects at large farms were twice the length of small farms for more representative coverage. Since the same tactics and planting regimes can be used at small and large farms, the only disparity between sites is the total hectareage. To compare large farms to small farms in spatial terms, we divided their honeybee and bumblebee counts by two.

When calculating population count averages and floral handling rates (defined as the number of flowers pollinated per minute), we combined data across all bloom times, farms, and transects. When analyzing the behavior and population surveys against bloom time, we again pooled data across all farms and transects. It should be noted that the method we used to measure behavior of the bees when three of each species was not available might have skewed the observation count but should not drastically change the overarching results.

By multiplying the average population count with the average floral handling rate we were able to compare the average number of flowers pollinated within transects by both species over a one minute period to determine the bee efficiency rate (see Equation 1). We examined the influence of bloom time and farm size on bee efficiency rates for honeybees versus bumblebees.

$$B = \text{[Equation 1]} \quad (1)$$

where

B = bee efficiency (average flowers pollinated per minute by total bee group)  
 = average bee population across all bloom times, farms, and transects  
 = average floral handling rate across all bloom times, farms, and transects.

## 3. RESULTS

### 3.1. POPULATION SURVEY

Results are separated into three categories: population survey, behavior survey, and bee efficiency. Honeybees had a total of 1746 counts while bumblebees had only 300 across all farms, which is a ratio of 5.8:1 (Table 1). The ratio of honeybees to bumblebees at the small farms was 18.9:1 as compared to 2.5:1 at the large farms.

**Table 1: Number of pollinators counted on 3 transects at 6 farms after 3 visits during April-May 2012**

<i>Small Farms</i>	Honeybee count (total number of individuals)	Bumblebee count (total number of individuals)
Farm A	451	31
Farm B	289	3
Farm C	414	27
<i>Large Farms</i>		
Farm D	118	32
Farm E	275	103
Farm F	199	104
Total	1746	300

### 3.1.1. FARM SIZE

We observed higher ratios of bumblebees to honeybees at small farms than at large farms. The three small farms contained an average of  $286 \pm 45.3$  (mean  $\pm$  standard deviation) honeybees and  $22 \pm 4.5$  bumblebees, whereas the three large farms contained  $148 \pm 75.9$  honeybees and  $39 \pm 12.8$  bumblebees.

### 3.1.2. BLOOM TIME

Pollinator abundance declined from early to late bloom season across all farms. Early bloom period for blueberry flowers yielded the highest average counts for both honeybees and bumblebees. In early bloom we observed 1261 honeybees and 155 bumblebees. In mid bloom we observed 368 honeybees and 123 bumblebees. In late bloom we observed 117 honeybees and 22 bumblebees. Both families had declining population patterns.

## 3.2. BEHAVIOR SURVEY

The behavior survey measured the number of flowers visited per minute by each bee group. The average floral handling rate from all surveys was  $3.5 \pm 1.28$  (mean  $\pm$  standard deviation) flowers pollinated per minute per bee for honeybees and  $11.2 \pm 1.1$  for bumblebees. On average bumblebees pollinated  $3.2 \pm 0.5$  times as many flowers as honeybees per minute.

### 3.2.1. BLOOM TIME

Early bloom had the highest rates of flowers pollinated per minute: 13.5 for bumblebees and 4.6 for honeybees (Figure 1). These numbers gradually declined through mid bloom and into late bloom, in which bumblebees pollinated 6.9 flowers per minute compared to honeybee’s 2.5 flowers per minute (Figure 1).

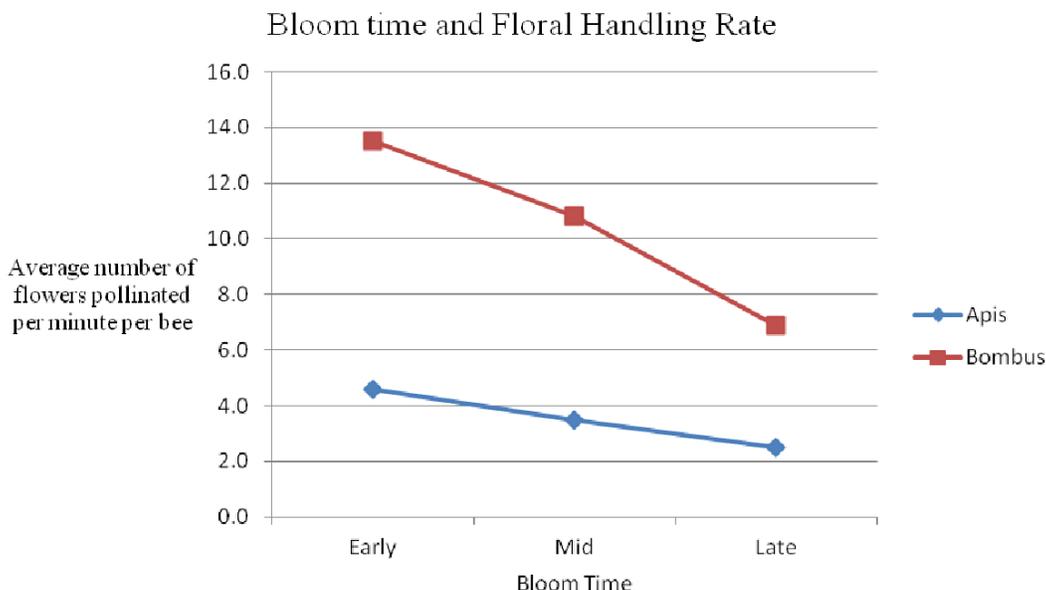


Figure 1: Floral handling rate (number of flowers visited per minute by a single bee) for honeybees (*Apis*) and bumblebees (*Bombus*) at 6 farms during April-May 2012.

### 3.3. BEE EFFICIENCY

#### 3.3.1. FARM SIZE

Although bumblebee presence was much smaller than honeybee, bumblebees are able to compensate for the number of flowers pollinated with their increased floral handling rate (Equation 1:  $B = +$ ) (Table 2).

**Table 2: Bee efficiency (average flowers pollinated per minute by total bee group)**

	Large Farms		Small Farms	
	<u>Bumblebee</u>	<u>Honeybee</u>	<u>Bumblebee</u>	<u>Honeybee</u>
<i>Population Count</i>	39	148	22	286
<i>Bee Efficiency</i>	438	521	247	1007

### 3.3.2. BLOOM TIME

Bumblebees were more efficient over all bloom periods. We determined efficiency by multiplying the bee populations by the average floral handling rate. During mid bloom honeybees were three times more abundant than bumblebees. However, bumblebees were more efficient pollinators as measured by bee efficiency rate (Table 3).

**Table 3: Bee efficiency (average flowers pollinated per minute by total bee group) during bloom time**

	<i>Early Bloom</i>		<i>Mid Bloom</i>		<i>Late Bloom</i>	
	<u>Bumblebee</u>	<u>Honeybee</u>	<u>Bumblebee</u>	<u>Honeybee</u>	<u>Bumblebee</u>	<u>Honeybee</u>
<i>Population Count</i>	58	369	40	121	8	41
<i>Bee Efficiency</i>	651	1299	449	426	90	144

## 4. DISCUSISON

Pollination services decreased after early blueberry bloom for all sites and measured variables. We hypothesize that this is due to the decline of available *Vaccinium* flowers as fruits come to replace them (Isaacs & Kirk 2012). This decline could also be attributable to a number of variables outside the scope of our study, such as the bloom times of other nearby plants. The variation of the species of plants adjacent to each farms' *Vaccinium* crops could have confounded our population counts. However, we believe that replacement of flowers with fruit had the largest direct impact on population counts. Our observation of 10.8 times as many honeybees and seven times as many bumblebees during early bloom as compared to late bloom is attributable to this loss of foraging resources. It is also important to consider that many of the farms had managed honeybee boxes on or near their sites. This could have impacted the natural habits of wild honeybees and native bumblebees that would otherwise have been on site. Additionally, honeybees may decrease bumblebee foraging efficiency and reproductive success (Hattfield et al. 2012). This increased pressure on bumblebee populations may have led to a decrease in their presence at monitoring sites.

Floral handling rate was also correlated to the number of available flowers. As available flowers decrease, the floral handling rate for honeybees and bumblebees decreases as well. We attributed this to the increased travel time and distance between each flower. As flowers become more scarce, more time is needed to find one that is neither already pollinated nor begun to turn into fruit. This emphasizes the importance of bees during the early stages of the blueberry bloom.

Not only is the presence of bees important during early bloom, but we also found that the type of bee can make a difference in the effectiveness of pollination. Bee efficiency declined from early to late bloom for both bee groups. In mid bloom, however, bumblebee efficiency was higher than honeybee efficiency. This could be attributed to many factors such as a change to poorer weather conditions. During mid bloom the weather was colder, windier and more overcast than during early and late blooms. We believe the ability to withstand colder temperatures allowed bumblebees to be more active and more effective during mid bloom (Stephen and Rao 2010). Across all farms bumblebees had a population one-fifth the size of honeybees, but were able to pollinate half the total number of flowers observed. This may be due to bumblebees' unique ability to buzz pollinate- a method, which allows for faster and more effective pollination (Javorek et al. 2002). Because bee efficiency is a compilation of population counts and floral handling rate, any change in either variable would directly alter bee efficiency.

In addition to bloom time, we also found that farm size may influence population counts. The large farms in our study contained half the amount of honeybees and 1.7 times the amount of bumblebees as compared with small farms. Walther-Hellwig and Frankl (2000) state that bumblebee flight range is one to two kilometers while honeybees are known to travel up to four and five kilometers. It is possible that because honeybee flight range is much larger than that of bumblebees, honeybees are more likely to forage a larger area and less likely to be concentrated along any single transect.

While our data provided insight into bee pollination activities, it also raised a number of questions that provoke further inquiry. More research is required to understand the potential for increasing pollination services provided by native bees. There were several variables unaccounted for in our study design that could have affected bee populations. Because native bees require specific habitats in order to survive, it is important for farms to provide that high quality habitat. We used a farm assessment protocol to qualitatively evaluate natural pollinator habitat (Native Bee Conservation Pollinator Habitat Assessment Form and Guide 2011) at each farm. A lack of data regarding the history, geology and flora of each site did not allow us to develop an accurate habitat quality assessment score for each farm. This information would allow for efficiency and population data to be cross-referenced with farm assessment scores to build a more comprehensive understanding of the importance of habitat quality on bee presence and pollination efficiency. Expanding the study to determine which species yields higher efficiency rates for other agricultural crops as well as the effects of on-site honeybee hives on bumblebee floral handling rates and populations also would provide valuable information.

This study has introduced an understanding of the role of native bees in providing pollination services to highbush blueberry plants in the Willamette Valley. This data is particularly significant as a baseline for future monitoring and research regarding the role of native bees in pollinating Willamette Valley crops. Bees make up the majority of all insects responsible for the biotic pollination and genetic diversity in plants. As honeybee populations decline, native bees provide an irreplaceable service. Farmers rely on these insects as an economic base for their harvest, while consumers depend on farmers to grow enough food to sustain current levels of food consumption. Therefore it is crucial for farmers to find ways to

increase their yields by improving the pollination services provided to their crops. The higher pollination efficiency of bumblebees on *Vaccinium* bushes found in this study implicates the importance of developing farm management practices that actively conserve bumblebee habitat and foraging resources.

In light of our findings, we recommend that farmers in the Willamette Valley take steps to increase native bumblebee populations by developing bumblebee-friendly habitat and forage.

There are various farm management techniques that will promote pollinators foraging and establishing nests on farm property. According to the Xerces Society for Conservation (Native Bee Conservation Pollinator Habitat Assessment Form and Guide, 2011), two important management practices include avoiding both tilling and pesticides. Tilling heavily disturbs ground nesting bee habitats. If tilling is a necessary aspect of the farm, nesting habitats should be maintained in other areas. Alternative methods to traditional tilling can also be used to avoid nesting disturbances. .

Reducing pesticide and herbicide use is another management practice integral to the success of pollinators (Xerces 2011). Ideally, a farm's management plan would include minimal to no pesticide or herbicide use. If pesticides are used, they are best sprayed at night when pollinators are not foraging. Of all pesticides, insecticides are the most damaging to pollinators. Even organic insecticides can harm or kill pollinators that are desired on the farm. Alternatives to conventional herbicides include organic herbicides and management of the weed seed bank in the soil (Mader, personal communication 2012). By killing unwanted plant seeds before they can establish themselves weeds can be eradicated without the use of herbicide. By effectively integrating pollinator conservation strategies in their farm management plans, *Vaccinium* farmers in the Willamette Valley can increase the pollination services provided them by native bees, increase their crop yields, and reduce their need for purchasing non-native honeybee colonies.

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# Beyond Elementary: Examining Conceptual Demands of Division of Fractions in Current US Curricula

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## ABSTRACT

The Common Core State Standards of Mathematics (CCSSM) is set of U.S. educational standards that were initially adopted in 2010 by 45 states. The CCSSM attempts to create a more rigorous and coherent set of standards for American students, making elementary math anything but elementary. The adoption of these new standards formulates the following research questions for this study: How well do current curricula match the CCSSM and how well do current curricula support teacher knowledge in implementing the standards? Three diverse curricula used in the United States, Prentice Hall, Singapore Math, and CK-12, were examined with three evaluation tools. The tools measure (a) the cognitive demands of the mathematical tasks in each curricula, (b) the mathematical coherency of an instructional unit, and (c) the resources in each curricula that support teachers' understanding of mathematics. The topic chosen for analysis is division of fractions because fractions are frequently encountered in algebra and provide the foundation for higher-level math. This study finds that Singapore Math's problems require higher-level cognitive demands more frequently than Prentice Hall and CK-12. Furthermore, Prentice Hall and CK-12's reliance on the standard division algorithm inhibit conceptual thinking for both students and teachers. Utilizing the Curriculum Review Tool, which focuses on teacher knowledge, I find that Singapore Math is most suitable in meeting the division of fraction requirements set by the CCSSM. To attain demands for the CCSSM, resource tools for teachers can be developed that better support students' learning by combining the strongest characteristics from each curriculum.

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## 1. INTRODUCTION

### 1.1. THE MATH CHALLENGE

The notion of failing U.S. schools and declining global competitiveness has been and still is the discourse surrounding U.S. education. National projects such as *A Nation at Risk*, published in 1983, *America 2000*, published in 1991, and *US Education Reform and National Security*,

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published in 2012, helped sparked this discourse. *A Nation at Risk* states that students' SAT scores dropped by 40 points in the mathematics and verbal sections and the need for remedial mathematics courses in colleges increased by 72 percent (Gardner et al., 1983). The *US Education Reform and National Security* reported that more than 25 percent of students fail to graduate from high school in four years and only 22 percent of U.S. high school students met college readiness standards in all of the core subjects; these figures are even lower for African-American and Hispanic students (Klein, Rice, & Levy, 2012). These projects' findings have resulted in an emphasis on higher test scores and heightened researchers' interest to investigate students' and teachers' knowledge pertaining to math and science. In addition, U.S. students have received only mediocre scores on international tests scores in mathematics (National Center, 2011a; National Center, 2011b). Furthermore, research illustrates that current U.S. mathematical curricula lack focus and coherence, while U.S. teacher knowledge of mathematics is inadequate (Ball, 1990; Ginsburg, Leinwand, Anstrom, & Pollock, 2005; Ma, 1999). It is debatable to label U.S. schools as failures as well as to emphasize the importance of testing and international rankings. However, the debate has sparked the attention of researchers whose studies have illustrated that there is room for improvement of students' and teachers' knowledge of mathematics in the U.S. This needed improvement is the U.S. challenge in mathematics.

Dr. Alan Ginsburg, formerly with the U.S. Department of Education, and his colleagues compared the United States' and Singapore's mathematics teachers, assessments, standards, and textbooks. The Trends in International Mathematics and Science Study (TIMSS) is an international science and math test conducted every four years for fourth and eighth graders. In the mathematics section Singapore placed first in 1995, 1999, and 2003. In 2007 Singapore's fourth graders placed second behind Hong Kong and its eighth graders placed third (National Center for Education Statistics, 2011a). Ginsburg et al. found that Singapore's mathematical system includes a "highly logical national mathematics framework, mathematically rich problem-based textbooks, challenging mathematics assessments, and highly qualified mathematics teachers whose pedagogy centers on teaching to mastery" (2005, pg. ix). These studies indicate that the U.S. mathematical curricula lack coherency, i.e., a logical progression of ideas, and encouragement of conceptual ideas compared with Singapore's curricula. For my analysis, conceptual understanding is defined as explaining (a) why mathematical procedures are performed and (b) how these procedures can be applied in various situations.

Similar to Ginsburg's et al. study, Dr. Liping Ma, a member of National Mathematics Advisory Panel, compared Chinese and U.S. elementary school teachers' mathematical knowledge. She interviewed 23 above average U.S. teachers with 72 Chinese teachers ranging from satisfactory to above average. Dr. Ma found that although most U.S. teachers have higher degrees than do China's teachers, they have a lesser understanding of elementary mathematics (1999). Deborah Ball, Dean of the School of Education at the University of Michigan, interviewed 252 prospective elementary and secondary mathematics teachers. She found that after their completion of college, prospective teachers' mathematical knowledge was dependent on rules without understanding why they worked (1990). These studies show some U.S. elementary teachers lack a comprehensive understanding of mathematics. Curricula that do not

support integrated mathematical thinking will make it difficult for teachers to effectively implement the Common Core State Standards (CCSS).

Introduced in 2009, the CCSS was developed in an attempt to enhance mediocre international rankings, inconsistent state standards, and persistent achievement gaps between socioeconomic and ethnic groups. The CCSS attempts to remedy these issues by offering more rigorous standards that states can choose to implement. The CCSS, spearheaded by the National Governors Association for Best Practices (NGA) and the Council of Chief State School Officers (CCSSO), were developed in consultation with teachers, experts, parents, and administrators to create higher standards. Forty-five states have adopted the CCSS, which include English Language Arts (CCSS ELA) and Mathematics (CCSSM), and plan to implement them by 2014.

States that have not adopted the CCSS include Alaska, Texas, Nebraska, Minnesota, and Virginia. These states have not adopted the standards because of their opposition to national tests, skepticism of the standards for improving state education, and fear of losing state control regarding educational standards. The monetary incentive from President Barack Obama's Race to the Top Fund encouraged states to adopt the CCSS. Receipt of educational funding from Race to the Top is dependent on a point scale. States that adopt the CCSS will receive 40 points out of a total 500 points. Some states also accepted the CCSS due to their belief that higher standards and more challenging objectives will improve U.S. education.

Despite opposing views of the CCSS, the standards of the CCSSM stress coherency, focus, clarity, and rigor (National Governors, 2010). Emphasis is placed on conceptual understanding of mathematics rather than memorizing procedures. The standards do not inform teachers how to teach, but rather specify the levels at which students should be performing. Although more resources are currently evolving to help teachers implement the CCSSM, educators will still rely on their manuals as a template to apply the CCSSM because of their familiarity and easy access to the materials. This raises the central research questions: how well do current curricula match the CCSSM and furthermore, how well do the curricula support teachers' mathematical knowledge?

## 1.2. SELECTED CURRICULA AND CCSSM TOPIC

I hypothesize that Singapore Math will most closely align to the CCSSM given that previous research has shown that Asian mathematical programs are generally better developed. To determine how well current curricula match the CCSSM and how supportive they are of teachers' mathematical knowledge, my project will analyze three different curricula materials in relation to the "division of fractions" standard of the CCSSM. These curricula include: Prentice Hall (Charles, 2008), Singapore Math (Singapore Math 2003; 2006), and CK-12 (Greenberg & Kershaw 2012a; 2012b). For the purpose of my project, curricula are synonymous with the terms "programs" or "teacher manuals."

Curricula have been chosen as one way of examining teacher knowledge because research suggests curriculum materials shape the ideas of a teacher's pedagogical practices and influence

classroom instruction (Grossman & Thompson, 2008). It has been shown that teacher knowledge influences student achievement (Coleman, 1966; Hill, Rowan, & Ball, 2005) and that elementary teachers rely heavily on manuals when teaching (Grossman & Thompson, 2008). Thus, curricula must be examined to determine how well it supports teachers' mathematical knowledge in achieving the CCSSM. Knowing how well current curricula support teachers' mathematical knowledge will help indicate how prepared teachers are for the CCSSM and potentially how well students will succeed since teacher knowledge influences student achievement.

To answer my research questions, I analyzed three different curricula: (a) Prentice Hall, a long-established published curriculum, (b) Singapore Math, a program based on the math curriculum developed in Singapore, and (c) CK-12, an on-line, open source curriculum.

Prentice Hall Mathematics is the leading publisher of middle school and high school textbooks. In 2008, the U.S. Board of Education approved of its use for mathematics instruction and has been chosen for this study as a representation of the quintessential US textbook. While Prentice Hall represents a ubiquitous curriculum, Singapore Math represents an uncommon alternative curriculum used in the U.S. These programs help represent the variety of curricula utilized in the U.S.

Singapore Math deserves to be looked at in comparison with the CCSSM because of Singapore's high international math ranking and its different approach to mathematics compared to traditional U.S. textbooks. Singapore's continual high achievements in mathematics has sparked the interest of the U.S. due to the concern of American failing schools and the worry of declining global competitiveness. Singapore's curriculum has been adopted in approximately 2500 U.S. schools and is popular with homeschoolers (D. Brillon, personal communication, April 9, 2013). It has gradually become well known throughout the U.S. as Singapore Math. Most U.S. textbooks attempt to cover a vast amount of information in a short amount of time; however, Singapore's curriculum devotes more time to fewer topics to ensure student comprehension.

Open source education provides resources that can be viewed by anyone online at no cost. These are a new source of mathematical programs that many regard as the way of the future. Open source education can provide teachers with additional options to help in the implementation of the CCSSM. In response to high textbook prices, CK-12, a non-profit organization established in 2007 by Neeru Khosla and Murugan Pal, produces free online resources for both students and teachers in a variety of subjects including mathematics. This program deserves to be analyzed because of its ease of accessibility and predicted future impact.

To conduct a comprehensive evaluation of the entire CCSSM is beyond the scope of this project. Therefore, I focused on one topic that is challenging for many students and will help to evaluate the mathematical rigor and coherency of the curricula stressed by the CCSSM: division of fractions. For students to fully understand division of fractions, they must rely on previous arithmetic concepts such as multiplication and repeated subtraction (Philipp, n.d.; Sharp &

Adams, 2002; Thompson, 1979; Wu, 2011; Yetkiner & Capraro, 2009). Students must understand place value or how rational numbers are different and similar to whole numbers. Within various types of curricula, ones that refer to previously learned concepts are good indicators of its alignment with the CCSSM. Furthermore, division of fractions occurs frequently in algebra. Considering that algebra is the foundation for higher-level math courses, students' understanding of division of fractions is one concept necessary to ensure success in algebra and higher-level math courses.

### 1.3. SPECIALIZED CONTENT KNOWLEDGE

To better understand the complexity of teachers' knowledge, researchers have categorized teachers' knowledge into different domains: content knowledge, pedagogical knowledge, and curriculum knowledge (Ball, Thames, & Phelps, 2008; Shulman, 1986). Specialized content knowledge is a form of knowledge used specifically for the teaching of mathematics. Specialized content knowledge guides teachers in determining patterns in a student's errors and ascertaining if nonstandard approaches to problems work. Specialized content knowledge requires elementary school teachers to understand elementary math at a conceptual level by emphasizing a comprehension of proofs and presenting mathematics to students in a variety of methods to enrich their understanding.

For example, when subtracting 168 from 307, some students might instead subtract 160 from 299, which yields the same answer—139. Why does this work? Furthermore, could it work in general? According to a teacher with specialized content knowledge, to avoid decomposing the three in the hundreds' place to subtract 168 from 307, a common number can be subtracted from these original numbers so that the larger number does not have to be regrouped. This will always result in the same answer. A teacher with specialized content knowledge would visually represent this with a number line, explaining that the distance between 168 and 307 as well as 160 and 299 is the same. In essence, both of the original values moved eight places to the left. Effective teachers must have specialized content knowledge to determine why alternative strategies work. Specialized content knowledge and the CCSSM require teachers to firmly understand mathematics; therefore each curriculum will be evaluated according to its support of teachers' specialized content knowledge.

## 2. METHODOLOGY

Three different evaluation tools were used to assess the curricula regarding their treatment of the "division of fraction" CCSSM. The Mathematical Tasks evaluation tool measures the cognitive demands of the curricula. The Six Essential Features Tool measures how comprehensive each curriculum is in addressing the conceptual demands of the division of fractions standard. Lastly, the Curriculum Review Tool assesses how well the curricula support teachers' specialized content knowledge and how thorough each curriculum is in meeting the division of fraction standard.

## 2.1. THE COMMON CORE SIXTH GRADE DIVISION OF FRACTION STANDARD

The CCSSM division of fraction standard states that students should:

Interpret and compute quotients of fractions, and solve word problems involving division of fractions by fractions, e.g., by using visual fraction models and equations to represent the problem. *For example, create a story context for  $(2/3) \div (3/4)$  and use a visual fraction model to show the quotient; use the relationship between multiplication and division to explain that  $(2/3) \div (3/4) = 8/9$  because  $3/4$  of  $8/9$  is  $2/3$ . (In general,  $(a/b) \div (c/d) = ad/bc$ .)*

(National Governors, 2010, Grade 6 section Number System Standard 1, para. 1).

Most students are taught division of fractions using the invert and multiply method without conceptually understanding how to divide fractions (Siebert, 2002). Such students would not be able to reach the CCSSM described above, as it requires students to explain their answers. For all students to reach this CCSSM standard, teachers must understand commonly used algorithms and relationships to other mathematical topics. This directly demonstrates the need for specialized content knowledge to teach division of fractions (Ball, 1990; Tirosh, 2000; Yetkiner & Capraro, 2009). For the duration of my project, I refer to this division of fraction CCSSM standard as simply “the standard.”

## 2.2. MATHEMATICAL TASKS

Mary Kay Stein and Margaret Smith investigated the professional development of teachers. Their Mathematical Tasks (1998) are used to examine the conceptual demands of current programs in relation to the CCSSM. Stein and Smith (1998) have identified four different types of tasks that they have divided into lower and higher-level demands, shown in Table 1.

**Table 1: Mathematical tasks**

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**Lower-Level Demands**

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Memorization

Procedures without connections (plug and chug)

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**Higher-Level Demands**

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Procedures with connections

Doing Mathematics

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Table from Stein & Smith (1998)

“Doing mathematics” is the highest-level demand where students conceptually understand a topic. At this level, students can be given a problem in non-standard form and correctly solve and explain the answer. A problem is classified under “procedures with connections” when algorithms are used and the problem asks for some form of explanation. These Mathematical Tasks measure the cognitive demands of problems in the three curricula indicating their ability to meet the standard.

### 2.3. THE SIX ESSENTIAL FEATURES TOOL

Research suggests that illustrating problems with pictures and representations, building off of students' existing knowledge, and creating real world problems are features that are the most helpful in teaching division of fractions conceptually (Philipp, n.d.; Sharp & Adams, 2002; Thompson, 1979; Wu, 2011; Yetkiner & Capraro, 2009). For example, since students are already familiar with repeated subtraction, multiplication, and equivalent fractions, these provide the building blocks and conceptual foundation to develop their understanding of division of fractions. The Six Essential Features Tool indicates the comprehensiveness in the programs' ability to address division of fractions. As the number of features incorporated into the curricula increases, the more comprehensive the curricula are at achieving a conceptual understanding of fractions. Table 2, below, creates a framework to evaluate the number of times each feature is referenced in each problem of the curricula. These features are not mutually exclusive as some problems may contain more than one feature.

**Table 2: The Six Essential Features Tool [Sample Table]**

<b>Features</b>	<b>Curriculum</b>
Repeated subtraction	<b>X</b>
Equivalent fractions	<b>X</b>
Multiplication	<b>X</b>
Real World Problems	<b>X</b>
Visual Representations	<b>X</b>
Concepts set up first, procedures second	<b>X</b>
Other	<b>X</b>

### 2.4. THE CURRICULUM REVIEW TOOL

Dr. Juliet Baxter, an associate professor in Education Studies at the University of Oregon, and Angie Ruzicka, a middle school science teacher in the Eugene 4J District, developed the Curriculum Review Tool. The Curriculum Review Tool was designed to help teachers assess mathematics curricula. It consists of yes or no questions regarding a curriculum's ability to: (a) develop mathematical ideas, (b) support effective instructional approaches, and (c) promote student thinking (Baxter & Ruzicka, 2008). This tool is used to indicate how complete each program is in meeting the standard and how supportive the curricula are of teachers' specialized content knowledge. Additional questions accompany Dr. Baxter and Ruzicka's Curriculum Review Tool to more broadly evaluate the division of fraction standard. Examples of these questions include: Are there story problems? Are there equations that represent division of fractions? Does the curriculum include common misconceptions that students have with division of fractions and how teachers can explain it? These questions provide detailed information regarding the programs' ability to reach the standard and evaluate curriculum features that support teachers' specialized content knowledge.

Using these three modes of analysis provides both quantitative and qualitative data pertaining to how well the curricula match the standard and if each curriculum is supportive of teachers' specialized content knowledge. Evaluating teacher manuals with Stein and Smith's Mathematical Tasks helps measure the cognitive demands of problems from current curricula. Because higher-level thinking parallels specialized content knowledge, the Mathematical Tasks also highlights the specialized content knowledge required of teachers using the curriculum. The Six Essential Features Tool illustrates how comprehensive each program is at explaining division of fractions, therefore assessing how well the program aligns with the standard. Baxter and Ruzicka's Curriculum Review Tool provides specific information pertaining to each program's strengths and weaknesses in achieving the standard as well as evaluating the curricula's support of teachers' specialized content knowledge.

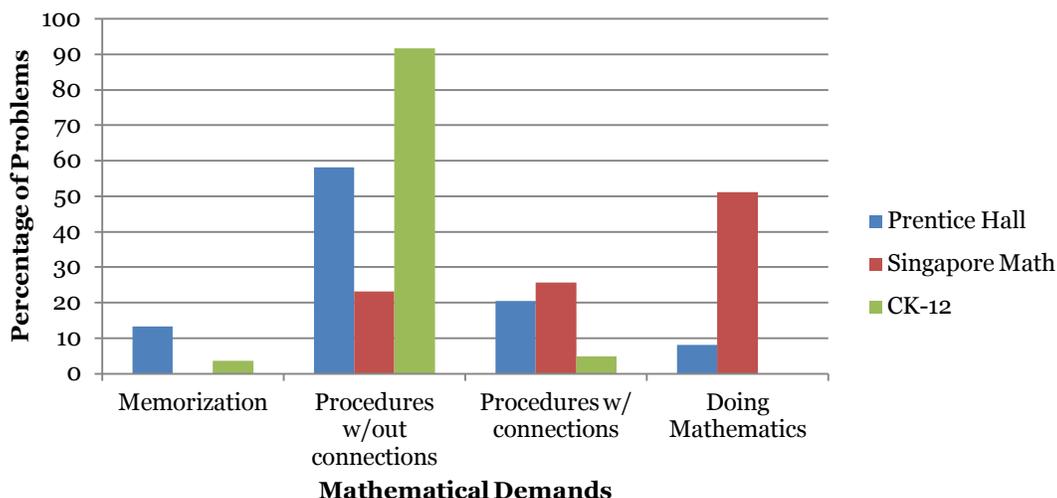
### 3. RESULTS

As previously discussed, the three evaluation tools were used to measure different areas of the three curricula including: cognitive demands, comprehensiveness, and support of teacher's specialized content knowledge. The findings from these tools are discussed in the following subsections.

#### 3.1. MATHEMATICAL TASKS

Using Stein and Smith's Mathematical Tasks, problems from each curriculum were categorized into one of four cognitive domains: memorization, procedures without connections, procedures with connections, or doing mathematics. Sixty-three of the 82 problems from Singapore Math promote higher-level thinking, which equates to procedures with connections and doing mathematics. This curriculum asked students to draw corresponding pictures with their work or solve word problems. This contrasts with CK-12 where only four of the 84 problems reached higher-level demands, none of which are classified under the highest level, "doing mathematics." Concerning Prentice Hall, 28 of the 98 problems reached higher cognitive demands, but like CK-12, the majority of their problems fell under "procedures without connections" which refers to the standard invert and multiply algorithm. Singapore Math, in contrast, did not contain problems where the curricula required memorized procedures or tasks. Graph 1 (below) illustrates a clear distinction between Singapore Math's high cognitive demands and CK-12 and Prentice Hall's reliance on lower-level thinking. Also notable is Prentice Hall's problems in all four categories.

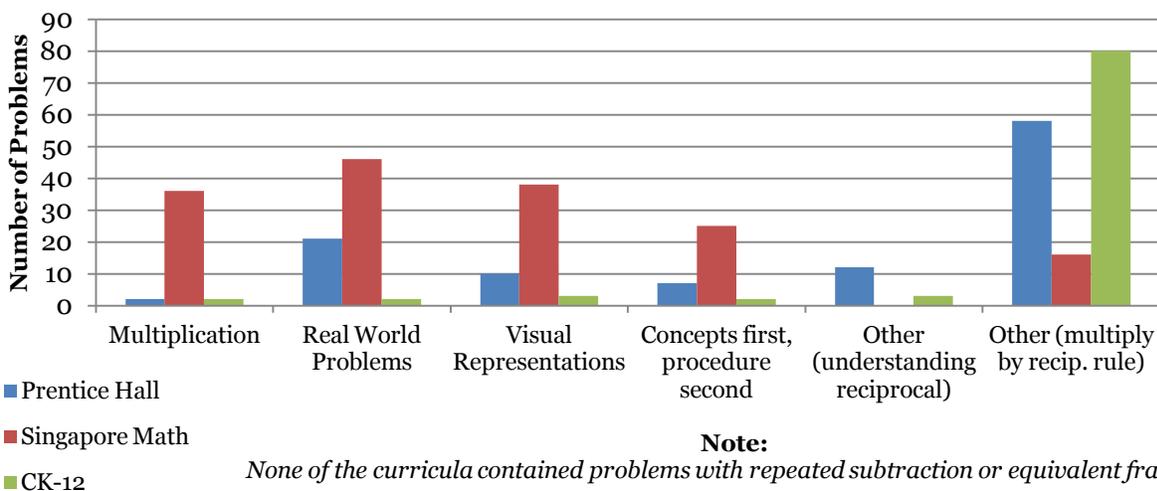
**Graph 1: Mathematical Tasks**



### 3.2. THE SIX ESSENTIAL FEATURES TOOL

The Six Essential Features Tool measures how comprehensive the curricula are in meeting the conceptual demands of the standard. Two features (repeated subtraction and equivalent fractions) were not found in the three curricula to help build students’ conceptual understanding of fractions. The results are shown in the graph below:

**Graph 2: The Six Essential Features Tool**



Thirty-eight problems from Singapore Math were presented with visual representations, whereas ten problems from Prentice Hall and three problems from CK-12 had visual

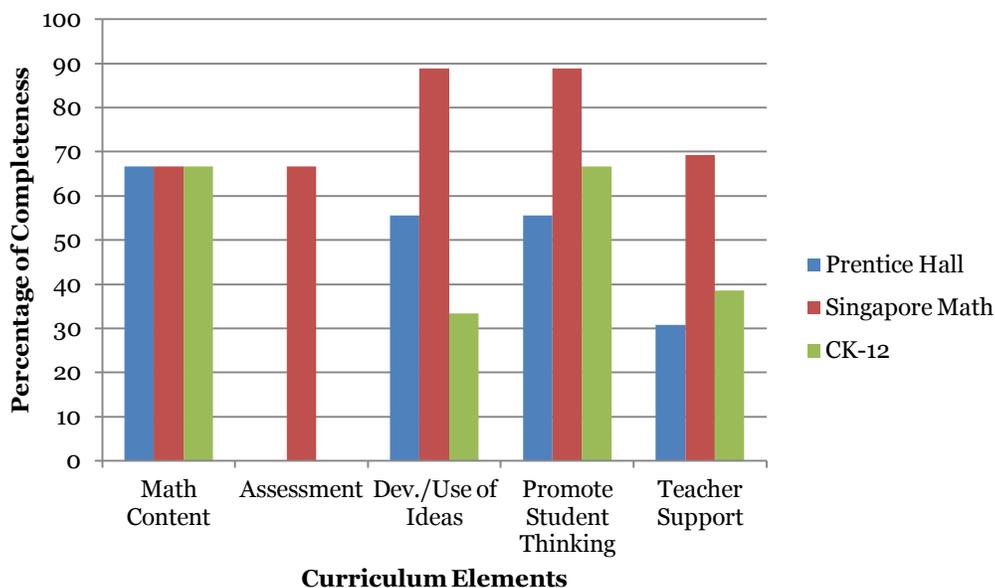
representations. Furthermore, out of Singapore Math’s 38 problems with visual representations, five of these asked students to use manipulatives, which provides further support for mathematical reasoning skills. Prentice Hall asked students to use manipulatives twice, but only one of the manipulatives was a part of the lesson plan. The other manipulative was offered as a side note to teachers.

Singapore Math outnumbered Prentice Hall and CK-12 in both categories of real world problems and multiplication. No problems from Singapore Math asked students to write the reciprocal of a fraction. Fifty-eight problems from Prentice Hall asked students to divide fractions using the multiply by reciprocal rule, whereas 80 problems from CK-12, and 16 problems from Singapore Math required this method. Not all of these features are mutually exclusive, and therefore overlap of problems did occur between these features during analysis. Singapore Math had the most overlapping features whereas CK-12 had the least.

### 3.3. THE CURRICULUM REVIEW TOOL

Baxter and Ruzicka’s Curriculum Review Tool measured how comprehensively each curriculum meets the standard and how supportive the curricula are of teachers’ specialized content knowledge. The individual curriculum elements have been analyzed for completeness and are shown in the graph below:

**Graph 3: The Curriculum Review Tool**



Pertaining to math content, all three programs allow students to interpret and solve division problems, division story problems, and use visual fraction models to explain quotients. Although CK-12 qualifies in the story problem category, there were only two story problems presented, which were completed for the students. Singapore Math was the only curricula with a majority

of problems that required students to make the connection between multiplication and division with fractions. CK-12 partially completed this category, but its main focus, as Prentice Hall's, was using the invert and multiply rule to solve division of fractions. None of the curricula had students use variables to find unknowns in division problems, and only Prentice Hall asked students to create their own story problem.

The assessment tasks for Prentice Hall and CK-12 provide a trivial way out for students to solve division of fraction problems by using the invert and multiple algorithm. Singapore Math does not heavily rely on this algorithm and therefore its application of ideas is closer to achieving the CCSSM. Out of the three curricula, only Singapore Math provides alternative solutions and advice for teachers to solve a particular division problem for students.

Concerning the development and use of mathematical ideas, Prentice Hall and CK-12 introduce the term "reciprocal" in preparation for teaching the invert and multiply rule. Singapore Math only refers to this word once. The majority of Prentice Hall's and CK-12's problems only ask students to solve division of fractions without a conceptual understanding. Furthermore, CK-12 does not contain word problems for students to solve independently. Although each curriculum does allow students to explain quotients via pictures, only three problems from Prentice Hall and two from CK-12 asked for this demonstration.

For the ability to promote student thinking about mathematics, Singapore Math references previously learned concepts when introducing division of fraction, reminding students of what it means to divide whole numbers. Prentice Hall does not reference any previously learned concept and CK-12 touches on the idea that multiplication is the inverse of division, but does not apply that relationship later to division of fractions. None of the curricula allow students to write about or reflect upon newly learned concepts.

The last domain of evaluation concerned the curricula's support of teachers and teachers' SCK. The three curricula support teachers' understanding of division of fractions, but Prentice Hall and CK-12 only accomplish this at a procedural level. Although each curriculum supports teachers to create a classroom environment that encourages students to make sense of mathematical ideas, CK-12 and Prentice Hall promote this using problems that require lower cognitive demands. None of the programs encourage teachers to promote student questioning during the lesson of division of fractions or address students' common misconceptions regarding division of fractions. None of the three curricula provide examples of students' work.

As Graph 1 and Graph 2 illustrate, there is a direct correlation between overlapping mathematical features and problems that require higher-level thinking. Simultaneously, Graph 1 and Graph 2 illustrate that a curriculum with a more equal distribution of the Six Essential Features correlates to higher-level thinking. This is associated with a more complete curriculum as seen by Graph 3.

## 4. DISCUSSION

The application of the evaluation tools on the collected data, suggest that a reliance on typically used algorithms hinders conceptual understanding of mathematics and teachers' SCK. This will make it more difficult to reach and implement the standard. The following subsections provide a more detailed analysis of the results of the study.

### 4.1. MATHEMATICAL TASKS

The results from Stein and Smith's evaluation tool indicate that Singapore Math is most closely matched to the standard because 76.8% of its problems reached higher-level demands. Only 28.6% of Prentice Hall's and 4.8% of CK-12's problems address higher-level demands. This clear distinction highlights that the implementation of the standard will be difficult for teachers relying on CK-12 and Prentice Hall, because these curricula involve primarily lower-level thinking. The CCSSM stresses conceptual thinking which CK-12 and Prentice Hall together do not even accomplish 50% of the time according to Stein and Smith's evaluation tool. However, Prentice Hall's numbers in all four categories reflect a more versatile curriculum, as it demands both higher and lower-level mathematical thinking in comparison to Singapore Math and CK-12. This versatility will appeal to different types of learners. However, the CCSSM is more concerned with higher-level thinking, and therefore, by examining Graph 1, it is clear how the cognitive demands of the standard are most closely reached by Singapore Math.

### 4.2. THE SIX ESSENTIAL FEATURES TOOL

The results from the Six Essential Features Tool show that the evaluated curricula did not refer to one third of the desired features. Researchers have deemed that these six features are essential to teach division of fractions conceptually (Philipp, n.d.; Sharp & Adams, 2002; Thompson, 1979; Wu, 2011; Yetkiner & Capraro, 2009). Without these features, the lesson plans for division of fractions are significantly less comprehensive. Therefore, it will be harder for teachers to make use of the CCSSM's framework for introducing equivalent fractions prior to division of fractions if teachers are using these curricula.

The features listed in Table 2 are not mutually exclusive; overlap between features occurred. Singapore Math had 79 overlapping features compared to Prentice Hall with 12 and CK-12 with eight. A typical problem from Singapore Math will demand more from a student because overlapping features require higher-level thinking. Therefore, Singapore Math coincides with the standard to a better extent than the other two curricula because conceptual understanding requires higher-level thinking.

Where Prentice Hall is more versatile by incorporating both higher and lower-level thinking, Singapore Math is more versatile because it incorporates a wider variety of problems. This allows Singapore Math to place greater conceptual demands on the learner. As Graph 2 presents, CK-12 and Prentice Hall make the majority of references to the traditional algorithm when presenting division of fractions. Prentice Hall suggests to teachers that, "Students might

find it helpful to recite ‘invert the second fraction and multiply’ procedure softly as they work” (Charles, 2008). Relying this heavily on the multiply by reciprocal algorithm discourages conceptually thinking of mathematics and teachers’ SCK due to the emphasis of the common algorithm. Singapore Math does not ask students to write reciprocals, indicating that the curriculum’s emphasis is not teaching common algorithm.

Pertaining to the multiplication feature, Singapore Math encourages thinking of division in two different ways. For example,  $(1/2) \div (1/4)$  is presented to teachers as, “How many  $1/4$ ’s are there in  $1/2$ ?” or “ $1/2$  is  $1/4$  of what?” with corresponding pictures and explanations (Singapore Math, 2006, p.4). Prentice Hall and CK-12 do not provide different solving methods for a particular problem, which perpetuates the idea that there is only one correct way to solve mathematic problems. This will make it difficult to achieve the standard, as it requires students to understand fraction division problems in a multitude of ways.

Singapore Math encourages teachers to have students justify their answers to problems. These suggestions emphasize the importance of student thinking and processing rather than just obtaining the correct answer. This is quantitatively supported by the “concepts first, procedures second” feature. Both Prentice Hall and CK-12 provide numbered steps for students to follow the common algorithm, which does not support student thinking and processing of a problem. This presentation of division of fractions makes math monotonous and procedural, rather than logical and versatile. Problems that encourage conceptual understanding are not frequently embedded in CK-12 and Prentice Hall. For example, Prentice Hall’s conceptual demands of division of fractions are most commonly found in small print to the side or at the bottom of pages.

From the Six Essential Features Tool, Prentice Hall’s biggest strength is its inclusion of real world problems. However, Prentice Hall does not support teachers properly in helping students solve these problems. In contrast, Singapore Math encourages teachers to use visuals and diagrams to apply the concept of division of fractions to real world problems, whereas Prentice Hall spends 71.4% of its curriculum focusing on lower-level demands. Prentice Hall does not prepare students well to solve real world problems considering that most problems can be solved procedurally. This leaves teachers with little help to guide student thinking when approaching such problems. CK-12 only includes two real world problems that are already completed for students, whereas Prentice Hall at least provides students an opportunity to solve such problems. However, CK-12 has the technological advantage to make revisions easier and better meet this feature. For now, teachers using Singapore Math will have less difficulty implementing the standard.

### 4.3. THE CURRICULUM REVIEW TOOL

The results from the Curriculum Review Tool indicate the completeness of each curriculum to meet the standard and the curricula’s ability to support teachers’ SCK. Singapore Math, Prentice Hall, and CK-12 complete the standard’s lower-level demands but miss the standard’s requirements for higher-level demands. This will make it harder for teachers who use these

curricula to implement the standard. For example, all three curricula have students interpret and solve division problems through some form of visual fraction models to understand problems, but the curricula's completeness diverge when discussing the relationship between division and multiplication as well as creating story problems. Where Prentice Hall provides opportunities for students to be creative by asking them to create their own story problem, Singapore Math and CK-12 succeed by relating division and multiplication. Prentice Hall and CK-12 succeed in introducing improper fractions while Singapore Math does not. In fact, the math content for each curriculum is not complete and this lack of completeness leads to less coherency and diminishes a student's conceptual understanding of division of fractions.

The Curriculum Review Tool further illustrates how the different structures of the curricula shape the development and use of mathematical ideas. For Prentice Hall and CK-12, problems introduced by the teacher were in the same style as problems to be completed independently by the student. This makes the common algorithm a necessity and diminishes the need for conceptual thinking. Although ten problems from Singapore Math were partially completed for students, hindering their independent thinking, 72 of the problems were not, which required students to conceptualize the problems independently. Therefore, division of fractions is better conceptually developed by Singapore Math than the other two curricula.

The three curricula do not provide students with the opportunity to write or reflect upon their understanding of division of fractions. This hinders the ability for each curriculum to promote students' thinking about mathematics. The inability of Prentice Hall and CK-12 to highlight the relationship between multiplication and division diminishes the opportunities for students to think about mathematics in familiar terms. This is confirmed by the results illustrated from Graph 2, which precisely indicates that Prentice Hall and CK-12 did not often refer to previously learned mathematical concepts.

The Curriculum Review Tool also highlights discrepancies between each curricula's ability to support teachers. Samples of students' work or responses are not provided to teachers in any of the evaluated curricula. This limits teachers' abilities to prepare for teaching division of fractions and does not support the development of their SCK. Singapore Math advises teachers to present "...division of fractions through the use of diagrams so that they [students] can apply principles to word problems, rather than simply memorizing 'invert and multiply'" (2006, p. 5). The Singapore Math curriculum is able to better support teachers than Prentice Hall and CK-12 due to its greater emphasis on conceptual thinking.

From the teachers' support domain, CK-12 and Prentice Hall do not encourage teaching division of fractions from a conceptual point unlike Singapore Math. This perpetuates the view of mathematics as a set of rules to follow rather than a logically solvable subject. This will make it more difficult for the two curricula to achieve the standard.

#### 4.4. LIMITATIONS

Although the three evaluation tools help elucidate where current curricula stand in comparison to the CCSSM, limitations with this study exist. This study has examined the treatment of only one mathematical concept in each curriculum. Examining one mathematical concept is surely not a comprehensive evaluation of the CCSSM as a whole. The results from the evaluation tools provide one snapshot to answer the questions of how well current curricula match the CCSSM and how well current curricula aid teachers' implementation of the new standards. Curricula alone cannot fully answer this question. Teachers' pedagogical practices, students themselves, and how problems are solved by students are all variables which contribute to answering the research questions: how well do current curricula match the CCSSM, specifically regarding division of fractions, and how supportive is curricula of teachers' SCK? Furthermore, other materials besides curricula, such as supplemental worksheets, can be used by teachers and students which were not evaluated in this study. Case studies about teachers' knowledge and use of the curricula are needed. Case studies are needed to determine how students solve division of fractions when exposed to these curricula. Such analyses would provide more comprehensive results.

Limitations arise within the Six Essential Features Tool, which provide six features that are not mutually exclusive. Some problems were counted in two or more categories due to overlapping features. This hinders the ability to interpret the calculated values as percentages and inhibits a comprehensive comparison of the three curricula. This might affect the validity of the findings, because one problem that may have contained the feature of multiplying by the reciprocal, discouraged by the CCSSM, might have also contained the visual representation feature, encouraged by the CCSSM. Although overlapping features help illustrate the level of intensity for each problem, the intensity can vary depending on the number of features overlapped, leading to ambiguity.

A future study could quantify students' conceptual understanding of division of fractions when exposed to only certain features as listed in Table 2. This would provide information as to which features are most important in the conceptual understanding of division of fractions. Assuming that each feature is equally valued, these programs are one third incomplete to conceptually teach division of fractions.

Concerning the Curriculum Review Tool, 40 equally weighted categories were assessed and evaluated by percentages. The category assessing the curricula's ability to welcome student curiosity might be weighted less than the categories assessing the curricula's ability to match the standard. For this project, the categories were allocated the same percentage points. Further research investigating the importance of each category would make the results more helpful.

To decide if the CCSSM are the optimal standards to teach to is beyond the scope of this project. However, standards like the CCSSM, which emphasize clarity, focus, coherency and rigor can only help students' mathematical thinking and help solve the math challenge. The

CCSSM may or may not be the “best” standard (which further research should investigate), but because it has been so widely adopted; it is the natural point for comparing curricula.

## 5. CONCLUSION

As this study shows, Singapore Math is more closely matched to the standard than Prentice Hall, and Prentice Hall more closely aligns with the standard than CK-12. From the analysis, my prediction holds true that Singapore Math more closely meets the standard. However, this is not a case of “winners” and “losers.” Each curriculum has important qualities, which support the implementation of the standard and should be incorporated in new resource tools to teach division of fractions conceptually. This includes Singapore Math’s conceptual emphasis of mathematics by incorporating multiple mathematical features in its problems, Prentice Halls’ inclusion of real world problems which encourages higher-level thinking, and CK-12’s ease of making revisions to reach the standard. However, CK-12’s and Prentice Hall’s overreliance on the invert and multiply algorithm is problematic, as it diminishes students’ conceptual understanding and teachers’ SCK for division of fractions.

Guidelines that encourage teachers to bypass conceptual understanding for quick, memorized rules can have devastating effects. These guidelines encourage teachers to think of mathematics as a set of procedures rather than a coherent, logical, and understandable subject. Curricula, which emphasize procedural thinking, have greater potential to diminish teachers’ SCK. Therefore, students may not be provided with the knowledge needed for a firm understanding of mathematics and will have difficulty reaching the objectives of the CCSSM. To meet the standard, and the CCSSM as a whole, curricula must incorporate problems that scaffold students’ thinking and allow them to solve higher-level tasks. The curricula must also support teachers’ SCK so that students can reach their optimal learning capacities.

The objectives of the CCSSM will improve U.S. mathematic education and help solve the U.S. challenge in mathematics. If all U.S. schools adopt the CCSSM and teach to these standards, students will develop better critical thinking skills, and understand the importance of asking questions, such as exploring why algorithms work. Furthermore, they would understand the coherency of mathematics. Equally important, such cognitive processes that the CCSSM stresses is applicable to other fields of study such as science and history. Students will not just accept presented facts, but question and investigate them. In doing so, the CCSS helps students become actively engaged with the material making their education more meaningful, pertinent, and exploratory.

Curricula, which fail to meet the standard and support procedural methods, only perpetuate the belief that mathematics is simply a subject of random rules. The beauty of arriving at an answer in multiple ways, the coherency of the subject, and the reward of persevering becomes fogged. Mathematics, as well as other subjects, becomes bland and meaningless when standards and curricula only require students to memorize facts and procedures.

Determining the quality of mathematics education cannot solely rely on standards themselves. Teachers' SCK, curricula, and funding of schools are few of many variables that can affect the quality of mathematics. However, the CCSSM are a step in the right direction regarding the U.S. math challenge. If the standards are met, they will help solve the math challenge because they require students and teachers to draw connections between already understood concepts. Overall, this reinforces their previous mathematical knowledge and problem solving skills.

Similarly, other areas of new development must be implemented to help solve the math challenge and ensure students' conceptualization of the standard. This includes assessment and teacher development programs. Assessments play a significant role in what is taught in the classroom. Therefore, problems on assessments must ask higher-level questions and not provide a trivial way out for students to solve the problem. Adherence to the standard through curricula and assessments cannot solve the math challenge alone. Teachers' knowledge of mathematics must be proficient to ensure students are taught mathematics clearly and logically. Teacher development and training programs must exist early on, where prospective teachers begin thinking of pedagogical practices of mathematics. Such collaboration must then continue as they begin teaching, whereby together teachers create mathematical lessons and discuss teaching strategies to use in the classroom.

Adopting and teaching to the standard is necessary to provide the foundation for students' success in algebra and other higher-level math courses. Higher-level thinking curricula will help ensure this foundation is laid properly. The CCSSM will help reconstruct mathematics education and solve the math challenge because the objectives develop students' problem solving skills, rather than encouraging the use of procedures and algorithms. Repetitive and procedural methods inhibit the ability to solve harder problems. Additionally, the cognitive thought processes that the CCSSM stresses help change the perception that education is bland. The discourse of education should not debate whether or not new objectives or standards should be implemented. The discourse should concern how educators can aid their students in reaching higher-levels of thinking. After all, student learning is the greatest goal for educators. In the words of John Dewey, a major leader of progressive education: "If only all instructors realized "that the quality of mental process, not the production of correct answers, is the measure of educative growth."

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# Marine Mammal Monitoring on Guam

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## ABSTRACT

Data on marine mammals, specifically information on their stock numbers, seasonal migrations, population structure, habitat use, and behaviors is limited. This study of island-associated resident pods of the long nosed spinner dolphin (*Stenella longirostris*) was conducted near the island of Guam, part of the Mariana Archipelago, south of Japan. A proposed expansion of United States military facilities in Guam may adversely affect these spinner dolphins through the increases in training activity, population growth, coastal development, and tourism associated with military growth in an area. This study compiles historical and current data on marine mammal sightings and behaviors to study possible impact of U.S. military presence. The long nosed spinner dolphins (*S. longirostris*) are of particular interest because of their proximity to shorelines, their habitat use, and their daily activity schedule. Current data was collected from interviews and sighting events. Standard photo documentation and field survey protocols developed by the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center (PIFSC) were used. This study created a preliminary marine mammal database for Guam and has expanded the limited information available. In addition, sighting information was used along with geographical information system (GIS) software to combine NOAA benthic habitat maps with multibeam bathymetry to gain a better understanding of the habitats occupied by documented species. Preliminary results suggest that *S. longirostris* populations in Guam have similar circadian and seasonal rhythms as Hawaiian *S. longirostris* populations. The results also demonstrate that Guam spinner dolphins show a preference for clear, relatively shallow open water bays with underlying, unconsolidated sediment (sandy bottoms). An increase in military use of shallow bays and dolphin-associated ecotourism could therefore negatively impact resident populations of the Guam spinner dolphins.

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## INTRODUCTION

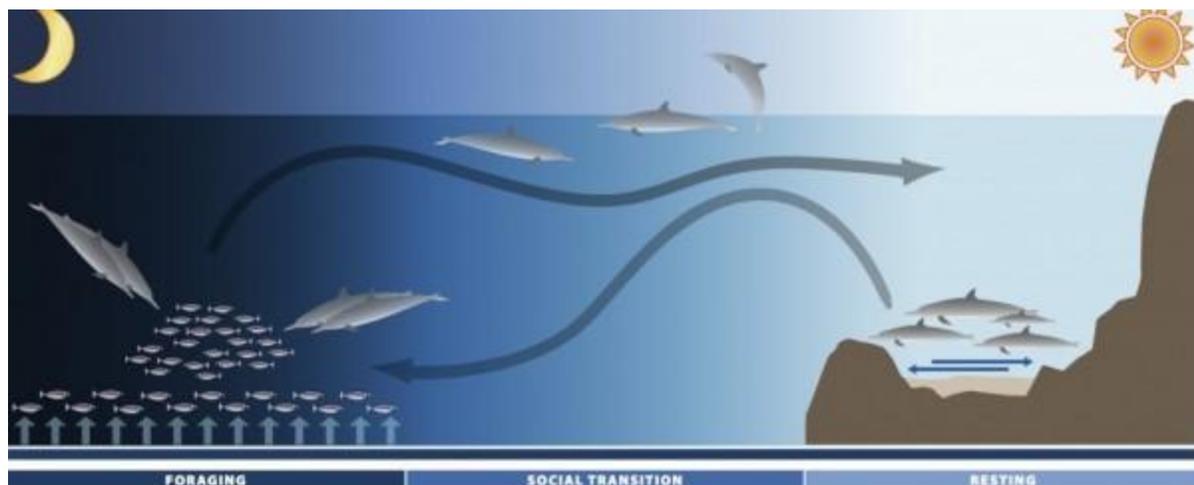
Information on the ecology and behavior patterns of marine mammal populations is minimal. This study focuses on compiling and analyzing data on the seasonality, diversity,

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population structure, habitat use, and behavior of marine mammal populations due to the critical need for increased scientific understanding of environmental threats to the population dynamics and health of marine mammals surrounding Guam. Guam is part of the Mariana Archipelago, a chain of islands between Japan and Papua New Guinea. The National Marine Fisheries Service's (NMFS) Pacific Islands Fisheries Science Center (PIFSC) is particularly interested in collecting marine mammal information on populations of spinner dolphins which inhabit the near-shore waters of the island. Spinner dolphins are a pantropical species found in "all tropical and most subtropical waters around the world" and, in many cases, can be the most common small cetacean in tropical waters (Perrin 2009). Because of their distribution and behavior patterns, spinner dolphin populations make an excellent case study of the impacts of human activity.

Island-associated spinner dolphins, such as those populations found in Hawaii and other central and western Pacific islands, prefer shallow, protected bays to rest and socialize in during the day. They typically move offshore during a transitional period before nightfall, when they feed in open water (Norris et al. 1994; Reeves et al. 1999; Benoit-Bird and Au 2003; Lammers 2004; Karczmarski et al. 2005; Oremus et al. 2007; Johnston et al. 2008). The daily circadian pattern of island-associated spinner dolphins is shown in Figure 1, below.

**Figure 1: Circadian movement pattern of spinner dolphins**



(Johnson 2011)

There is a large potential for human impact on spinner dolphins because of the species' behavioral pattern of using shallow, near-coastal areas as resting sites in the daily migratory cycle between these resting sites and deeper water feeding sites. Studies on the Hawaiian spinner dolphins indicate that their resting period can be critically interrupted and prematurely curtailed by approaching vessels and swimmers (Johnston and Bejder 2011; Würsig 1996; and Courbis and Timmel 2009). Interruption of these daily-resting periods in near-shore, shallow bays may negatively impact the physiology of the dolphins, and by extension, diminish their population.

The National Marine Fisheries Service has established guidelines for recreational activities associated with marine mammal viewing that are consistent with the Marine Mammal Protection Act's (MMPA) regulations (NMFS Protect Dolphins Brochure). The MMPA makes it illegal to "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." Since the spinner dolphin species is pantropical, it is useful to consider the impacts of vessel traffic and human interactions on the Hawaiian populations as models for studying other island-associated spinner dolphin populations, such as those found near Guam.

The purpose of this study is to document natural populations of marine mammals surrounding the island of Guam, with particular focus on spinner dolphins. This area of investigation is of particular importance due to the proposed expansion of the United States military on the island. According to an article in the Feb 9, 2012 issue of *Defense Industry Daily*, "Guam is likely to see between \$400 million and \$1 billion in military construction each year for a period of six to 10 years." Estimates made by the World Resources Institute describe military development projects budgeted at well over \$10 billion and which include a new Marine Corps base and airfield, a new Army base, new docking facilities for nuclear aircraft carriers, and expansion of existing Navy and Air Force facilities (The Defense Industry Daily, Feb 9, 2012). This proposed military development has received much attention in Guam, both negative and positive. It is clear that significant military personnel increases will have an impact on both the infrastructure and environmental status of Guam. A major consequence of this development is the projected increase in the use of shallow bays for both military training purposes and for tourist excursions to watch and swim with dolphins.

Prior to the authorization of any changes to the spinner dolphins' near-shore habitat, research needs to be conducted to establish baseline population estimates of the dolphins in the area and to determine how the spinner dolphins use the bays. This will ensure accurate predictions of environmental impacts. Previous studies of marine mammals near Shark Bay, Australia have documented decreased population sizes in relation to increased boating activity (Bejder et.al 2006). This current study represents the first effort to compose a marine mammal database to aid in the future collection of data on marine mammals, with specific emphasis on spinner dolphins around Guam. Using spinner dolphins as an indicator species, because of their near shore habitat usage and their relatively high numbers, will help management agencies and other stakeholders predict what possible effects increased military presence and ecotourism may have on these dolphin populations.

## METHODS

### HISTORICAL RECORDS

Prior to the collection of any field data, extensive historical searches of the literature were conducted to establish a historical timeline for determining which marine mammals have been identified in the waters surrounding Guam and the habitats they might be using. A careful review of the literature allowed more information about the commonly observed marine mammal species to be compiled along with single sightings, beaching, and stranding events.

Historical data were also collected by communicating and collaborating with local resource agency personnel and more than 20 boat captains of Guam.

All previously recorded sightings, beachings, and other encounters were compiled from two comprehensive sources, one published and one field record. The published source was compiled by Dr. L. G. Eldredge in his 2003 article "The Marine Reptiles and Mammals of Guam." This record includes three decades of marine mammal encounters spanning the 1970s, 80s, and 90s. The relevant records from this report were transcribed from the text of the publication and entered into table form (Appendix A) to facilitate comparison with current data.

The other comprehensive source is the field record supplied by Brent Tibbatts, a Fisheries Biologist with the Division of Aquatic Wildlife Resources (DAWR) in Guam. A sample of this record, which contained sightings, beachings, and other encounters from September 7, 1962 through July 6, 2011, is also organized in table form (Appendix B). In addition to Brent Tibbatts, other resource personnel included staff of NOAA's National Marine Fisheries Service Pacific Islands Regional Office, (Valerie Brown, PIRO).

Any information obtained concerning marine mammals in the rest of the Mariana Archipelago is also included in the appendices. All available details surrounding the nature, location, date, or species involved in the encounters were recorded.

## CURRENT RECORDS

### BOAT-BASED OBSERVATIONS

The procedure used for photo documentation of spinner dolphin sightings was consistent with the Pacific Island Fisheries and Science Center (PIFSC) photo documentation and survey protocols. Photographic images were taken using a digital SLR Canon 60D camera fitted with a 100-300mm lens. Observations focused on Guam's Agat Bay, Apra Harbor, and included an all-day series of multiple north-to-south trips along the west side of the island with Marie Hill, PIFSC Cetacean Specialist, and her research team. Sighting locations and geographical positioning system (GPS) locations were overlaid with NOAA's benthic habitat maps to determine the extent of marine mammal habitat use. A total of seven trips on vessels were made within the span of two weeks between July 5 and July 19, 2011. The eighth and final trip with Marie Hill and the PIFSC team took place at the beginning of August 2011. Information recorded during observational trips included species identification, group numbers, behavior, location, and general weather and water conditions. All eight photo documentation sessions were performed from the deck of ships of several different dolphin tour boat operators and dive boats.

At each site, we located a point of origin within a pre-existing macroplot study area managed by IAE, LCOG, or the City of Eugene. From the point of origin, we established a baseline transect based on the site descriptions provided by IAE. Using the systematic sampling method, we set up transects perpendicular to the baseline transect, with the first transect randomly located and each subsequent transect following at an equal interval of 4-5 meters. Along each transect, the

first sample point was randomly located and each following point was spaced at an equal interval of 4-5 meters for a total of 200 sample points per study site. At each sample point, we collected data for topography, water level, vegetation height, and litter (fallen dead vegetation) depth.

## ANECDOTAL INTERVIEWS

All of the 24 local fisherman and tour boat operators who provided observational opportunities were also interviewed in July and August 2011. This information establishes a broader understanding of seasonality, diversity, and location of key habitat areas for the spinner dolphins specific to Guam from the local perspective.

## RESULTS

### HISTORICAL AND CURRENT DATA COMPARISONS

The most common species, both as observed in the literature as well as in field encounters, was the spinner dolphin *Stenella longirostris*. Samples of these records are given in **Appendix A** and **Appendix B**. Eldredge reports a total of 13 cetacean species from the waters around Guam and the Mariana Islands. The boat-based sightings in the current study included three of the thirteenspecies: the *Stenella longirostris* - spinner dolphin; *Stenella attenuata* - pantropical - spotted dolphin; and *Globicephala macrorhynchus* – short-finned pilot whale. Brent Tibbatts (DAWR) documented a total of 23 marine mammal species. **Appendix A** also includes the more current sighting information updated from the boat-based surveys conducted in this study. These boat-based sighting events were recorded on eight non-consecutive days during the study period and are designated by asterisks. Field log sheets were submitted to NOAA's Pacific Island Regional Office (PIRO) to be added to ongoing data collection efforts by the Joint Institute for Marine and Atmospheric Research (JIMAR) at the University of Hawaii, Manoa.

All of the 24 local fisherman and tour boat operators who provided observational opportunities were also interviewed in July and August 2011. This information establishes a broader understanding of seasonality, diversity, and location of key habitat areas for the spinner dolphins specific to Guam from the local perspective.

### PHOTOGRAPHIC AND GPS DOCUMENTATION

This study collected additional data on the eight field days using standard photo documentation and survey protocols developed by the NMFS, Pacific Islands Fisheries Science Center (PIFSC). Photographs were submitted to the Pacific Islands Photo Identification Network (PIPIN) database. Sample photographs of the distinctive individuals are included here as **Appendix C**.

Selected sighting locations for *S. Longirostris* and corresponding geographical positioning system (GPS) locations were combined with NOAA's benthic habitat maps. Boat track lines and dolphin locations are noted in **Appendix D**. Image **D<sub>1</sub>** is the satellite image with boat tracking

and *S. Longirostris* sightings and image **D<sub>2</sub>** illustrates the same information overlaid with NOAA's benthic habitat map.

## ANECDOTAL INTERVIEWS

Samples of the interviews with the local fisherman and dolphin tour boat operators frequenting the area are listed in **Appendix E**. This appendix includes the following for each boat based observations and marine mammal sightings: date and time of day, vessel, captain, number of individuals sighted, observations, and captain's comments—if any. These entries document numbers of individuals sighted, their direction of travel, and include the objective and subjective observations offered by the boat captains, including, in some cases, evidence of effects of dolphin-vessel interactions.

These records of observations, documented sightings, and combined anecdotal information provide supporting evidence for a circadian and seasonal pattern in the life of spinner dolphins on Guam as noted in other studies done in Hawaii by Silva (2009). Specifically, these data confirm the same known habitats of *S. longirostris* as reported for the Hawaiian spinner dolphin populations. The field observations and data presented by both the fishermen and the dolphin tour boat operators show that the key habitat used by Guam's spinner dolphins includes the use of sandy, shallow bays for daytime resting and transitional social behavior.

In order to measure microtopography at each site, we used a surveyor's level (Harrelson et al. 1994). First, we set up the tripod, and secured and leveled the instrument to ensure consistency in our measurements. Next, we took a backsight reading to the point of origin, which had an arbitrary elevation of 100 meters. The height of the instrument (HI) was then calculated by adding the backsight reading to the standard elevation value of 100 meters. At each sample point along each transect, a foresight (FS) was recorded. The elevation of each sample point was calculated by subtracting the foresight from the height of the instrument ( $HI - FS = ELEV$ ). At the approximate mid-point and end of the survey, we took another backsight to the benchmark to ensure the level had not moved or shifted significantly (Harrelson et al. 1994). In addition to measuring elevation, at each point we recorded the depth of standing water with the surveyor's rod to the nearest millimeter.

## DISCUSSION

Spinner dolphins' reliance on near shore habitats for a critical resting stage in their circadian behavior renders them vulnerable to displacement by human activity. Ostman-Lind et al. (2004) studied specific times during the day when the Hawaiian spinner dolphins were particularly susceptible to disturbance. They found that human disturbance was highest in mid-morning, just when spinner dolphins were returning to rest. As the dolphins begin or end their resting period, they engage in aerial spinning and leaping behaviors that are noticeable from shore (Würsig et al. 1994) and therefore attractive to human spectator involvement.

Ostman-Lind et al. (2004) also found that secondary resting areas, areas that had less boat traffic, were being utilized more than primary areas after boat traffic increased in the primary areas. This suggests that the dolphins had been displaced from their primary resting areas. The secondary resting areas, however, may not provide the same quality of rest or same amount of protection from predators, making them less preferable to primary rest areas.

During periods of rest, spinner dolphin behavior consists of synchronous dives and extended periods of swimming in quiet formation along the shallow bottom (Norris and Dohl 1980; Norris et al. 1985). Spinner dolphins sleep with one half of their brain at a time (Ridgway 2002). Figure 2 illustrates a brain scan from the right and left hemispheres during dolphin sleep. This alternation of resting and vigilance may be beneficial for protection against predation, indicating the importance of the spinner dolphin's resting environment. The shallow bays where resting occurs may be ideal for keeping watch for predator outlines, particularly sharks, against the sandy bottom (Perrin et al. 2009).

**Figure 2: Dolphin sleep patterns**

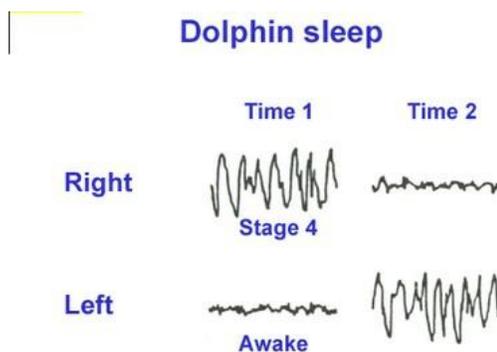


Image from <http://www.colorado.edu/intphys/Class/IPHY3730/14biologicalrhythms.html>

This study focuses on Agat Bay, one of the larger bays on the southwest side of Guam, but there may be many other ecologically sensitive areas critical to the health of marine mammal populations in the area. Studies on the influence of disturbances such as boating traffic and underwater sound pollution on spinner dolphins (*Stenella longirostris*) and other small cetaceans have shown that these marine mammals exhibit distinct behavioral responses to those disturbances beyond simply leaving the primary area for a secondary area. These behavioral responses include: changes in swimming speed, diving and aerial behavior, vocalization patterns, as well as movement patterns and overall avoidance of higher traffic areas (Corbis & Timmel 2009). Similar behavioral responses were also noted in interviews with tour boat operators. These local experts further noted that they often observed similarly disrupted behavior when submarines and military hovercraft were training in the area.

Genetic and reproductive studies in the Hawaiian spinner dolphin populations have contributed to the body of evidence that indicates there is not regular interaction between populations of individuals that reside in consistent geographic locations. In fact, a recent study by population geneticist K. R. Andrews et al. (2010) suggested that gene flow, dispersal, and

social structure of the Hawaiian spinner dolphin may be influenced by the availability of habitat and resources between islands. Photo-identification data collected during surveys in the waters surrounding Tutuila (American Samoa), indicate the presence of a resident population of spinner dolphins (Johnston et al. 2008). Approximately one third of the individuals within the photo-ID catalog were sighted in multiple years (Johnston et al. 2008). In addition, some of these individuals demonstrated "strong site fidelity and were encountered within only a few kilometers from one year to the next" (Johnston et al. 2008). Significant genetic distinctions were found between spinner dolphins sampled at five different islands and atolls, which included Hawaii, Oahu/4-islands, Kauai/Niihau, Pearl and Hermes Reef, Midway Atoll/Kure (Andrews 2009; Andrews et al. 2010). This indicates that spinner dolphins in these areas are residents of these areas and do not genetically mix with other populations. From anecdotal interviews of boat captains and field observations conducted in this study, it appears that there is also very limited mixing and interactions between separate pods of spinner dolphins around Guam. This means that each pod likely has a defined range and does not regularly interact with other pods. Any disruption of one pod's habitat therefore, could disrupt the integrity of the entire pod.

Photo-identification studies, over time, provide insight into habitat use and movements of individual cetaceans. Some species can be identified by naturally occurring markings on their bodies, often located on the dorsal fin, but also on flukes or the body. Photographic records of these scars, nicks, notches, or color patterns can be used to reliably identify individuals. Photographs are archived and combined with other data, including sighting location, group size and structure, and behavior. Individuals can be tracked over time and between locations on the basis of their unique photo-IDs (<http://www.pipin.org/community>).

Further documentation of pod integrity comes from the photo identification data. Data from the current study, specifically Agat Bay, indicate that the same individuals (those detailed in **Appendix C**, the distinctive individuals which were identified by their markings) were associated with each other in the same location on multiple days throughout this study period. However, without genetic or multi-year, long term photo- identification data, it is difficult to establish connections between these individual dolphins as part of a stable, resident population. It is also difficult to estimate the size of the populations and corresponding key habitat that the dolphins occupy without long term studies that utilize the following methodologies: 1) visual and acoustic line transect surveys, 2) genetic and photo-identification studies both long-term and multi-year, 3) passive acoustic monitoring, and 4) habitat modeling and ecosystem observations.

Hawaiian spinner dolphins are identified as a stock of Pacific spinner dolphins (Norris et al.1994). If the situation in Guam can be compared to that of Hawaii, as it appears it can since spinner dolphins are pantropical and their behaviors and habitat requirements are essentially the same, then it will be important to minimize disturbances. Those disturbances include shoreline development, recreational boating traffic (with its resultant increased noise levels from motorized vessels), as well as military activity, involving ship traffic and training exercises,

use of sonar, and detonation of explosives. **Figure 6** illustrates geographical relationships of island-associated Pacific spinner dolphins emphasizing their pan-Pacific distribution.

**Figure 3: Pan-Pacific distribution of island-related Pacific spinner dolphins**



## IMPORTANCE OF THE MARINE MAMMAL PROTECTION ACT

Spinner dolphin resting bays would likely be considered significant areas for survival of this species as defined by the Marine Mammal Protection Act (MMPA). The United States Congress passed the MMPA in 1972 in response to the following findings and policies, as quoted from the NOAA Fisheries Service MMPA Fact Sheet (MMPA, 1972):

- Some marine mammal species or stocks may be in danger of extinction or depletion as a result of human activities;
- These species or stocks must not be permitted to fall below their optimum sustainable population level (OSP);
- Measures should be taken to replenish these species or stocks;
- There is inadequate knowledge of the ecology and population dynamics; and
- Marine mammals have proven to be resources of great international significance.

According to Cicin-Sain & Knecht (2000), the publically recognized issues that motivated this legislation were: (1) the decline in whale populations around the world, (2) harvesting of baby seals in Canada, and (3) increased public awareness of large numbers of dolphins, specifically spinner dolphins, being drowned as a result of commercial tuna fishing practices. However, according to a number of stakeholders, the MMPA is too ambiguously worded to protect the spinner dolphins from harmful interactions with humans in the coastal waters of the Hawaiian Islands (and other island populations) and legislative terminology such as “harassment,” “take,” and “disturb” was not sufficiently detailed in the original act (SAPPHIRE 201; <http://www.nicholas.duke.edu/spinners/Total%20Ecology>).

The MMPA recognizes that there are marine mammals threatened by human activities that do not involve traditional harvesting practices. As a result, public attitudes “shifted from a focus on their killing and material utilization to a more aesthetic interest in observing these creatures in the wild, in captivity, and in various media forms” (Lavigne, Scheffer et al. 1999). “Traditionally,” marine mammals “were viewed mainly from a utilitarian perspective,” and the focus was strictly on how they would be used as a resource (Lavigne, Scheffer et al. 1999). The legislative language exists to protect marine mammals, but, in practice, our interactions with nearly all marine mammals have changed since the law was first drafted, as has our understanding of their habitat requirements. It is also important to consider advancements in the scientific and popular understanding that all organisms are part of a larger system. Marine mammals are only one of many important components of marine food webs, which include complex interactions at a variety of levels. Thus, although MMPA also lists significant habitat as an important consideration in the protection of marine mammals and encourages the establishment of significant areas for protection (MMPA 1972), environmental impact is an increasingly critical area of study for understanding how marine mammals and their ecosystems can best be conserved. The specific habitat requirements of spinner dolphins put them at risk for degradation of population fitness and possible decline in numbers.

New attitudes and understandings that focus more on the non-consumptive use of marine mammals have led to “a dramatic increase in the viewing of marine mammals in their natural habitats” (Lavigne, Scheffer et al. 1999) and have raised a new set of concerns for the protection of marine mammal species. For example, in Hawaii there are multiple “Swim-with” programs that target spinner dolphins in their resting bays and, while they may raise public awareness and conservation efforts on behalf of dolphins, critically interrupt the dolphins’ resting behavior. If the dolphins are not able to rest and recover from feeding offshore all night, this could prevent them from reaching or maintaining their optimum sustainable population (OSP)—one of the main objectives of the MMPA—by negatively affecting reproduction, foraging, and other normal behavior (Courbis and Timmel 2009). Harassment is defined by the MMPA as “Any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild; or has the potential to disturb a marine mammal... by causing disruption of behavioral patterns” (MMPA 1972), and any study of human impact on marine mammal environments must take such a definition under serious consideration.

If there is too much tour activity in a bay and dolphins leave the bay, do not behave as they usually would, or change their behavior while they are in the bay in response to human activity (exhibit an increase or decrease in aerial behavior, etc.) then this may qualify as harassment. There is evidence that swim-with programs have had these types of effects on spinner dolphins in Hawaii (Courbis and Timmel 2009). If the spinner dolphin’s resting bays are considered key habitat for the survival of island-associated populations, then they should consequently be considered significant areas for protection.

In addition to current military training, the study site of this project, Agat Bay, is also routinely used for boating, dolphin experiences, and jet ski recreation. If not timed and

managed correctly, all of these human activities could pose a threat to the natural behavior, and ultimately, health, longevity, and sustainability of local dolphin populations.

## ECOTOURISM

Viewing wild marine mammals has become a popular tourist activity, particularly in areas where the marine mammals are accessible, such as in the shallow, near-shore sandy bays frequented by island-associated spinner dolphins. Recent studies have raised concerns about the effect of increased ecotourism on the spinner dolphins in the Hawaiian Islands and elsewhere. Recreational activities in Hawaii and Guam have an increasing focus on tourist sightseeing activities, featuring small cetaceans, with a particular emphasis on viewing spinner dolphins as they come and go from their resting areas. The National Marine Fisheries Service (NMFS) has an official policy that encourages members of the public to view and enjoy spinner dolphins, but stipulates that these activities must be conducted in ways that are consistent with the provisions of the MMPA (EIS 2007). According to the Hawaii Tourism Authority (HTA), eco-tourism is "an economically, socially and environmentally sustainable activity that responsibly and authentically connects visitors with natural and cultural landscapes resulting in beneficial exchanges among these landscapes, the host community and the visitor" (Cusick et al. 2010).

The Pacific Islands Regional Office (PIRO) of the NOAA Fisheries Service initiated a dolphin human interaction Environmental Impact Statement (EIS, 2007) in response to concerns that human activities were negatively impacting Hawaii's spinner dolphins and held five scoping meetings in the fall of 2006 to collect comments from all stakeholders and any others interested in the issue (EIS 2007). There had been an increasing number of complaints that spinner dolphins were routinely disturbed by people who attempted to approach the animals near enough to feed and pet the dolphins. These interactions were conducted from motor-powered vessels, kayaks or in "swim-with-wild-dolphin" activities (EIS 2007), further contributing to their potential to disturb, or harass the dolphins in their key habitat.

Some general guidelines have been established for lessening the impact of human activities on dolphin populations. These are publicized by the NMFS in pamphlets and other forms of information distribution. The guidelines suggest safe distances and give reasons for not petting and feeding, or chasing marine mammals but have little impact for enforcement. Even if these guidelines were followed and effectively enforced, excess noise and boat traffic in the shallow bays as a consequence of Guam's projected military development could still further disrupt the resting pattern of these pods. Displacement from primary resting areas could negatively impact spinner dolphins by forcing them to use secondary resting areas that may not provide the same quality of rest or protection from predators and, consequently cause detrimental individual-level and population-level impacts to these dolphins by, for example, negatively affecting female fecundity.

This research shows that maintaining conditions for healthy populations of spinner dolphins in Guam should be paramount in considerations of human activity in their habitat, and similar priorities should guide efforts to maintain conditions for healthy populations in the Hawaiian

spinner dolphins. In both cases (Guam and Hawaii), maintaining conditions for healthy environments necessary to conserve cetacean populations requires a sound scientific understanding of stock structure, abundance, habitat use, natural and anthropogenic threats, and estimates of reproduction and mortality rates. The MMPA's use of the concept and term "significant habitat" could be used as a mechanism to protect the shallow, near-shore sandy bays essential to spinner dolphins' successful survival in Guam. This is especially true when considering the evidence that Hawaiian spinner dolphins, another island-associated species, have been shown to leave a bay if they are disturbed (Norris et al. 1994).

This study's findings stress the importance of retaining minimized disturbances in key habitat areas for marine mammal populations. The results demonstrate that Guam spinner dolphins show a preference for clear, relatively shallow open water bays, with underlying, unconsolidated sediment (sandy bottoms). An increase in military use of shallow bays and dolphin-associated ecotourism could negatively impact resident populations of Guam's spinner dolphins if not managed properly. This population and behavioral data emphasizes the importance of preserving key habitat for spinner dolphins in Agat bay, both for the health of the spinner dolphins and for the sustainability of Guam's ecotourism industry.

The compounding evidence from this and many other studies in similar regions and environments emphasizes the need for increased documentation and information-gathering in order to preserve the natural structure and activity patterns of spinner dolphins. Such data will be particularly important in documenting further habitat use in other areas near Guam prior to any military expansion. Despite our best intentions, human actions may alter the natural patterns of spinner dolphin life, and consequently affect their sustainability as a species in a vulnerable, interconnected ecosystem. This is why we need to document, as completely as possible, the biology and ecology of island-associated spinner dolphins so as to minimize any detrimental human environmental impacts that may threaten these or any other marine mammal populations.

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## APPENDIX A

Genus	Species	Common Name	Date	Island	Location	Who	Documentation
<u>Mysticeti</u>							
<i>Balaenoptera</i>	<i>edeni</i>	Bryde's Whale	August 31st, 1978	Guam	500m north of Sella Bay	Eldredge, 2003	(Davis, 1878) widely distributed species, speculative decomposed carcass washed ashore
<i>Balaenoptera</i>	<i>borealis</i>	Sei Whale	1972	Saipan	west of island	Eldredge, 2003	(Horwood, 1987) single specimen sighting.
<i>Balaenoptera</i>	<i>borealis</i>	Sei Whale	1987	Northern Mariana Islands	Northern Mariana Islands	Eldredge, 2003	(Horwood, 1987) two tagged whales from NMI where killed just south of western Aleutian isl.
<i>Megaptera</i>	<i>novaeangliae</i>	Humpback Whale	February 25, 1991	Guam	Uruno pt.	Eldredge, 2003	Eads pers. comm. two individuals 100m off reef margin.
<i>Megaptera</i>	<i>novaeangliae</i>	Humpback Whale	February 13, 1991	Guam	West coast.	Eldredge, 2003	Eads pers. comm. three off west coast of Guam.
<i>Megaptera</i>	<i>novaeangliae</i>	Humpback Whale	February 1991	Saipan	off Saipan	Eldredge, 2003	(Darling & Mori, 1993) A group of three were photographed off Saipan.
<i>Megaptera</i>	<i>novaeangliae</i>	Humpback Whale	Late February	Rota	East coast	Eldredge, 2003	Stinson pers. comm. A mother and her Calf sighted off Rota's east coast.
<i>Megaptera</i>	<i>novaeangliae</i>	Humpback Whale	January 1996	Guam	Apra Harbor, entrance	Eldredge, 2003	(Anon, 1996) A group of six or more photographed at entrance to Apra harbor.
<u>Odontoceti</u>							
<i>Ziphius</i>	<i>cavirostris</i>	Cuvier's Beaked Whale	1972	Marianas & Bonin Island area	Mariana & Bonin Island area	Eldredge, 2003	(Masaki 1972) cosmopolitan species that has been reported for these areas.
<i>Physeter</i>	<i>macrocephalus</i>	Sperm Whale	1935	Micronesia	Micronesia	Eldredge, 2003	Townsend, charts showing sightings throughout the year between 1761 & 1920
<i>Physeter</i>	<i>macrocephalus</i>	Sperm Whale	September 5, 1962	Guam	Acho bay, Inarajan	Eldredge, 2003	(Bordallo, 1965) 15m longbeached albino sperm whale.

## APPENDIX B.

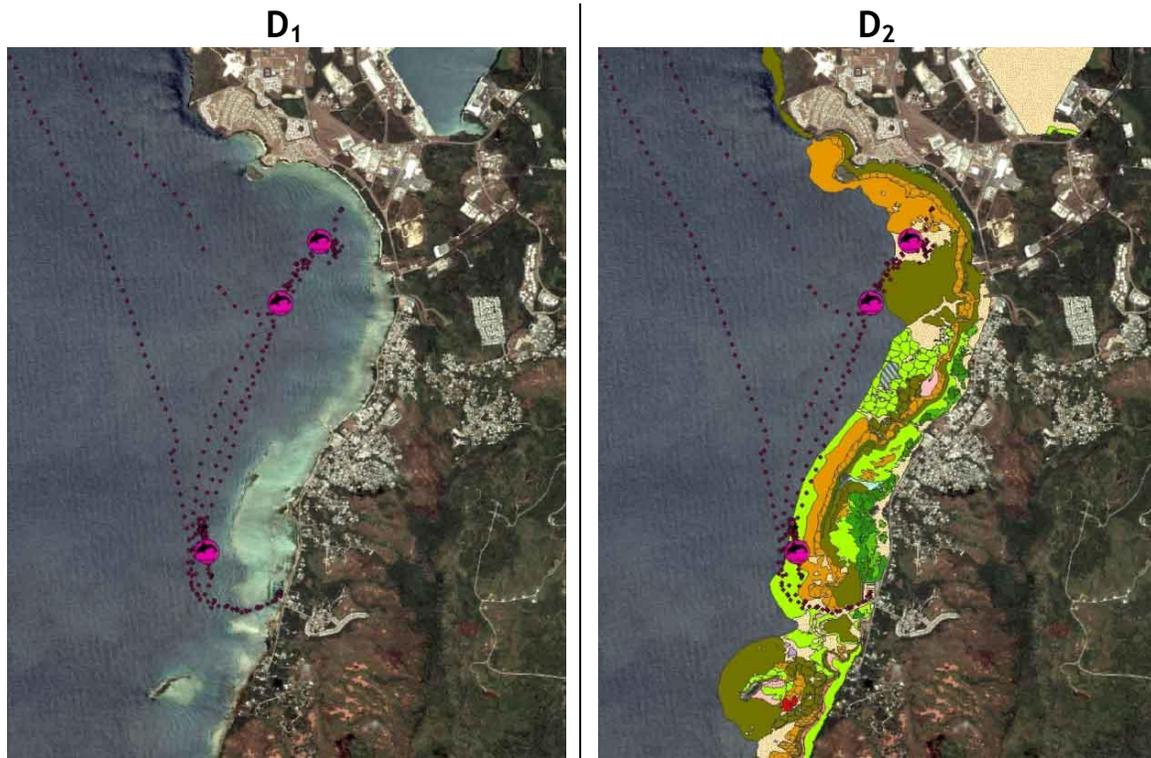
Date	Species	Scientific Name	Location	Alive	Identification	Comments
9/7/1962	Sperm whale	<i>Physeter macrocephalus</i>	on shore	No	????	Acho Beach
7/15/1965	Sperm whale	<i>Physeter macrocephalus</i>	at sea	Yes	????	Orote Point, 3 pods of 6,4, and 3 individuals
3/25/1970	Dwarf sperm whale	<i>Kogia simus</i>	on shore	No	DAWR Staff	Asan
May-74	Pygmy Killer whale	<i>Feresa attenuata</i>	on shore	No	N. Drahos	confirmed, beached
12/6/1974	Dwarf sperm whale	<i>Kogia simus</i>	on shore	No	J. Villagomez	Rizal Beach
2/25/1978	Humpback whale	<i>Megaptera novaeangliae</i>	at sea	Yes	John Eads	2 individuals 100 meters offshore at Urunao
8/31/1978	Bryde's Whale	<i>Balaenoptera edeni</i>	on shore	No	Gerry Davis	Unconfirmed
4/6/1980	Melonheaded-whale	<i>Peponocephala electra</i>	on shore	No	Terry Donaldson	Inarajan
7/6/1980	Short-finned Pilot Whale	<i>Globichala macrorhynchus</i>	on shore	No	DAWR Staff	Togcha
no date	Spinner dolphin	<i>Stenella longirostris</i>	at sea	Yes	DAWR Staff	seen from aerial surveys frequently
1992	Spinner dolphin	<i>Stenella longirostris</i>	on shore	No	DAWR Staff	Hilaan, lacerated
no date	Pantropical Spotted Dolphin	<i>Stenella attenuata</i>	at sea	Yes	DAWR Staff	seen from aerial surveys frequently
8/2/1981	Killer Whale	<i>Orcinus orca</i>	on shore	No	DAWR Staff	Orote Point
9/17/1993	Killer Whale	<i>Orcinus orca</i>	at sea	Yes	USCG	
2/9/1989	Pygmy sperm whale	<i>Kogia breviceps</i>	on shore	No	T. Sherwood	NSD
7/8/1990	Common dolphin	<i>Delphinus delphis</i>	at sea	Yes	Gerry Davis	Galvez
no date	Bottlenose Dolphin	<i>Tursiops truncatus</i>	at sea	Yes	DAWR Staff	seen from aerial surveys frequently
2/13/1991	Humpback whale	<i>Megaptera novaeangliae</i>	at sea	Yes	John Eads	3 individuals off East Agana
5/14/1993	Short-finned Pilot Whale	<i>Globichala macrorhynchus</i>	at sea	Yes	Greg Pangelinan	Urunao, approximately 50 individuals at sea

## APPENDIX C. Distinctive Individuals - *Stenella longirostris*



\*All pictures were taken at Agat Bay by author

APPENDIX D. ( $D_1$  &  $D_2$ )



## APPENDIX E. Interviews and Marine Mammal Observations

### July 5 2011, – Vessel: southern cross. Alan.

- 1st sighting 8:52am-9:03 ~20 to 25 individuals, heading NE in Agat Bay
- 2<sup>nd</sup> sighting 3:12pm-3:21 ~18 to 20 individual, heading SW in Agat Bay

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### July 12 2011, - Vessel: Alii Nuii. Ken. Agat Bay

- 1<sup>st</sup> sighting 9:12am-9:27am ~20 individuals, localized behavior playing in boats wake.
- 2<sup>nd</sup> sighting 11:24am-11:39am ~25 individuals, very shy/ not confronting the boats as they did earlier in the morning. Group split into two groups when approached by the Margarita boat. First group headed north towards Apica pt. second group headed southwest and group became very scattered and spread out.
- Late afternoon trip ~ 3:30 - did not see any dolphins

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### July 13 2011 – Vessel: Alii Nuii. Ken. Agat Bay

- No Sightings, Too Rough. Sighted early in the morning over radio seen headed south in Agat

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### July 16 2011 – Vessel Alii Nuii. Ken. Agat Bay

- No Sightings, Clear/fair weather but still large surge and murky water. Relatively ruff inside the reef margin. Radio sighting - other boats saw dolphins beyond Anae island moving south.
- Captain Ken- said that sometimes the dolphins are just hanging around in deeper clear areas of the reef waiting for the water clarity closer to shore to clear up.

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### July 17 2011- Vesel Southern cross. Jackie. Apra to Pitti

- No Sightings. Went from Apra harbor to Pitti to set mooring for next dolphin cruise. Very big waves still so they needed to move the cruise location. Still no dolphins.
  - Captain Ken- said that normally they see dolphins all around the island: Patti pt., Talofof Bay, Santa Rosa Banks, Tumon, Pitti. However they mainly see dolphins in North Agat and Billy Bay though because these are more sheltered areas. When winds come from the north they generally move south, and when the winds come south they generally move north to the south pt of Apra. Ken also said that he has noticed an ill-effect of the sub on the dolphins behavior they are never in proximity when the sub is around. He also said that the coast guard boat seems to be very disruptive to the dolphins natural behavior and that dolphins will generally move from the area when it is around. He speculates it is their sonar/pinging.
-