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Integrating Traditional Ecological Knowledge with Modern Day Ecosystem Management and Restoration Practices

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This Master's Project

INTEGRATING TRADITIONAL ECOLGOCIAL KNOWLEDGE WITH MODERN DAY ECOSYSTEM MANAGEMENT & RESTORATION PRACTICES

By

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Chapter 1. Introduction

Before the invention of 'Western Science' and even before science had its name, generations of man had developed close relationships with the environment, recognizing natural patterns and developing methods to access nature's benefits. Forestry, farming, and aquaculture practices were crafted over time, through trial and error, discovering the best ways to extract resources for survival, with some ways more sustainable than others. A recent term describing this type of interaction with and manipulation of natural processes by human cultures is traditional ecological knowledge (TEK) (Berkes, et al., 2000).

TEK varies depending on cultural beliefs of nature and is most pronounced in cultures closely intertwined with natural processes, such as those found in the Pacific Islands and other areas of the globe with indigenous peoples. Documentation of TEK is a worthwhile endeavor and critically important for maintenance of these cultural practices and identity.

This research discusses TEK methodology and describes application of these practices in Hawai'i and other indigenous cultures. Further, this research compares TEK between cultures as well as with modern day ecosystem application, and whether of TEK ecosystem and restoration management theory and techniques can be used cross-culturally.

1.1 History of TEK

Paul Feyerabend (1987), a philosopher of environmental science, defined and distinguished abstract and historical traditions of ecosystem management. Scientific ecology originates from the idea of abstract traditions while TEK originates from knowledge of rituals and cultural practices of peoples outside of the Western science realm. Interest in the study of TEK began around the 1980s, leading to recognition of the need for more research on the subject. Various terms were used to describe ecological knowledge, but the term TEK was established by the International Union for Conservation of Nature (IUCN) working group (Berkes, et al., 2000). The integration of TEK into biodiversity, rare species, sustainable resource use, ecological processes and services, and other management practices has piqued interest from all kinds of researchers for scientific, social, and economic purposes (Berkes et al., 2000). Traditional knowledge is a holistic approach to resource management that adapts to local and current conditions, learning by trial and error that is then passed on through the generations. Ecological knowledge can be obtained from traditional, cultural practices of indigenous groups through folklore, practitioners, stewards, leaders, elders, and others.

Collecting TEK is important because it helps perpetuate traditional knowledge by documenting what were once oral traditions. TEK contributes to science research by providing both ecological and biological insights and filling in knowledge gaps, mostly historical gaps, that science may or may not be able to provide (ICUN, 1986; Robertson and McGee, 2003). Locals can provide TEK when it comes to development or restoration projects. Local communities, especially those that still subsist, can better assess the environment (cost and benefits) because they depend on it for their livelihood (Calamia, 1999). Involving local perspectives and incorporating TEK into the planning process can make implementation much easier and involved locals are much less resistant to the changes (McGee and Robertson, 2003). TEK can also help in designing protected areas for conservation and education; protected areas can be designated so that local communities can continue to subsist or continue their traditional lifestyles (Calamia, 1999). Lastly, TEK can greatly contribute to contemporary ecosystem management, especially for fisheries in tropical areas. Rules developed by traditional resource managers that were enforced by social and cultural beliefs and systems were just as effective as Western science prescriptions (Calamia, 1999).

1.2 Definition of TEK

Local and traditional knowledge (LTK), traditional ecological knowledge (TEK), and indigenous knowledge (IK) are synonymous terms used in various case studies that investigate the usefulness and applicability of LTK/TEK/IK in current ecosystem management practices. LTK is a broader term that includes knowledge, that is, strictly speaking, not particularly ecological knowledge (Thornton and Scheer, 2012). For the purposes of this research, the term TEK is used.

Traditional Ecological Knowledge (TEK) is a culmination of knowledge, practice, and belief about the relationships of people with each other and the environment that is passed down through the generations (Gadgil et al, 1993; Berkes et al., 2000). TEK is a knowledge-practice-belief complex that incorporates knowledge of plants and animals, land and resource management systems, social institutions, and worldviews (Davidson-Hunt and Berkes, 2001). TEK is also a holistic approach to ecosystem management that evolves through adaptive management and it is beneficial to Western science in that it supplies more information about the natural world than science may be able to provide. There are differences between TEK and scientific knowledge, but it must be recognized that TEK offers room for improvement in ecosystem management approaches and environmental impact assessment.

1.3 Documenting TEK

Traditionally, TEK was passed down orally from generation to generation. For researchers, there are four different methods for collecting TEK, which include (Huntington, 2000): 1) semi-directive interview, 2) questionnaires, 3) analytical workshops, and 4) collaborative fieldwork. It is up to the researcher to select the “best” participants to supply the information needed, but imperative to apply ethical principles to ensure respect for community and individual rights.

The first approach, semi-directive interview, allows participants to converse with researchers (interviewers) in a way that is not forced (Huntington, 2000). There are no set questions or time limit; however, the interviewer may have a list of broad topics in order to prompt further discussion. This method is useful, especially in situations where the participant is uncomfortable with direct questions. The second approach, questionnaires, is useful when the research knows the exact information that he/she is seeking (Huntington, 2000). Questionnaires can help quantify information and simplify comparisons between participants. Open-ended questions can be used to gather more detail. In some cultures/areas, participants may feel more comfortable answering a questionnaire rather than participating in a semi-directive interview. Questionnaires may not generate thorough information like that obtained during an interview, but can be useful to gather ideas and insights. Third, the analytical workshop approach can help to interpret the information that is already known (Huntington, 2000). A workshop can bring together science professionals, governmental agencies, local/cultural agencies, and practitioners of TEK to share knowledge and generate new ideas that can be incorporated into existing ecosystem management paradigms. Lastly, the collaborative fieldwork approach is as it sounds; this is an integrative approach that allows researchers to hire locals familiar with the environment to assist in field research and data collection (Huntington, 2000). Locals that were hired for field assistance contributed far more to the research than logistical support.

1.4 Goals of TEK

Houde (2007) identified six goals of TEK (Figure 1) that are all integrated and ultimately derived from the philosophy of how the environment works: 1) document factual observations, classifications, and system dynamics; 2) integrate into ecosystem management systems and practices; 3) examine how traditional practices (past and current uses) have translated through the generations; 4) re-instill traditional ethics, values and beliefs about the environment; 5) preserve and perpetuate indigenous culture and identity; and 6) identify the principles of how the environment works and how everything is connected (cosmology). There is also a seventh goal aside from Houde's (2007) goals and that is to allow indigenous cultures and local communities to be included in the planning and management process.

Figure 1: Seven Goals of Traditional Ecological Knowledge (TEK). (Adapted Houde, 2007)

In many indigenous cultures, TEK is passed down through oral traditions, stories, and songs. The first goal of TEK is to then document those traditions along with factual observations, classifications, and system dynamics that would otherwise be held in the language (Houde, 2007). While documentation is important, it is also important to understand the interrelationships in the environment, spatial distributions, and historical trends in population patterns so that integrated monitoring and measuring approaches can be developed. Thus the second goal is to integrate TEK into ecosystem management practices (Houde, 2007). For centuries indigenous peoples have sustainably subsisted off the land by using adaptive management. Ecosystems are dynamic and complex; indigenous peoples understood how to utilize resources while adapting to changes in the environment. Integrating TEK into modern ecosystem management practices can help ensure resource conservation, multi-crop management, and even pest management (Houde, 2007).

TEK translates through time, utilizing the knowledge of the past for current uses and practices; therefore, the third goal is to examine how traditional practices have translated through the generations (Houde, 2007). Historical information like land-use patterns, population trends, and harvest levels or locations of medicinal plants and cultural sites help identify areas for preservation. These three goals are the easiest to understand and integrate into Western science and management practices. The following three goals are much more abstract and pertain to indigenous peoples' ways of thinking, which is harder to integrate into Western science and thinking.

The fourth goal of TEK is to re-instill traditional values and beliefs about the environment to younger generations (Houde, 2007). Indigenous cultures held the land in high regard, having respect towards all living and non-living things. They protected sacred spaces as a way to preserve and conserve resources and the environment. The Haida people of British Columbia oppose bear hunting because it is disrespectful towards the animal (Houde, 2007). The Buddhist community in Sikkim Himalaya, northeast India places religious significance on their lakes. The Khecheopalri Lake is known as the "land of hidden treasures"; during the Bumchu festival, the people believe that the water from the lake will purge them of their sins. These beliefs illustrate that the lake is held in high regard, leading to the continued preservation of the water and the lake (Rai, 2007).

Indigenous peoples' culture and identity is rooted in the land and the language. The fifth goal of TEK places emphasis on how culture and identity (i.e., traditions, values, stories, and language) contribute to the conservation and perpetuation of indigenous cultures (Houde, 2007). The language holds the stories and traditions of the indigenous people. Without the language and the land, the people would lose their identity and sense of self.

The last goal of TEK is cosmology. Cosmology is the study of how the universe, in this case the environment, was constructed and developed; this is the core goal of TEK (Houde, 2007). This goal of TEK explains various worldviews of how complex relationships within the environment work and how it is all connected. Researchers have achieved this goal with Inuit peoples, exploring understanding their views of the environment, its complex relationships with humans and non-humans and how these views affect social relationships and obligations of community members in ecosystem management (Houde, 2007).

Another goal of TEK, separate from Houde, is allowing indigenous peoples and locals feel part of the process (Schafer and Reis, 2007). In order to perpetuate cultures, promote conservation, and enhance management practices, TEK of indigenous peoples and locals should be integrated into the overall management plans in forestry, agriculture, and marine/aquaculture ecosystems.

1.5 Research Summary

This research addresses the application of TEK to Hawai'i and other indigenous cultures to identify TEK methods for ecosystem management. This chapter defines TEK and presents its overall goals for both indigenous cultures and ecosystem management. The history and application of TEK within three ecosystem types (forestry, agriculture, and aquaculture/marine ecosystems) in Hawai'i is discussed in Chapter 2. Chapter 3 also looks at applications of TEK in the three ecosystem types, but for other indigenous cultures in various parts of the world, including Asia, North America, South America, and Pacific Islands, other than Hawai'i. Chapter 4 compares TEK applications in Hawai'i and the other cultures presented in Chapter 3. TEK based knowledge is then compared to modern day ecosystem management and restoration applications in Chapter 5. Lastly, Chapter 6 presents research conclusions and the feasibility of integrating TEK in modern day ecosystem management and restoration practices.

Chapter 2. Application of TEK in Hawai'i

The relationship Hawaiians have with the land is best described by an ancient Hawaiian creation story retold in Handy and Handy (1991) Native Planters in Old Hawai'i. *Papa*, Mother Earth, and *Wākea*, Father Sky, together bore a daughter, *Ho□ohōkūkalani*, the stars. Together *Wākea* and *Ho□ohōkūkalani* bore a son named *Hāloa-naka.* Unfortunately, *Hāloa* was born stillborn and then buried in the ground. From his burial, the first *kalo* or taro grew. *Wākea* and *Ho□ohōkūkalani* then had a second child, whom they also named *Hāloa*, and he became the first Hawaiian man. *Hāloa* is the younger brother of taro and the ancestor of the Hawaiian people; therefore it is *Hāloa*'s duty to take care of his elder brother, the taro. From this story, generations of taro farmers have dedicated their work and lives to *malama □āina* (land) and *malama Hāloa* (taro) (Handy and Handy, 1991).

The following sections discuss other aspects of Hawaiian culture related to traditional ecological knowledge (TEK), and their application to forestry, agriculture and aquaculture/marine ecosystems.

2.1 *Ahupua'a* – Watershed Management System

The word *ahupua'a* can be split into two words, *ahu* and *pua'a*. *Ahu* means altar and *pua'a* means pig, together the word literally means pig altar (Mueller-Dombois, 2007). An altar with a wooden carving of a pig's head would be used to mark ahupua'a boundaries. Offerings were also placed at this altar to the agricultural god *Lono* in prayer for a good harvesting season. Ahupua'a was a watershed-based management system that delineated vertical slices of land from the mountain to the sea (Berkes et al., 2000). The ahupua'a *ali'i* or chief would designate ahupua'a to a *konohiki*, land manager, who was responsible for land maintenance, water regulation, organizing the communal labor, and ensuring the sustainable maintenance of resources (Handy and Handy, 1991). The konohiki was assisted by a farming specialist (*luna 'ai*), irrigation specialist (*luna wai*), and fishing specialist (*luna i'a*) (Mueller-Dombois, 2007). Figure 2 depicts what a traditional Hawaiian ahupua□a system looked like, showing forestry, agriculture, and aquaculture/marine ecosystem sections of the land divided by elevation and rainfall (Costa-Pierce, 1987).

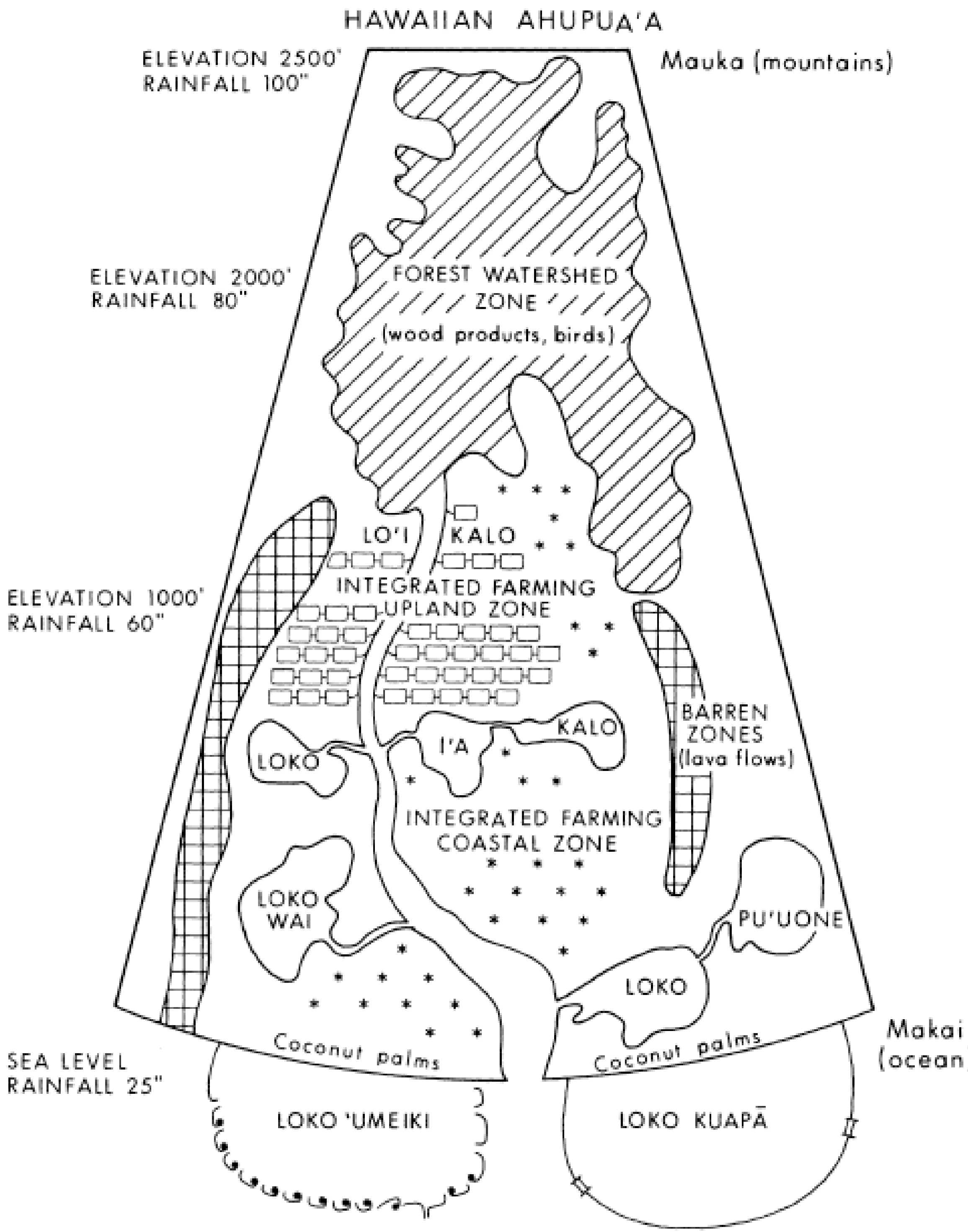

Figure 2: Layout of Traditional Hawaiian Ahupua□a System (Costa-Pierce, 1987).

The application of ahupua'a to forestry, agriculture and aquaculture/marine ecosystems is discussed in the sections below.

2.1.1 Forestry

The Hawaiian people divided the forest into two sections: *kula* or *wao kanaka* and *wao akua* (Kamakau, 1991). Kula was the forested upland area (*wao*) in which the people (*kanaka*) would dwell. Wao akua was the forest area above the Kula in which the spirits dwelled (Kamakau, 1991). The forest was a very sacred place; only certain people were allowed to enter the forest and, upon entrance, a strict protocol had to be followed. Chants describing identity, purpose of entrance, and the resources being gathered were required upon entry. The main tree and fern species that were harvested from the forests were *koa* (*Acacia koa*), *kī* (*Cordyline fruticosa*), □*ohe* (*Schizostachyum glaucifolium*), *hala* (*Pandanus tectorius*), *kamani* (*Calophyllum inophyllum*), *kukui* (*Aleurites moluccana*), and □*ōhi*□*a* (*Syzygium malaccense*) and ferns *hāpu*□*u* (*Cibotium species*), □*ama*□*u* (*Sadleria species*), and *palapalai* (*Microlepia strigosa*) (Kamakau, 1991?). These tree and fern species were all important to the Hawaiian people, whether it was for cultural, religious, or subsistence needs. Koa was used for canoe building, kī was used for food preparation, and the □ōhi□a represents the physical manifestation of one of the main Hawaiian gods, Kū, rendering it as sacred tree (Williams, 1997; The Nature Conservancy of Hawai□i, 2007). Laka is the goddess of *hula* and the palapalai fern is dedicated to her, and therefore used as garland or *lei* in hula (Ticktin et al., 2005). The forest was home to many native birds that evolved from from a single finch to 50 specis of honeycreepers (The Nature Conservancy of Hawai□i, 2007). Feathers from these birds were used to fashion capes, cloaks, helmets, and leis for Hawaiian royalty. The forest was also a sacred place because Hawaiians understood that the forest was the source of all water provided to the land and the people. TEK continues to be passed on through the generations especially through *hula hālau* or hula schools that continue the strict protocol upon entering and gathering ferns and flowers for hula lei (Ticktin et al., 2006).

Today, the majority of the forests in Hawai□i are dominated by □ōhia□a and koa, but there are 48 different types of native Hawaiian forests and woodlands (The Nature Conservancy of Hawai'i, 2007). Hawai□i's forests house more than 10,000 native species (plants and animals), of which 90 percent are endemic to Hawai’i. With a degraded landscape, introduction of invasive species, and increased urbanization, Hawaiians have lost their ability to subsist from the forests and almost 60% of the species are listed as endangered (The Nature Conservancy of Hawai’i, 2007). In order to preserve native Hawaiian forests, preserves have been created. Hawai□i has the 11th largest stated-owned forest that encompasses 700,000 acres of land and 250,000 acres of privately owned land (The Nature Conservancy of Hawai’i, 2007). Partnerships between public and private land owners have contributed to the protection and survival of native Hawaiian forests. The Hawai□i Association of Watershed Partnerships includes 11 different partnerships across the islands that are formed by various federal, state, city, and private entities. In working together, these partnerships have developed comprehensive conversation plans to protect Hawai□i’s watersheds, continue forest conservation, and promote the efficient use of resources (The Nature Conservancy of Hawai’i, 2007).

2.1.2 Agriculture

Indigenous peoples that lived on islands are perceived to have relied on fishing. For Hawaiians, the opposite is true; of all the other Polynesian cultures, Hawaiians centered their work and interests in cultivating the soil (Handy and Handy, 1991). The presence of dog, pig, and rat bones and the absence of marine mollusks in the upland parts of the ahupua□a of Puanui provided a proxy measure for inland subsistence with little connection to coastal resources (Field et al., 2011). For other Polynesian cultures like in the Marquesas and New Zealand, training boys to fight was more important than training them to subsist. In Hawai□i, the art of agriculture meant feeding the community and upholding religion, tradition, and customs (CTHAR, 2008). Farming was the main work within an ahupua□a system. Farmers or *mahi□ai* dedicated their lives as young boys to the Hawaiian god, Lono, the god of abundance, fertility, and growth (Williams, 1997). Throughout their lives, these boys would be guided by their mentors, and observe and become knowledgeable of the seasons, soil, water, and weather. They also observed the appropriate soil, sun exposure, moisture, and elevation needed to grow different varieties of plants like bananas, taro (*kalo*), sugar cane, and sweet potato.

Early Hawaiians intuitively knew that the changes in the moon also brought changes in tides, but they also observed that changes in the moon also meant changes in planting (Handy and Handy, 1991). *Mahiʻai* followed a strict moon calendar for planting. The first two moons *Hilo* and *Hoaka* were days good for planting taro and sweet potatoes; taro varieties used specifically for its leaves were planted on these days. On the third (*Kū kahi*), fourth (*Kū lua*), fifth (*Kū kolu*), and sixth nights (*Kū pau*) taro, sweet potatoes, and bananas could also be planted. Taro planted on *Kū kahi* would have one shoot, *Kū lua* two, and so forth. Plants planted on these days would also grow and stand erect (*kū*) (Handy and Handy, 1991). The seventh to tenth nights were not recommended for planting, hence the Hawaiians names for these nights all began with the word *ʻole* meaning nothing or not productive. The eleventh night, *Huna*, meant hidden so plants with extensive root systems or plants with dense foliage like gourds would be planted. The twelfth night was a good night to plant flowers. Fruits, fish, and seaweed were *kapu* on this day because it was a day dedicated to the god *Kāne*, the life giver (Handy and Handy, 1991). On the fourteenth night, offerings were made to all of the gods for a good harvest, both in agriculture and aquaculture. On the fifteenth night, planting resumed primarily for trees. The sixteenth night, Māhealani, was a good day for all work, meaning farming, harvesting, and fishing. On the seventeenth night, *Kulu*, meaning drop, meant fruits would drop. This would also be a time to offer the fruits to the gods. *Lāʻau* (tree) nights (eighteenth to twentieth) were good days for collecting medicines from trees and planting more trees like banana and breadfruit. Another set of *ʻOle* nights would occur from the twenty-first to the twenty-third days. These days were considered "lazy days for farmers" (Handy and Handy, 1991). Following *ʻOle* nights were three *Kāloa* nights; these days were productive for fishing and planting bamboo, *wauke* (paper mulberry (*Broussonetia papyrifera*)), breadfruit, and liana (vine) species. The next two nights, *Kāne* and *Lono*, were nights dedicated to both Hawaiian gods. On these days and nights, the people prayed for good health, food, and rain for prosperity. Planting and fishing did not occur on these sacred days. The last two days of the moon calendar (and month) were *Mauli* and *Muku*. *Mauli* implied rich, dark-green vegetation would prosper and *Muku* implied bananas, trees, and sugar cane would grow one *muku* long (length from tip of fingers of one hand to opposite elbow) (Handy and Handy, 1991).

The main crop in traditional Hawaiian agriculture was taro or *kalo*. Taro comes from the family Aracea; there are four basic genera: *Colocasia, Xanthosoma, Alocasia,* and *Cyrtosperma* (UH-CTAHR, 2008). Hawaiians grew 200 varieties of kalo, primarily *Colocasia*, and some were bred to adapt to different soil types across the islands (Kaneshiro et al., 2005). Each kalo was given a first name and last name; the first name indicated the Hawaiian-designated group Lehua, Mana, Piko, Lauloa, Kai, Ulaula or ‘Ele’ele and the second name described the quality that distinguished it from other types of kalo (UH-CTAHR, 2008).

2.1.3 Aquaculture/Marine Ecosystems

The ocean provided many resources, primarily protein food sources for Hawaiians found in a variety of fish and crustaceans. While the ocean provided food, most of the time labor was not expended near the ocean. Each ahupua’a had a skilled fisherman; this skilled fisherman passed on his knowledge to his sons and other boys in the community so that it would be carried on through the generations (Handy and Handy, 1991). The skilled fisherman relied on past observations of the environment, recognizing patterns in ocean currents, cloud formations, movements of stars and winds, and even signs from the birds flying overhead at different points in time. Fishermen learned the different names for each fish and the meaning behind the names. The fisherman used locations, plants, elements, and basic characteristics (e.g., color, form, size) to name fish. An example would be the triggerfish, the Hawai’i State fish, whose name is *humuhumunukunukuāpua’a* meaning “nose like a pig” because its snout is similar to a pig snout (Williams, 1997).

Conservation efforts were part of daily life; these efforts were in the form of observation and *kapu* or taboo (Handy and Handy, 1991). Fishermen understood that if they took all the fish out of a fishing area that no fish would return to replenish the area, so no fishing areas were left bare (Williams, 1997). Fishermen also only took what they needed and any excess would anger the chiefs, □*ali*□*i*, and the spirits. Fishing for certain types of fish was not allowed during certain seasons and therefore were *kapu*. Fishing for fish during its spawning season was also *kapu.* Octopus and mullet were *kapu* during spawning season because both produced their young in the open ocean, vulnerable to predators and fishermen. The ocean bonito (*aku*) and mackerel (□*ōpelu*) were both high quality, deep-sea fish that traveled in schools. Both could not be harvested at the same time. The *aku* could only be fished between January and June while the □*ōpelu* could be fished between July and December (Williams, 1997). In Hawaiian tradition, these two fishes were very sacred and even saved the life of a chief on his voyage from Tahiti during a storm by rising to the surface and calming the waters (Williams, 1997).

Loko iʻa or fishponds, both freshwater and saltwater, were built so that the chiefs would always have a supply of fish. There are five types of fishponds: *loko wai, loko iʻa kalo, loko puʻuone, loko kuapā,* and *loko ʻume iki* (Keala et al., 2007). Loko wai were inland freshwater fishponds made from a natural depression or lake that was filled by diverted streams and/or natural springs. Loko iʻa kalo was a mixture of aquaculture and agriculture; fish were raised in the irrigated taro terraces. Loko puʻuone was a brackish water fishpond that was formed off a sandbar or coastal reef. Loko kuapā was strictly a coastal fishpond built over a reef flat enclosed by a semi-circle *kuapā* or seawall made of coral and stone. *Mākāhā* or sluice gates were constructed on the kuapā to allow fish to come in and out during the tide Loko ʻume iki were more fish traps than fishponds. The fishpond structure is similar to loko kuapā, but instead of the use of sluice gates, fish lanes were constructed along the fishpond wall. Fish lanes were assigned to certain families; families would lay their nets at the mouth of the fish lane and trap fish by natural movements of the fish (Keala et al., 2007).

Fishponds regularly raised *āholehole* (Hawaiian flagtail), *ʻamaʻama* (mullet), and *awa* (milkfish), amongst others (Williams, 1997). Women and children caught smaller fishes (*ʻoʻopu*) in freshwater fishponds and even in the taro fields. Like the open ocean, fish harvests were regulated in fishponds. In the 1900s, 360 loko iʻa were identified that were over half a millennium old, but only 99 of them were active (Keala et al., 2007). The active fishponds produced as much as 679,692 pounds of fish, consisting of 485,531 pounds of mullet and 194,161 pounds of milkfish (Keala et al., 2007). By 1953, there were only 56 fishponds with potential to be reinstated, 21 of which were in good to excellent condition to be restored (Madden and Paulsen, 1977). Fishpond restoration and continued transmission of TEK in the management of fishponds has been successful for Moʻomomi on the island of Molokaʻi (Poepoe et al., 2003), Miloliʻi and Hoʻokena on the island of Hawaiʻi (Levine and Richmond, 2014), Haʻena on the island of Kauaʻi (Levine and Richmond, 2014), and soon Heʻeia Fishpond on Oʻahu (POH, 2013). The success of these fishpond restorations has been because of legislation passed in 1994 establishing Community-Based Subsistence Fishing Areas (CBSFAs) and community effort to perpetuate Hawaiian TEK (Levine and Richmond, 2014).

2.3 Ahupua□a of Puanui and Lapakahi– Leeward Kohala Field System

There were two types of agricultural systems in early Hawai□i: irrigated, wetland taro systems and rain-fed systems (Kagawa and Vitousek, 2011). The Ahupua□a of Puanui and Lapakahi were traditionally rain-fed agricultural systems. The ahupua□a of Puanui and Lapakahi is part of the greater Leeward Kohala Field System (LKFS) located on the northwestern tip of Hawai□i Island (Big Island). The ahupua□a systems in LKFS had similar management structures to those on other islands; the only difference was water availability. Rain-fed systems were constructed in areas with opitmal rain and were better suited to for □*uala* (sweet potato), dryland kalo, and *uhi* (yams) (Kagawa and Vitousek, 2011). The Hawai□i Biocomplexity Project was a collaboration among archaeologists, ecologists, demographers, and others that sought to better understand and one day reinvigorate the traditional rain-fed agricultural system in LKFS (Kagawa and Vitousek, 2011).

^{14}C dating in charcoal and coral has placed Hawaiian settlement around AD 1400-1520 (Field et al., 2011).. Early settlement showed little connection to coastal ecosystems as agriculture was the main work in ahupua□a systems (Handy and Handy, 1991). Archaegolical studies from the 1960s-1970s showed that field alignments, trails, and shelters connected the upland communities to fishing communities in Lapakahi, which verified two things: the existince of ahupua□a systems and Hawaiian’s use of adaptive management in the face of population expansion. Analysis and dating of architecture and coral indicated larger residences and a period of population expansion between 1520-1650 (Field et al., 2011). Population expansion explains the increase in number of trails for coastal connections and increase in shelters along the coast. This population increase also translates with TEK of ahupua□a systems; ahupua□a systems were also subdivided into □*ili*, small land divisions, that were farmed by individual households when there were new residents in the ahupua□a (Kamakau, 1976).

The Field et al. (2011) study showed that traditional rain-fed agriculture occurred in LKFS. Kagawa and Vitousek (2012) conducted planting experiments in the ahupua□a of Puanui to see if rain-fed agriculture could be re-established. Three exclosures were set up along the ahupuaʻa gradient, one in each of the upper, middle, and lower (coastal) elevations. *Kō* (sugarcane, *Saccharum officinarum*), dryland kalo (*Colocasia esculenta*), and ʻuala (*Ipomoea batatas*) were planted in all three exclosures. During the time of experiment from March 2009 – February 2010, precipitation ranged from 1,304 millimeters (mm) at the highest exclosure to 102 mm at the exclosure nearest the coast (Kagawa and Vitousek, 2012). The average rainfall at the highest exclosure is about 2,200 mm/yr and about 200 mm/yr at the lowest exclosure (Giambelluca et al., 1986); it was a dry year at the time of the experiment. *Kō* grew best in the higher elevation exclosure, while *ʻuala* had substantial yields in the higher and middle exclosure plots. Dryland taro failed to produce any yields at all three of the plots. There were seasonal trends in precipitation; rainfall was greatest in the winter months and lowest in the summer months.

These seasonal influences validate Rosendahl's (1994) analysis of residential construction, abandonment, and modification within the ahupuaʻa of Lapakahi. Dryland farmers had to be mobile during the dry seasons and focus their work in the fishing communities. This planting experiment sparked the attention of local communities and attracted 600 visitors in just two years, providing a great service-learning opportunity. The TEK provided by Hawaiian experts and locals in conjunction with research conducted in this area has contributed to both the local and scientific communities' understandings of traditional rain-fed agricultural systems.

2.3 Ahupuaʻa of Heʻeia – Kākoʻo ʻŌiwi and Paepae o Heʻeia

Heʻeia Fishpond is located on the island of Oʻahu and is a walled (*kuapā*) style fishpond that sits on a fringing reef. This 88 acre fishpond is about 600-800 years old with its *kuapā* stretching about 1.3 miles long to form a complete circle around the pond, which took about 2-3 years to construct (Henry, 1993). Along the fishpond wall are six *mākāhā* or sluice gates that regulate what fish come in and out of the fishpond. It is unknown who originally built the fishpond, but its construction likely required hundreds or thousands of people to pass and stack the rocks and coral to create the *kuapā*. The first recorded owner of the fishpond was High Chief Abner Paki who was the *konohiki* of the ahupuaʻa of Heʻeia (Henry, 1993). After the Great Māhele of 1848, all of the lands of Heʻeia were given to Paki. He then passed them on to his daughter, Princess Bernice Pauahi. Princess Pauahi was the great grand daughter King Kamehameha the

Great. She married Charles Reed Bishop in 1850, who helped her establish and maintain after her death, Bishop Estate. The fishpond is still owned by Bishop Estate, now known as Kamehameha Schools.

Development during the 1930s and 1960s did not heavily impact the fishpond, but the Keapuka Flood of 1965 destroyed 600 feet of the *kuapā* (Henry, 1993). This extensive damage had left the fishpond unused for almost 25 years. The introduction of invasive mangrove (*Rizophora mangle*) to the Heʻeia area in 1922 had gone unchecked and unmanaged; mangrove growth flourished after the flood. In 1988, Mark Brooks the then owner, along with many volunteers, began to restore the fishpond by removing mangrove and stacking rocks and coral to reconstruct the broken *kuapā*. In 1991, Brooks filed a Conservation District Use Temporary Variance Application (DLNR, 1991) to repair, operate, and develop the aquaculture potential of the fishpond. The fishpond is a symbol of the Hawaiian people's expertise and relationship with the land. Its preservation and operation may be a challenge in modern times with the advances in science, management, and food production, but its success would be the result of combining the best of old and new management practices.

Brooks was succesful at raising fish like *ʻamaʻama* (mullet, *Mugil cephalus*), *moi* (threadfin, *Polydactylus sexfilis*), and tilapia. He also experimented with other aquaculture ventures (Henry, 1993). Brooks parterned with the University of Hawaiʻi at Mānoa to create a class, *Mālama Loko Iʻa*, that had students working at the fishpond and learning traditional Hawaiian management practices. This class inspired a young group of Hawaiians to form Paepae O Heʻeia (POH), a non-profit organization that partners with Kamehameha Schools to manage and maintain Heʻeia Fishpond for the community (POH, 2013). The current Executive Director of POH, Hiʻilei Kawelo, continues to teach the *Mālama Loko Iʻa* class. She works with students at *Hālau Kū Māna*, a public charter school with a Hawaiian language based curriculm, to formulate senior science projects at Heʻeia Fishpond. POH offers community work days every other Saturday of the month for members of the community and people from all over the world to come and help rebuild the *kuapā.* Under her direction, the entire *kuapā* is nearly refirbished (Figure 2). The wall is now rebuilt about 3,500 feet away from the dock, which is where the *kuapā* begins (POH, 2013). POH also partners with the Hawaiʻi Institue of Marine

Biology, working to bridge the gap between science and community. Both undergraduate and graduate students participate in scientific research, investigating fishpond ecology; the students also participate in community work days and workshops hosted by Hi□ilei to understand the cultural aspect and importance of the fishpond. Since 2004, POH has removed invasive *limu* (seaweed) from the fishpond. There are three invasive *limu*: *Kappaphycus alvarezii, Gracilaria salicornia*, and *Acanthophora spicifera* (POH, 2013). As of 2012, POH has removed 50 tons of invasive limu, all of which has either been sold at the local markets for food or shared with upland partners as fertilizers for taro farming, sweet potato patches, and other types of gardening.

Figure 2. Aerial View of He’eia Fishpond (POH, 2013).

POH has been working together with another non-profit organization, Kāko□o □Ōiwi, whose mission is to restore 405 acres in the ahupua□a of He□eia, upland from He□eia Fishpond, to its original agricultural function as part of the He□eia ahupua□a system (Kāko□o □Ōiwi, 2010). Kāko□o □Ōiwi applies integrated management approaches with the help and knowledge of *kupuna* or elders and science based research institutions like the Hawaiʻi Institute of Marine Biology (HIMB) and the University of Hawaiʻi College of Tropical Agriculture and Human Resources (UH-CTAHR) among others. These institutions are helping Kākoʻo fill in knowledge gaps by conducting reasearch on hydrology, soil productivy, and topography (Kākoʻo ʻŌiwi, 2010). Like POH, Kākoʻo also provides educational opportunities to students and the community on traditional taro farming and management practices. Taro production has been successful and they have begun selling *poi* to the community. Kākoʻo Ōiwi (2010) acknowledges that the knowledge and wisdom of the *kupuna* will help provide a foundation for agricultural land management practices, while modern science research and technology will enhance their management and maintenance strategies. In traditional ahupuaʻa systems, the activites that occur upland in the taro fields affect what happens below in the fishpond. Incorporating both TEK and science will make the restoration of the ahupuaʻa of Heʻeia successful.

Chapter 3. Application of TEK in Other Cultures

This chapter discusses the application of TEK for forestry, agriculture and aquaculture/marine ecosystems in indigenous cultures and local communities from Asia, North America, South America and Pacific Islands other than Hawai'i.

3.1 Forestry

Most of the world's biodiversity can be found in forest ecosystems (Long and Zhou, 2001). In order to protect forests and the resources they provide, forest management requires cooperation and understanding among local communities, science, and goverments. A cross-cultural approach can engage all of the stakeholders in forest management, giving agencies a better understanding of indigenous people, the carriers of knowledge, and the role indigenous knowledge has in decision-making (Stevenson, 2006). Documenting and incorporating indigenous knowledge into management decisions is desirable, but allowing indigenous and local communities to mobilize their knowledge and participate in the entire planning process is the most appropriate application of TEK.

3.1.1 Asia

3.1.1.1 China

Xishuangbanna, Yunnan Province, in southwest China is considered an ecological hotspot with more than 5,000 plant species and 758 vertebrate species (Long and Zhou, 2001). A small ethnic group of about 18,000, the Jinuo, have inhabited this area for centuries. The Jinuo history, culture, laws, and management practices have been passed on orally for hundreds of years. The people believe that everything has a soul and spirit and have many taboos. Cutting down big fir tree (*Ficus* spp.), hunting wild buffalo (*Bos gaurus redei*), and horse like deer (*Muntiacus munjak vaginalis*) are taboo (Long and Zhou, 2001). The Jinuo are also polytheistic, worshiping their ancestors using totems like a Water Gourd (*Lagenaria siceraria*). About 45 years ago, the

Jinuo community organized themselves into patriarchal clan communes. A neighboring indigenous group, the Dai, politically governed the area and helped the Jinuo appoint a commune head or *Nai* to oversee the whole Jinuo commune. The eldest (and most knowledgeable) man became the clan headman or *Ashiu/Youbao*. With the help of an assistant, *Louba*, both the *Ashiu* and *Louba* carried out traditional forest management practices under the supervision of the *Nai*. They decided which areas would be cleared or cultivated and which crops to grow or harvest. The *Ashiu* and *Louba* also managed religious and cultural practices (Long and Zhou, 2001).

Traditionally there are three categories of forest in China: nature reserve, state forest, and community forest (Long and Zhou, 2001). Community forest can be further broken down into ten specific types according to its function (Table 1). The shellac, fire protection, swidden-fallow, timber, and fuel wood forests are managed by swidden (slash and burn) cultivation. The watershed, auspicious, sacred, village boundary, and burial forests are parts of the whole that add to overall ecosystem succession, regeneration, and sustainability (Long and Zhou, 2001). Traditional tea gardens were constructed around forests for various reasons including income (from selling tea), biodiversity conservation, and water source protection. Tea gardens included tea trees, shade trees, and other useful plants that had economic (edible, medicinal) and/or cultural value (e.g., fig trees). A 3-hectare (ha) tea garden could have about 283 vascular plant species (Long and Zhou, 2001).

Since the 1960s, the ecosystem and Jinuo have seen various changes from economic and land reforms (Long and Zhou, 2001). National nature reserves have been established, which has had positive and negative effects. Primarily it has taken away available land for the Jinuo to practice traditional swidden cultivation. The Jinuo must now ask for official permission in order to live in a community forest (Long and Zhou, 2001). The demand for timber and fuel wood has increased, decreasing space for the villagers and degrading the ecosystem by facilitating non-native species invasion. While governments have taken responsibility of the overall forests, at the local level the people still look to the headman forestry and agricultural management. The commune system has been effective in the past and the community continues to follow it (Long and Zhou, 2001).

Table 1: Forest Distinction and TEK Management Methods in Jinuo, China. (Long and Zhou, 2001).

No.	Name	Local Name	Location	Function	Management
1	Watershed forest	Yikuomou	Valleys near villages	Water supply	Carefully conserved
2	Auspicious forest	Yokuazele, zuomi-azele	Along travelled roads, Surrounding village	Providing pleasing walking & living conditions	Conserved by customary regulations
3	Sacred forest	Chu	Tops of ridges and hills	Religious believes	Carefully conserved
4	Shellac forest	Budu-ake	Swidden fallow	Shellac harvest	To manage lac host tree under headmen's instructions
5	Village boundary forest		Village and clan boundaries	Territory limitation	Preserved by folk rules
6	Fire protection forest		Swidden field borders	Fire protection	Managed by the owners
7	Burial forest	Hrudu	North of a village	Worship ancestors	Conserved by the eldest women
8	Timber forest	Zuokele-diaoyo	Well-regenerated swidden fallow	Timber production	Managed by both local government and village headman
9	Fuelwood forest	Mizuo-diaoyo	Swidden fallow near village	Fuelwood collection	Managed by village leader and clan headman
10	Swidden-fallow forest	Xiaogsuo	Swidden fallow	Next swidden cultivation	Managed by village heads

3.1.1.2 Northeast India

About 15,579.10 square kilometers (km^2) of the areas in Arunachal Pradesh and Sikkim, northeast India is protected forest areas with biosphere reserves, national parks, and sanctuaries to offer protection to biodiversity (Rai, 2007). Of that total forested area, 29.88% are considered “unclassified state forests”, meaning these areas have no clearly defined legal status. The local and state officials recognize that different communities in the “unclassified state forests” have a cultural attachment to the land; therefore, community control is implied for areas that are not protected because goals of preservation and conservation align with the people’s religious and cultural beliefs (Rai, 2007).

3.1.2 North America

Pikangikum First Nation is an isolated indigenous community located in boreal forests of northwestern Ontario, Canada. The community has a population of about 2,300, the majority of which are under the age of 39 (O’Flaherty et al., 2008). The Pikangikum First Nation wanted to create economic opportunities for their younger population through resource-based, tribal enterprises like commercial forestry, so in 1996 they established a land-based community economic development renewal and stewardship program called the Whitefeather Forest Initiative (O’Flaherty et al., 2008). The Whitefeather Forest Management Corporation (WFMC) directly consults with Pikangikum elders on land-use strategies and forest management strategies. The elders are the keepers of land-based knowledge (*Ahkeeweekeekaytuhmuhweeneeng*), TEK obtained by generations of experience working directly with the land (Berkes, 1999; O□Flaherty et al., 2008). The elders are also responsible for passing on the traditions to the younger generations.

The overall conservation goal for the Ontario boreal forests is to conserve and preserve the forests for woodland caribou. The Ontario Ministry of Natural Resources (OMNR) reported declines in woodland caribou populations and planned to designate areas of the Whitefeather Forest as areas for woodland caribou calving (O□Flaherty et al., 2008). These observations and management plans are in stark contrast to what the Pikangikum people want and believe. The Pikangikum people take a stewardship approach to managing the Whitefeather Forest. Their beliefs are rooted in personal responsibility to the land, ensuring that all living, non-living things, and resources are protected. They believe that the Creator has gifted the people with everything that they need to survive. Instead of setting aside pieces of the Whitefeather Forest for woodland caribou, the Pikangikum believe that the entire Whitefeather Forest should be protected (O'Flaherty et al., 2008). The Pikangikum have already included in their land-use strategies to not participate in practices that would threaten the forests, land, and caribou. The responsibilities should be placed on all other First Nations' lands to protect their forests for woodland caribou and not just the Whitefeather Forest. Designating a tract of land in the Whitefeather Forest for woodland caribou calving will not guarantee that they will actually go there; therefore all First Nations should take on the responsibility to conserve and preserve their forests so that woodland caribou populations will also be preserved (O'Flaherty et al., 2008).

The OMNR has tried their best to integrate First Nations' perspectives by implementing the community-based, land-use planning policy, which gives First Nations' an opportunity to participate in the planning and management of their forests (O'Flaherty et al., 2008). This policy lays the foundation for cross-scale planning, being that First Nations' priorities are consistent with regional goals of conservation and preservation. The differences in views pertaining to woodland caribou populations and scale of forest protection have made cross-scale planning difficult. In order to effectively integrate TEK and science based research, both entities (OMNR and First Nations) need to respect and understand each other's cultural differences in order to find a middle ground that will ultimately result in the conservation and preservation of the regional boreal forests, and in turn the woodland caribou (O'Flaherty et al., 2008).

3.1.3 South America

The Coconucos and Yanaconas of Colombia hold the forests in high regard; the forest is the home to the spirit Jucas, the provider of all natural resources needed to sustain life (Redford and Stearman, 1993). This TEK has contributed to the establishment of the Purace National Park, which the people guard themselves, upholding their beliefs and traditions (Redford and Stearman, 1993). While TEK is being passed on in Colombia, TEK has been lost among the Ka□apor and Guaja people of Maranhao, Brazil. High forests drained by the Amazon River located in present day Maranhao, Brazil is a forest that dates pre-Amazonian colonization (Balee, 1993). High forest areas are considered areas that were preserved and fallow forest, areas that were once used for agriculture, but are now covered in forests (Balee, 1993). Ecologically important trees were preserved in the high forest such as *Eschweilera coriacea, Lecythis idatimon,* and *Sagotia racemosa;* the high forests have rich biodiversity with an average of 135 species, all of which are indigenous species (Balee, 1993). The main tree species in the fallow forest is babacu palm (*Orbignya phalerata*). The people have no historical memory of having managed the forests and if a site is left fallow for a long time, the people begin to consider it a high forest rather than a true fallow forest (Balee, 1993). There is a need for research on TEK in this area of forestry management.

The indigenous peoples of Amazonia have lost their forests to the rubber and timber industries (Sears et al., 2007). Other native natural resources that have been exploited by market economies are rosewood (*Aniba rosaeodora*), barbasco (*Lonchocarpus* sp.), and *leche caspi* (*Couma macrocarpa*) and more recently mahogany (*Swietenia macrophylla*), tropical cedar (*Cedrela odorata*) and *virola* (*Virola surinamensis*) (Sears et al., 2007). Only after the collapse of the large-scale timber business in Amapa, Brazil, was TEK integrated with technologies to restore communities (Sears et al., 2007).

The Coordinadora de las Organizaciones Indigenas de la Cuenca Amazonica (COICA) is made up of 229 native Amazonian groups in Peru, Bolivia, Ecuador, Brazil, and Colombia that have come together to conserve biodiversity in the Amazon rainforest (Redford and Stearman, 1993). COICA published an agenda for Amazonian development, highlighting their concerns as indigenous peoples to the world of science. COICA (1989) reinforced that indigenous people have accumulated knowledge over the centuries of the forest and developed deep respect for all plants and animals; this knowledge is the key to maintaining the environment, in this case, the Amazon forest.

3.1.4 Pacific Islands Non-Hawai'i

Peoples of the Pacific Islands were able to establish traditional agricultural systems because of forest conservation and protection (Thaman et al., 2000). The forests provided ecological functions such as erosion control, flood/runoff control, plant and animal habitat and cultural functions like timber (both commercial and subsistence), food, and religious representations (Thaman and Clarke, 1987). The earliest evidence of forestry management began in Papua New Guinea and the Solomon Islands around 40,000 years ago, 4,000 years ago in Eastern Melanesia, Western Polynesia and Micronesian islands, and 1,000 years ago or less in some parts of Eastern Polynesia and Micronesia (Thaman et al., 2000). Early inhabitants of the Pacific Islands selectively cleared lowland forests for agriculture/agroforestry and protected upland forests. The migration of peoples throughout the Pacific allowed the transportation of various plant and tree species leading to the diversification of forests (Thaman et al., 2000). The development of multi-species agroforestry (MSA) has allowed peoples of the Pacific Islands to preserve ecologically and culturally significant plant and tree species. It has also allowed the people to subsist from the land.

In the Kiribati Atolls, the people grew multipurpose trees like *Pandanus* spp., beach gardenia (*Guettarda speciosa*), and Octopus Bush (*Tournefortia argentea*) to improve soil fertility and provide mulch for swamp taro (*Cyrtosperma chamissonis*) agriculture (Thaman et al., 2000). The *Pandanus* spp. also provided food, medicines, and the wood was used for houses, thatch, and fiber for clothing. In Tonga, many fruit trees were grown like the Malay apple (*Syzygium malaccense*), Polynesian plum (*Spondias dulcis*), and the perfume tree (*Cananga odorata*) (Thaman et al., 2000). Some of the tree species were maintained and protected because of their cultural significance like koka (*Bischofia javanica*), Pacific litchi (*Pometia pinnata*), maululu (*Glochidion ramiflorum*), and toi (*Alphitonia zizyphoides*) (Thaman et al., 2000). Foliage from these trees provided organic material for agriculture.

Many of these tree species helped in agriculture management whether it was providing shade, nutrient cycling, and/or food and materials when agricultural lands were in fallow. Unlike modern forestry systems, traditional forestry systems produced yields in the absence of external inputs (e.g., fuel, nutrients, fertilizers), provided food and resources to the people, contained rich biodiversity from a polycultural system, and also contributed to the establishment and maintenance of agricultural systems (Thaman et al., 2000). TEK in forestry management persists on some islands of the Pacific through community-based management, but has decreased or is lost on other islands that have been subject to deforestation for commercial forestry.

3.2 Agriculture

Traditional agricultural systems have sustained populations in various areas of the world and for various indigenous peoples before the introduction of Western or European technologies. TEK for agriculture covers two broad aspects, the characteristics of crops and the management of those crops (Wilken, 1987). Biotic diversity and polyculture were the key practices integrated in traditional agricultural management that made subsistence possible in indigenous and local communities (Manner, 2008). These integrated agricultural systems, also called agroecosystems are diversified and have the ability to naturally regulate pests, recycle nutrients, conserve energy, produce sustainable yields, and rely very little on external inputs (Clarke, 1977). Different types of agroecosystems are discussed below.

3.2.1 Asia

3.2.1.1 China

The Jinuo currently subsist off the land and practice traditional swidden cultivation; both forests and agriculture provides more than 65 percent of subsistence (Long and Zhou, 2001). The Jinuo used shifting traditional swidden cultivation, leaving only plants and trees that had economic or other values. Species like timber (*Schima wallichii*), fruit (*Syzygium szemaoense*), and sacred tree (*Ficus altissima*) were preserved because it facilitated cultivators and other agricultural crops.

3.2.1.2 Northeast India

Areas in northeast India are considered biodiversity hot spots, with forests (Rai, 2007) and even agricultural systems (Barooah and Pathak, 2009) containing copious amounts of genetic biodiversity. The *Thengal-Kacharis* is a small clan of the *Boro-Kachari* ethnic group in Assam, India. Their rich cultural history stems from an ancestor *Thengal* who was thought to have ascended to heaven (Barooah and Pathak, 2009). *Thengal-Kacharis* are some of the oldest inhabitants of the area, whose close relationship with the land has enabled them to adopt various conservation and sustainable practices. *Bari* farming systems is a common practice in northeast India; the *bari* is area on a homestead where various crops are grown with livestock, poultry, and fish next to the main household. This type of system, in conjunction with cultural/religious taboos, have contributed to conservation and management of biodiversity and allowed the *Thengal-Kacharis* to subsist sustainably (Barooah and Pathak, 2009).

Thengal-Kacharis women have played a key role in the continuation of traditional farming practices because they are the principal managers of the *bari* (Barooah and Pathak, 2009). After centuries of observation and experimentation, the women have developed a general *bari* structure, selecting crops that can co-adapt and provide aggregated benefits. This structure has also been designed to optimize sunlight by fitting plant phenological classes together in space and time through niche diversification. The elderly women pass down this knowledge along with growth habits, plant uses (including medicinal), pest and disease management, and seed selection and storing to the new generations of *bari* managers (Barooah and Pathak, 2009). Crops and plants are assembled in multi-tier canopies and zones with the highest crop diversity near the home. The first zone, nearest the house, is used for planting spices, medicinal plants, vegetables, and herbs for readily use. Bananas, plantains, and citrus are planted in the second zone and arecnut, jackfruit, and other fruit trees are reserved for the third zone (Barooah and Pathak, 2009).

Bamboo was found everywhere and in every *bari* system (Barooah and Pathak, 2009). Bamboo harvesting is sustainable so that the people could continue to benefit from the resources it provided, with harvesting permitted on only certain days and on every new moon. Conservation and preservation efforts for specific species were developed from *Thengal-Kacharis'* religious and cultural beliefs (Barooah and Pathak, 2009). *Dhekia* (*Diplazium esculentum*), a leafy vegetable, is taboo during the fall because that is when the plant sporulates and propagates. Women are not allowed to enter the *bari* during their menstrual cycle. Many plants are also taboo and reserved for religious rituals like the holy tree, *Sijou Goch* (*Ephorbia nerifolia*) (Barooah and Pathak, 2009).

Another method of conservation and preservation comes from the womens' extensive knowledge on how to store food and seeds. Seeds from ladyfinger, brinjal, and chilies were stored and dried in the fireplace (*dhua chang*) to prevent pathogen attack (Barooah and Pathak, 2009). Sesame, ash gourd, pumpkin, and cucumber seeds are removed, sun-dried, and stored in bamboo for the next growing season. Medicinal plants like *cowa* (*Garcinia cow*), myrobalan (*Terminalia chebula*), and *anola* (*Eblica officinalis*) are also dried and stored (Barooah and Pathak, 2009).

Areca catecu nuts are stored in pits lined with banana or palm leaves because they help preserve the nuts for consumption until the next growing season.

3.2.2 North America

The Maya people of southeastern Mexico and Central America have been subsisting off self-sustained *milpa* (to the field) agricultural systems for almost three millennia (Flores-Delgadillo et al., 2011). The Maya traditionally used the slash-and-burn methods to manage agriculture of maize, beans, and squash, among other plants for food and medicinal purposes; they also used terracing in their agricultural fields and manipulated wetlands for agricultural production (Flores-Delgadillo et al., 2011).

Maya people had settled in an area that was thought unsuitable for agriculture. Soil in the Maya Lowlands is characterized as thin with exposed limestone bedrock (Flores-Delgadillo et al., 2011). Instead of tillage, Maya used a different cultivation method that made their agricultural system effective. They used site-specific crop management by planting crops and perennial plants in soil filled cavities of limestone bedrock (Flores-Delgadillo et al., 2011). Flores-Delgadillo et al. (2011) conducted a study to evaluate the physical and chemical qualities of the soil and found that the soils had high rate of organic mineralization, neutral to moderately basic pH, and retained moisture from being in the cavities of the bedrock. The Maya today continue planting in the cracks of limestone and slash-and-burn milpa, although the slash-and-burn milpa agricultural practice is degrading the physical, chemical, and biological qualities of the soil (Flores-Delgadillo et al., 2011). More than a million farmers practice slash-and-burn milpa cultivation and the farmers recognize that the land is “fatigued”, but efforts to use alternative forms of cultivation are halted by other environmental, economic, and social factors (Flores-Delgadillo et al., 2011).

3.2.3 South America

The Bolivian Amazon, also known as Llanos de Mojos, is located in the southwestern part of the Amazonian drainage basin (Balee and Erickson, 2006). Peoples of the Bolivian Amazon heavily altered the savanna and forest landscapes to develop advanced agricultural systems, water management techniques, and organized communities’ millennia before European contact (Balee and Erickson, 2006). The area consists of 20,000 sq. km. of low, flat landscape, rivers, savanna grasslands, scrub forests, and wetlands. It is fairly dry with poor soils, making farming difficult. So the people had built raised agricultural fields, canals, reservoirs, mound settlements, and even constructed wetlands to alter drainage patterns in order to promote crop development. Similar raised agricultural fields and earthworks have been found in Colombia, Ecuador, Venzuela, Peru, and Surinam (Denevan, 2001). Raised fields were constructed above seasonally flooded savannas and wetlands, which helped improve soil conditions, nutrient cycling, and water management and drainage (Balee and Erickson, 2006). A significant amount of earth was required to construct raised fields and took about 900 days to construct; the amount of labor needed to build these raised fields meant a highly organized and cooperative community (Balee and Erickson, 2006). About 35,000 raised fields were recorded through aerial analysis and ground surveys (Balee and Erickson, 2006). Sweet potatoes, peanuts, beans, squash, and manioc were the common crops harvested on these raised fields. Stab and Arce (2000) conducted raised field experiments of squash, sweet potatoes, beans, and maize. Yields for these crops surpassed yields from slash and burn fields even with poor soil quality in the raised fields. Regular, seasonal burning helped manage and maintain the savanna.

The peoples of the Bolivian Amazon had transformed a flat landscape into an alternating landscape of raised fields and canals and causeways. These construction changes ultimately changed drainage patterns and increased biodiversity in terrestrial and aquatic interfaces (Balee and Erickson, 2006) Mounds were also constructed for forest islands (family orchards and gardens), hunting grounds, political boundaries, settlements, cultural/religious practices, and even cemeteries.

Tsimane people, a small indigenous group in Bolivia, had an isolated community up until the 1940s (Gomez-Baggethun and Reyes-Garcia, 2013). They subsisted off the land by utilizing the raised bed agricultural system and slash and burn techniques to maintain agriculture. By the 1950s, Tsimane began to integrate into Bolivian society, transforming their entire social and economic system. The people were introduced to market based economies, using crops for cash and selling forest products (Gomez-Baggethun and Reyes-Garcia, 2013). Even with modernization and the introduction of new technologies, Tsimane still heavily rely on the environment for their resources. TEK transmission is evident in the crop diversity of their agriculture; however, some of the knowledge, especially knowledge of edible and medicinal plants, is being lost and forgotten (Gomez-Baggethun and Reyes-Garcia, 2013). TEK is an adaptive management technique and while some knowledge is being lost, new traditional knowledge, like knowledge of plants used for building (bigger) homes is being discovered and passed on to younger generations (Gomez-Baggethun and Reyes-Garcia, 2013). Tsimane people were able to retain sovereignty over the land, giving them the opportunity to maintain ecological resilience by continuing their traditional practices.

3.2.4 Pacific Islands Non-Hawai'i

Manner (2008) classifies five types of traditional agricultural systems that occur(ed) on islands of the Pacific like Micronesia, Papua New Guinea, Pohnpei, Yap, Palau, and others. The first type of traditional agricultural system combines tree gardening, agroforestry, and arboriculture (the culture of trees). The earliest uses of this type of agricultural system, particularly arboriculture, was found in Papua New Guinea on the Mussau Islands, and dated back to 3,500 years ago (Manner, 2008). The people grew two to three species of breadfruit (*Pandanus*), *Inocarpus fragifer*, *Canarium* nut (*Canarium acutifolium*), and the Polyensian vi apple (*Spondias dulcis*). This mixed tree garden approach allowed the people to subsist off the land, providing materials like timber, leaves for thatch, culturally valued items, and food. Mixed tree gardens in Pohnpei were species rich with herbaceous species like *Alocasia macrrorhiza, Piper methysticum, Ananas comosus, Colocasia esculenta, and Cyrtosperma chmissonis* (Manner, 2008). Mixed tree gardens in Yap placed near the home are known as "home tree gardens" for easy access and still persist today (Manner, 2008).

The second type of agricultural system is intermittent tree or shifting cultivation. The majority of the islands practiced shifting cultivation in their home gardens. Coconut and breadfruit trees are planted in home gardens and would fruit in time to replant the garden for a new growing season (Manner, 2008). The third type of agricultural system is intensive open field agriculture and ditching in savannas. In Palau, savannas are known as keds; keds have rugged terrain, acid soils, and sparse vegetation of ferns *Nepthenthes* and *Lycopodium*. People practice burning, turning of soil, and crop rotation to reduce pest problems. Common crops include sweet potato (*Ipomoea* *batatas*), yams (*Dioscorea* spp.), and cassava (*Manihot esculenta*) (Manner, 2008). In Yap, savannas are called tayid or ted. The people of Yap also grow sweet potatoes, but on rectangular shaped mounds surrounded by ditches. Grass cover on these mounds are slashed then covered with 50 cm of more soil (Manner, 2008).

The fourth type of agricultural system is wetland cultivation systems for taro and giant swamp taro (*Colocasia esculenta* and *Cyrtosperma chamissonis*) (Manner, 2008). Similar to Hawai'i, *C. esculenta* is cultivated in irrigated terraces in Fiji (*tuatua,* taro terrace) and New Caledonia. The Rewa Delta of Fiji uses raised fields to grow *C. chamissonis,* while in Pohnpei, Yap, Palau, and Micronesia the *C. chamissonis* is grown in lowland swamps (Manner, 2008). The fifth type of agricultural system is kitchen or backyard gardening (home gardens). Home gardens are an extension of mixed tree gardens that may include trees, shrubs, and herbaceous plants or vines that grow near the home. Citrus fruits, coconuts, breadfruit, and bananas are the most common fruit trees found in home gardens. In Guam, Palau, and Yap, the betel nut (*Areca cathecu*) and betel pepper vine (*Piper betle*) are common in home gardens (Manner, 2008). *Crateva speciosa* has cultural importance in the central Caroline Islands and is therefore found in the home garden. The common thread in all of the traditional agricultural systems, except for wetland cultivation systems, is polyculture. Each system, mixed tree gardens, shifting cultivation, open field agriculture, and backyard home gardening involves the planting, harvesting, and rotation of various types of crops.

Traditional agricultural practices are self-sustaining, conservative of the environment, and allow indigenous and/or local communities to maintain their traditions and beliefs. The Bomagai-Angoian of Simbai Valley of Papua New Guinea locally control their agriculture, using simple tools, non-polluting practices, shifting cultivation, and polyculture (Clarke, 1977). Bomagai-Angoian views the environment as "garden mother" and therefore conserve its resources.

Population and market demand increases have placed pressure on traditional agriculture practices in islands of the Pacific. Losses of TEK in agricultural practices are the direct result of introduced market economies. Forest clearance in Pohnpei for the commercial cultivation of *Piper methysticum*, used to make *sakau* (psychoactive drink), has caused a 70 percent reduction in forest cover from 1975 to 2002 (Manner, 2008). The introduction of copra plantations caused the people of Micronesia to abandon traditional swamp taro cultivation (Manner, 2008). The people replaced swamp taro pits with coconut trees, also grown as cash crops (Manner, 2008). Interest in agricultural jobs has decreased as the involvement in cash economies in conjunction with education increases, causing peoples throughout the Pacific to migrate away from the islands and/or take on government and office type jobs. There is a need for long-term monitoring studies on traditional practices to assess their sustainability, factors affecting sustainability, and identify the impacts on biodiversity in the Pacific Islands. Indigenous groups and others have to be (re)educated on the importance of preserving TEK and traditional practices in environmental management in order to ensure TEK perpetuation.

3.3 Aquaculture/Marine Ecosystems

The use of TEK in marine ecosystem management is fairly new and interest in this application of TEK is expected to rise. TEK can contribute to adaptive and conservation practices by helping identify historical baselines, establishing restoration or sustainable species targets, increasing ecosystem resiliency, and improving coastal zone, spatial planning, and fisheries management (Thorton and Scheer, 2012). Applying TEK in aquaculture/marine ecosystems is very location specific, but it increases the knowledge of environmental linkages and culture and science linkages (Drew, 2005).

3.3.1 Asia

3.3.1.1 China

Rice-fish farming is an integrated aquaculture and agriculture venture that combines fish rearing and rice farming (Costa-Pierce, 1987). This type of farming has been practiced in China for more than 1700 years and has been traced back to the Eastern Han Dynasty (25-220) (Lu and Li, 2006). China's long rich agro-cultural experience with rice fish-farming has been listed and recognized by the Food and Agriculture Organization of the United Nations (FAO) as a Globally Important Ingenious Agricultural Heritage Systems (GIAHS) (Lu and Li, 2006). Rice fish-farming is primarily practiced in the mountainous areas of China in the southeast and southwest, consisting of 1.5 million hectares (Lu and Li, 2006). This system not only generates 33 percent of the world's total yield of rice, but also promotes fish biodiversity. The main fish species seen in rice fields are red carp (*Ctenopharyngodon idellus*), common carp (*Cyprinus caripio*), tilapia (*Tilapia nilotica*), black carp (*Mylopharyngodon piceus*), silver carp (*Hypophthalmichthys molitirx*), pond loach (*Mysgurnus anguillicaudatus*), Nile tilapia (*Oreochromis niloticus*), and *Barasilcorus asotus* (Cao et al., 2001). Two important fish species stand out in the rice fields: *Cyprinus carpio*, an omnivorous fish that lays eggs in easily accessible areas for collection, and the Oujiang red carp (*Ctenopharyngodon idellus*), an indigenous species that is still used in rice fish-farming in Zhejiang, China (Lu and Li, 2006). Another type of carp, the Heyuna carp, is a hybrid of the Hebao red carp from Wuyuan County, Jiangxi province and wild carp from Yuanjinang County, Yunnan province (Lu and Li, 2006).

The integrated rice-fish farming system has complex interactions between fish, rice, and microbes, each promoting the other's success. Rice provides shade for the fish, which in turn allows fish to thrive, especially during the summer season when the water temperature becomes warmer. The fish feed off microorganisms from decomposing rice plant material. Fish also loosen up the soil, increasing permeability and oxygen input to the soil (Lu and Li, 2006). Fish feces serve as a natural fertilizer to the rice crops and fish even serve as bio-control by preying on pests and weeds. Almost no fertilizer is used in integrated rice-fish farming and there are very low incidences of pests and diseases, unlike standard monoculture rice farming (Lu and Li, 2006). Huang et al. (2001) showed that because of the lack of fertilizer use in this integrated system, rice-fish farming emits 34.6 percent less CH_4 than monoculture rice farms. *Azolla filiculoides* (water fern) is added to rice-fish farming fields to increase nitrogen fixing, provide feed for fish, and in turn provide fertilizer for the rice (Huang et al., 2001).

Rice-fish farming systems are labor intensive and with the growing population demands and economy, this type of integrated farming is becoming less favorable among the younger generations. More research and education is needed to highlight the benefits of integrated rice-fish farming in order to preserve and perpetuate this agro-cultural practice.

3.3.1.2 India

The *bari* system in India also included small dug-out ponds for fish harvesting. (Pisciculture, Barooah). Fish consumption was taboo during the monsoon season because it was breeding season. Fishes were fermented to be stored for the monsoon season.

3.3.2 North America

The goliath grouper (*Epinephelus itajara*) is the largest grouper in the western Atlantic and is recognized by the IUCN as critically endangered because of it is vulnerability for fishing (Aguilar-Perera et al., 2009). The *E. itajara* has slow growth rates, late sexual maturity, is late to spawn, and resides in common fishing areas. Fishing for *E.itajara* has been prohibited in the Caribbean since 1993, but still remains severely exploited in the Gulf of Mexico and the Atlantic (Aguilar-Perera et al., 2009). Fisheries off southeastern Mexico have placed regulation and concern on just the red grouper, *Epinephelus morio*, rather than *E. itajara*. Lack of information on the biological and reproductive characteristics of *E. itajara* in the Yucatan Peninsula area has made it difficult to establish current population sizes and conservation management strategies.

With limited data, TEK from local fishermen in two traditional fishing ports, Dzilam de Bravo and Puerto Progreso, were collected to help fill in gaps of research and develop conservation and management strategies for *E. itajara*. Fishermen were asked to provide as much information as they could on historic populations of *E. itajara*, possible spawning areas, habitat preferences, and even most common fishing gear (Aguilar-Perera et al., 2009). The old-time fishermen (coming from generations of fisherman) have noticed population declines in *E.itajara*. Just 35 years ago, areas where *E. itajara* were common, they are no longer found. The new generations of fishermen noted that *E. itajara* are in fact rare catches on fishing trips. The old-time fishermen believe that *E. itajara* declines began around 1973 when commercial fisheries and lobster (*Panulirus argus*) fisheries were established; *E. itajara* were lobster fisheries catches, about 100 individuals per month during lobster season (Aguilar-Perera et al., 2009). Lobsters like to dwell in the shallow rocky bottoms off Dzilam de Bravo. Remains of lobster were found in the bellies of *E. itajara*, reaffirming their susceptibility for by-catch. The fisherman also noticed an increase in gonads between the months of July and September, indicating a reproductive period and presence of mature *E.itajara*. This increase in gonads correlates to peak catches in other areas like the Florida Keys between the months of July and August (Aguilar-Perera et al., 2009). More research is needed to evaluate the status of *E. itajara* and TEK from local fisherman.

3.3.3 South America

3.3.3.1 Bolivia

In the process of creating the raised bed agricultural system, causeways, and settlement mounds in Bolivia, the indigenous peoples also created complex landscape zigzag structures as fish weirs (Erickson, 2000). In the savanna of Baures, Bolivia, zigzag structures were constructed from raised earth that were assembled in linear segments 1- 2 meters (m) wide, 20 – 50 centimeters (cm) tall, and changed direction every 10 – 30 m (Erickson, 2000). As fish would migrate to spawn in the savanna during the wet season, and would get trapped in natural water bodies formed by the zigzag structure as the water receded. The people would then go to these pools and collection fish for consumption. Unlike contemporary fish weirs, these traditional fish weirs are permanent earthworks built in rivers, streams, or permanent bodies of water and do not have to be rebuilt each season. This fish weir system also contributed to water management by acting as reservoirs, storing the first rains and floodwaters (Erickson, 2000). These natural fisheries produce about 100,000 to 400,000 fish per hectare of river channel (Erickson, 2000). Artifical ponds were also constructed to store water year round and support fish such as buchere (*Hoplosternum* sp.), yallu, cunare (*Cichla monoculos*), palometa (*Serrasalmus* sp.), sabalo (*Prochilodus nigricans*), and Benton (*Erythrina* sp.) (Erickson, 2000). Edible snails, *Pomacea gigas*, also thrive in the weir system. Hunters today still stalk these pools while hunting for game.

3.3.3.2 Brazil

The Patos-Mirim Lagoon system is comprised of both the Patos Lagoon off the southern coast of Brazil and the Mirim Lagoon off the southern coast of Brazil and northern part of Uruguay. It is the largest lagoon system in South America with a surface area of 10,360 km^2 (Schafer and Reis, 2008). The Patos Lagoon only makes up 10 percent of the entire lagoon system, but provides more than 90% of the total artisanal fishery catch in the Rio Grande do Sul State. During the 1960s-1970s, total catches in these artisanal fisheries surpassed commercial fisheries and significantly added to the total percentage of catches. By the 1980s these artisanal fisheries were in a crisis from overexploitation; only two of the six target species remain: pink shrimp (*Farfantepenaeus paulensis*) and mullet (*Mugil platanus*) (Schafer and Reis, 2008). To gain a better understanding of the fisheries crisis and recommend potential management strategies, Schafer and Reis (2008) approached local fishermen to document their TEK.

The nautical chart for this area indicated 25 traditional fishing areas. After speaking to the local fisherman and traveling with each to his/her preferred fishing spot, the locals were able to name 124 fishing areas that were not designated and registered (Schafer and Reis, 20088). About 80 percent of the fishing areas were only known amongst the fishermen. Fishermen used four criteria to qualify an area as a "fishing area": The area had to have various depths: *coas* (1mm, *sacos* (5m), and *canais* or *canaletes* (5+m). There had to be wooden logs at the bottom of the lagoon so that fixed nets could be anchored to them. There had to be gradients of water transparency and lastly, the area was frequented or traditionally used (Schafer and Reis, 2008). The fishermen also provided the names of the fishing areas, which had either cultural significances or were created from observations. The Lamerao da Figueira fishing area was named after a fig tree that settled in the sandbank after a rainstorm (Schafer and Reis, 2008).

All of the fishermen were descendants of fishing families, with traditions and fishing practices passed down from father to son through the generations (Schafer and Reis, 2008). The fisherman had detailed their relationships with the natural environment, taking cues from the environment to gain their bearings, and identifying almost five times the amount of currently known and listed fishing areas. These newly identified areas will help in the analysis of fish distributions and fishermen migration patterns (Schafer and Reis, 2008). It will also help identify zones that require fishing restrictions for resource conservation. The TEK that the fishermen provided is now documented and will be preserved. The fishermen now feel that their knowledge is valued and feel comfortable in participating in management decisions concerning their local fishing areas (Schafer and Reis, 2008).

3.3.4 Pacific Islands Non-Hawai'i

3.3.4.1 Samoa

Like Hawaiʻi's Community-Based Subsistence Fishing Area (CBSFA) Act, American Samoa has taken similar steps to restore traditional fishing practices in local villages through the Community-Based Fisheries Management Program (CFMP) developed by the American Samoa Department of Marine and Wildlife Resources (DMWR) (Levine and Richmond, 2014). DMWR evaluates villages to determine if they can participate in the CFMP. Unlike Hawaiʻi, American Samoa continues to function by traditional Samoan values and tenure systems of organization, where fisheries management is organized at the village and family level (King and Faasili, 1999). For the most part, American Samoa's tenure functions today as it did long before European and Western contact, with the only Western influence being Christianity (King and Faasili, 1999).

DMWR evaluates village interest and suitability for the program by examining village organization, marine environment, problems of the local fishery, and willingness of the village to address existing problems (Levine and Richmond, 2014). Village cooperation and involvement has contributed to the continuation of TEK in community-based management. The CFMP is a collaborative effort between villages and the American Samoa government in developing fisheries management plans to conserve marine environments through the continued use of TEK practices. The government provides training, monitoring, and aids for implementation of CFMP to villagers, while villagers are responsible for enforcement and protection of the marine environment (Levine and Richmond, 2014). Village fisheries management and advisory committees with advisory from the DMWR have also established village marine protected areas (VMPA) in an effort to regulate and conserve fish populations. Table 2 provides a list of the rules and regulations of VMPAs established by individual villages.

Table 2: Village Marine Protected Areas (VMPAs) (Levine and Richmond, 2014).

Village	CFMP process initiated	Management status
Alofau	2001	Open 1 day/week (Saturday) to villagers only.
Amaua and Auto	2003	No-take for 3 years, open again for 1 month, closed again. Currently open to villagers only to fish.
Aoa	2005	No-take as of early 2008. Previously only open 1 day/week (Saturday).
Fagamalo	2003	No-take area designated in village, permanent no-take area designated adjacent to village waters.
Masausi	2002	No-take until early 2008, now open to villagers only.
Matu'u and Faganeanea	2005	Closed for 3 years, now open periodically (at chief's discretion) to villagers only.
Amanave	2008	Closed to everyone. In the process of finishing management plan. Village largely destroyed by 2009 tsunami.
Maloata	2009	Currently closed. In the process of finishing management plan.
Poloa	2001	Only villagers allowed to fish.
Sa'ilele	2005	No-take in village waters.
Tau	2011	Officially a CFMP village in 2012. A portion of their reef was designated as a no-take area for 3 years, but this is no longer in place. Is under reconsideration.
Vatia	2001	No-take. Reserve was opened for a period of 3 months, then closed again. Now open to villagers only.

The direct management and involvement of villages in the CFMP process contributes to the compliance, enforcement, and success of the fisheries management plans. Villages apply penalties for local violators through traditional fines like taking away pigs or canned goods. Social pressures also contribute to village compliance. In 2005, DMWR incorporated village rules and regulations into the department statute so that penalties could be legally applied (Levine and Richmond, 2014). In 2008, the DMWR director was granted the authority to deputize villages for CFMP violations and village policemen were allowed to issue citations (Levine and Richmond, 2014). Nonvillagers must also follow the rules and regulations of CFMPs from each village and are subject to fines and citations as well (Levine and Richmond, 2014). Perpetuating and integrating TEK in fisheries management in American Samoa has been successful due to the collaborative efforts of government entities and local communities.

3.3.4.2 Solomon Islands

The Solomon Islands became an independent nation in 1978. While it is not recognized in the law, administration has shown its support for the continuation of TEK in fisheries management in Marovo Lagoon (Hviding and Baines, 1994). Marovo Lagoon is about 700 sq. km. and is broken into land sections called *puava* (Hviding and Baines, 1994). The puava system is very similar to the Hawaiian watershed management system in that tracts of land are divided into puava (Hawai'i- ahupuaʻa) and a kin group or *butubutu* manages each puava (Hviding and

Baines, 1994). The puava concept is also similar to ahupua□a systems in that land and inshore areas are interdependent.

Customary Marine Tenure (CMT) is another name for the type of fisheries management used within the puava system in Marovo. Customary refers to a system derived from traditional practices that maintains cultural and ecological linkages from the past, as it adapts to changes in the environment and policy. Each butubutu is in control of the defined area of land and butubutu's within a puava that includes reef and lagoon is in control of seabeds, coral reefs, seagrass beds, and estuaries (Hviding and Baines, 1994). Young, educated males (*bangara*) have been appointed to lead the butubutu under the guidance and counsel of the elders. These leaders may impose fishing prohibitions to preserve fish stocks and grant permission for those not from the butubutu to fish in their area of the lagoon. The Marovo people practice TEK in their fisheries management by rotating fishing grounds and stocks to limit overfishing and reduce habitat destruction. The Marovo people's traditional fisheries knowledge has also provided classifications of 400 types of fish, 60 different methods for naming fish, and 40 terms for distinct types of reef (Hviding and Baines, 1994). Butubutu also receive royalties from commercial fishers who are charged per night, per vessel. These royalites are then distributed within the butubutu.

Even with the support of the Solomon Islands administration, the Marovo people are up against the pressures of commercial fisheries and ocean (i.e., reef and fish stocks) degradation. There is also conflict within butubutu on the distribution of royalties. The CMT system in Marovo allows the people to be involved in management decisions by controlling stock rotation, stock monitoring, reef closures, and passing on TEK in the process. Integrating this type of system with research and financial guidance may allow the people to continue to subsist off the land.

3.4 Summary of TEK in Hawai'i and Other Cultures

Various types of TEK were and are still being practiced in various indigenous and local communities around the world. The differences and similarities in TEK compared to TEK practiced in Hawai'i are discussed below and summarized in Table 3.

Table 3: Summary of TEK practices in Hawai'i and Four Other Regions by Ecosystem Type.

Ecosystem Type	Types of TEK				
	Hawai􏰀i	***Asia***	***N. America***	***S. America***	***Pacific Islands (Non-Hawai􏰀i)***
Forest	Cultural Preservation	Swidden; Cultural Preservation	Integrated management with wildlife	Polyculture; Culture Preservation	Polyculture, Agforestry
Agriculture	Wet-cultivation (taro), Open field	Swidden; Bari (homegarden)	Swidden (milpa); Site-specific crop management	Raised-bed farming	Agroforestry, shifting cultivation, open field & ditching, wetland cultivation, home garden
Aquaculture/ Marine Ecosystem	Fishponds	Rice-fish farming; Ponding	Fisheries	Zig-zag structures	Fisheries

3.4.1 Forestry

Indigenous and/or local communities in both Asia and South America have similar forestry management practices as in Hawai'i. In China, India, and Colombia, indigenous groups managed their forests through cultural preservation. The forests held cultural significance and were therefore maintained and preserved according to traditional and cultural beliefs. Kiribati (Pacific Islands) practice polyculture, managing various tree species. The Ka􏰀apor and Guaja people of Maranhao, Brazil used to practice polyculture, but TEK is being lost and the younger generations are unsure of their cultures origins, let alone their cultures' practices. In North America, the Pikangikum people from near Ontario, Canada have managed their forest ecosystems in conjunction with caribou management.

3.4.2 Agriculture

The Jinuo peoples of China and Mayan people of Mexico and Central America both practice swidden or slash and burn agricultural management practices. The Thengal-Kacharis people of Northeast India practice home gardening like on the islands of Guam, Palau, and Yap. With poor soil quality in South America, the people had reconstructed the landscape and built raised agricultural fields. The island of Palau had similar agricultural practices to Hawai'i, such as open field agriculture on Kohala, Hawai'i. Fiji and New Caledonia also had similar agricultural practices to Hawai'i with respect to wet taro cultivation.

3.4.3 Aquaculture/Marine Ecosystems

Aquaculture/marine ecosystem management practices were similar across the majority of the indigenous and local communities. In China, fish farming was integrated into rice farming, similar to Hawai□i's taro farming and fish farming system. People in Northeast India dug out ponds in their bari to farm fish, similar to the inland type of fishpond in Hawai□i. In South America, the people also constructed waterways and canals when they constructed raised fields. These constructed waterways formed a zig-zag structure that would trap fish when there was seasonally flooding. This form of fish farming was also similar to Hawaiian practices. Samoa and the Solomon Islands may seem to have similar aquaculture/marine ecosystem management practices given that these are islands in the Pacific, however, peoples on these islands did not use an integrated watershed management approach. Peoples in Samoa and the Solomon Islands are organized by villages; each village has its own fishery and has the ability to self-manage its fishery. If a person from one village would like to fish in another village, this person would have to ask permission from the chief of the other village.

Chapter 4. Comparison of TEK to Modern Day Ecosystem Management

There are four main differences between TEK management practices and modern day ecosystem management practices.

The first difference is that TEK is an adaptive approach that bases management practices on trial and error. Modern day ecosystem management practices are based on experiments that oversimplify complex ecological systems by trying to control different variables (Gadgil et al., 1993). Basing management practices on a “controlled” ecosystem will only lead to resource exhaustion and environmental degradation in naturally changing ecosystems (Gadgil et al., 1993). The term “tradition” used in TEK to some denotes that traditional knowledge is outdated and leaves no room for change (Houde, 2007). But TEK is adaptive and is the result of generations of trial and error; taking note of practices that did not work and perpetuating practices that did work.

The second difference is that TEK contains history of ecosystem functions and patterns that only people who have lived on the land for centuries would know and understand. Modern ecosystem management recommendations are usually based on a current snapshot of the ecosystem, not taking into account land use history, ecological patterns and functions, and changes or trends over periods of time. In Kanyapella Basin, Australia, very little history and scientific data was recorded regarding hydrological and ecological changes (Robertson and Mcgee, 2003). Through interviews, researchers were able to validate local TEK observations with existing research and were able to record TEK that has not yet been recorded or found in studies. Over the years, the locals had noticed changes in hydrology, water quality, and loss of local vegetation and fauna. The locals noted that large floods inundated the Basin every 15-20 years, which was validated in the Lower Goulburn River Floodplain Management Study (Robertson and Mcgee, 2003). The hydrology had noticeably changed as the locals pointed out large-scale death of River Red Gum (*Eucalyptus camaldulensis*) because of regular inundation (Robertson and Mcgee, 2003). A local resident observed 90 different species while only 38 species were identified in published literature. Local knowledge filled in the knowledge gaps and supplemented the scientific literature.

The third difference is that TEK used in ecosystem management was for the purposes of subsistence, while the majority of modern ecosystem management practices are for commercial purposes. Management practices based on TEK in Hawai□i, Asia, North America, South America, and Pacific Islands Non-Hawai□i were all used for subsistence purposes. With the introduction to market based economies, some indigenous groups and local communities have turned to modern day ecosystem management practices in order to maintain commercial crops like commercial forestry in the Pikangikum First Nation, Panama, and Hawai□i. Continued deforestation for commercial timber or monoculture in agricultural businesses is causing ecosystem degradation, habitat loss, decreased biodiversity, and a lowering of the intrinsic or cultural value of the environment.

The fourth difference is that both TEK and modern ecosystem management practices are based on different beliefs. TEK, especially in indigenous cultures, is derived from beliefs that man is part of the environment and neither can thrive without the other. Modern science and ecosystem management practices view humans as separate and/or above the natural world (Gadgil et al., 2003). Not all indigenous cultures and/or local communities adopted TEK for sustainable resource management, like hunter and gatherer communities (Gadgil et al., 2003). Communities that used TEK for sedentary fishing, horticulture, and/or subsistence agriculture had maintained their beliefs about the environment and ultimately managed their ecosystems sustainably.

Some indigenous cultures and local communities continue to practice TEK in resource rotation, succession management, multiple species management (i.e., polyculture), and maintaining ecosystem structure and function (Table 4). TEK from these practices are not used in modern day ecosystem management and restoration practices (Berkes et al., 2000). TEK has also contributed to complex ecosystem management practices like watershed-based management and landscape patchiness management. TEK is an adaptive approach that allows managers to respond to changes in the environment, ecological processes at multiple scales, and nurture sources of ecosystem renewal (Berkes et al., 2000).

There are some TEK practices that are still being used by indigenous and local communities and incorporated into modern day ecosystem management practices. These practices include monitoring resource abundance and changes in ecosystems, temporal restrictions on harvest, and protection of certain species, vulnerable life stages, and specific habitats (Table 4) (Berkes et al., 2000).

Table 4: Current Management Practices based on TEK (Berkes et al., 2000).

Management practices based on ecological knowledge

- Practices found both in conventional resource management and in some local and traditional societies
  - Monitoring resource abundance and change in ecosystems
  - Total protection of certain species
  - Protection of vulnerable life history stages
  - Protection of specific habitats
  - Temporal restrictions of harvest
- Practices largely abandoned by conventional resource management but still found in some local and traditional societies
  - Multiple species management; maintaining ecosystem structure and function
  - Resource rotation
  - Succession management
- Practices related to the dynamics of complex systems, seldom found in conventional resource management but found in some traditional societies
  - Management of landscape patchiness
  - Watershed-based management
  - Managing ecological processes at multiple scales
  - Responding to and managing pulses and surprises
  - Nurturing sources of ecosystem renewal

Social mechanisms behind management practices

- Generation, accumulation, and transmission of local ecological knowledge
  - Reinterpreting signals for learning
  - Revival of local knowledge
  - Folklore and knowledge carriers
  - Integration of knowledge
  - Intergenerational transmission of knowledge
  - Geographical diffusion of knowledge
- Structure and dynamics of institutions
  - Roles of stewards/wise people
  - Cross-scale institutions
  - Community assessments
  - Taboos and regulations
  - Social and religious sanctions
- Mechanisms for cultural internalization
  - Rituals, ceremonies, and other traditions
  - Cultural frameworks for resource management
- World view and cultural values
  - A world view that provides appropriate environmental ethics
  - Cultural values of respect, sharing, reciprocity, humility, and other

Chapter 5.0 Conclusions and Recommendations for Integration

5.1 Conclusions

TEK is not easily understood by scientists, researchers, and government officials, which leaves room for misinterpretations, misunderstandings, and an unwillingness to change. TEK is not broadly accepted and used because of two primary factors, inertia and inflexibility (Huntington, 2000). TEK is met with inertia, a resistance to change and familiarity, because it is easier to work within an established framework rather than adapting to changes and new ideologies. TEK is also met with inflexibility, which can be a result of a resistance to integration, questioning TEK's reliability, concern of authority over management, and an unwillingness to work with the community (non-scientists and indigenous groups alike). Researchers may be unfamiliar with the social science aspect of engaging with TEK holders and TEK holders may be reluctant to share their knowledge and values with those outside of the community. Indigenous groups and local communities may also be unsure of their TEK, possibly misinterpreting the information and making researchers skeptical of the information credibility (Table 5) (Martin et al., 2010). TEK, like other areas of expertise and discipline, are sometimes wrong. Research should be conducted in a way that considers the usefulness of TEK and its integration in environmental management and restoration practices, while being reaffirmed by documented scientific research.

Table 5: Components, Challenges, and Opportunities of the Six Goals of TEK (Houde, 2007).

Face	Key components	Challenges	Opportunities
Factual observations	Empirical observations Classifications Naming of places Descriptions of ecosystem components Understanding of interconnections Spatial and population patterns Ecosystems dynamics and changes	TEK open to misinterpretation Equitable sharing of TEK monetary benefits	Enhancement of scientific knowledge Added information for monitoring of environmental changes Criteria and indicators for environmental impact assessments and management of species at risk Preparedness for social or ecological surprises
Management systems	Practices adapted to context Methods for conservation Methods for sustainable resource use Methods for adapting to change Appropriate and effective technologies	Diversification of management regimes and methods Transfer of responsibilities by central administrations to develop context-specific management models	Decentralized, appropriate management regimes Novel sustainable approaches
Past and current uses	Land-use patterns Occupancy Harvest levels History of the cultural group Location of cultural and historical sites Location of medicinal plants	Misinterpretation of oral history Misinterpretation of occupancy patterns Equitable sharing of TEK monetary benefits	Reappropriation of aboriginal geographies Increased aboriginal negotiation power Identification of medicinal plants
Ethics and values	Correct attitudes to adopt	Values often incompatible with dominant discourse Values not explicit in current management processes Abstract dimension for nonaboriginals	Inspiration for new environmental ethics Socially acceptable resource management systems
Vector for cultural survival	Links life on the land, language, identity, and cultural survival	Acceptance of aboriginal societies as vibrant and multifaceted Conciliation of multiple meanings	Rich cultural diversity Restorative benefits of appropriate cultural landscapes
Cosmology	Assumptions about how things work Beliefs Spiritual relationship to the environment	Mistrust of alternative narratives Structural and methodological problems for TEK holders in working with government bureaucrats	Reevaluation of long-lasting assumptions Preparedness for social and ecological surprises

Indigenous/locals goals and values may not necessarily align with conservation and preservation. The Loma Alta watershed in Ecuador includes a self-sustaining *garua* (moist) forest that has rich biodiversity and provides many ecosystem good and services to the surrounding villages (Becker and Ghimire, 2003). Two villages maintained their garua forests for two specific and different reasons. People from the Rio Blanco village valued the forest only for supplying Panama hat fiber (*Carludovica palmate*), an important export crop and commercial timber. While the people from the El Suspiro village recognized the importance of the *garua* forests and the ecosystem services, water supply and filtration, it provided (Becker and Ghimire, 2003). While the forest provided habitat for various plant and animal species, women of Rio Blanco felt safer when trees were cut down in the garua forest, because when they would wash clothes in the rivers, it was easier to be attacked by jaguars (Becker and Ghimire, 2003).

There may also be generational differences that cause losses in TEK or a change in attitudes and beliefs in TEK. The Itza Maya people of San Jose, Guatemala are known as the last Mayan group to be conquered by the Spaniards. They currently reside in the buffer zone of the Maya Biosphere Reserve with a population 3,720 (Cristancho and Vining, 2009). In an effort to conserve traditional practices in community based management, the Guatemalan government granted the people control of the Bio-Itza, 1000 hectares (ha) of protected forest area. The older generations continue to subsist off the land and practice traditional forestry management practices, but struggle to instill the same TEK in younger generations because of the changing economy and increased urbanization.

TEK may also be difficult to integrate into modern day ecosystem management and restoration practices because of the lack of enforcement and institutional framework. In Hawai□i, formal community structures are not clearly defined and there is no clear leader to represent the community (Levine and Richmond, 2014). The Miloli□i community on Hawai□i Island wanted to be designated as a Community-Based Subsistence Fishing Area, but the perceived leader of the community did not have the community's full support. The Department of Land and Natural Resources therefore was not able to collaborate on establishing a community institution for aquaculture management (Levine and Richmond, 2014). The designation process and setting up a community to co-manage resources is a difficult and time-consuming process that can take years to put in effect. Government agencies such as Hawai□i□s Division of Conservation and Resources Enforcement (DOCARE), responsible for enforcing the rules and regulations in ecosystem-based management systems for marine ecosystems, do little to enforce (Tissot et al., 2009). DOCARE does not issue citations to violators so the policing is left to the community. In the absence of a community structure, rules and regulations in the end are not enforced.

Lastly TEK may be difficult to integrate into modern ecosystem management and restoration practices because of differing beliefs. Indigenous groups and some local communities are interconnected with their ecosystems and ecosystem processes. These communities developed the best TEK and sustainable practices for survival, by taking only what was needed. TEK was also a knowledge practice and belief system, where indigenous and local communities embedded religious beliefs and folklore (i.e., cultural preservation) into management (Martin et al., 2010). Modern day ecosystem management and restoration practices however, see humans as separate from nature and do not have the same religious ties to the environment. These conflicting views about the environment make it difficult for both sides to understand and collaborate with each other.

5.2 Recommendations for Integration

The goals of TEK discussed earlier in this paper were documenting factual observations; integrating TEK into ecosystem management systems and practices; examining how traditional practices (past and current uses) have translated through the generations; re-instilling traditional ethics, values and beliefs about the environment; preserving and perpetuating indigenous culture and identity; identifying the cosmology or principles of how the environment works and how everything is connected; and allowing indigenous cultures and local communities to feel part of the process. Each goal has its own implications or challenges (Table 5) like misinterpretations, differing views, and resistance to change. In order to achieve these goals with the successful integration of TEK into modern day ecosystem management and restoration practices, more research is needed, continued education for both the scientific and indigenous/local communities, and collaboration between science, community, and government agencies.

TEK has only been recognized in the scientific field since the 1980s (Berkes et al., 2000). There is much more to be learned in this field and the only way to acquire and document TEK is through more research. The first recommendation is to conduct more research, particularly about TEK uses in ecosystem management and how those techniques could be reflected in new management plans. Research will give the opportunity for knowledge exchange between TEK holders and researchers. TEK holders can learn about the science behind ecosystems and ecosystem services, while researchers can learn the land use histories and culture surrounding ecosystem management.

The second recommendation is producing programs or strengthening existing programs that push for the teaching, practicing, and continuation of TEK. With differing environmental goals, beliefs, and even generational differences, integrating TEK into modern ecosystem management and restoration practices can be difficult. Education is key to overcoming these differences and can help bridge gaps between indigenous/local communities, researchers, government agencies, and even between generations. In Hawai□i schools like Hālau Kū Mana, a Hawaiian Emersion Charter School, immerse students in subjects strictly taught in Hawaiian. Every student in the senior class chooses an area of study (*mauka* – mountain or *makai* – ocean) for his/her senior project. Students that choose makai, work with Hi□ilei Kawelo at Paepae o He□eia on a science project that incorporates Hawaiian language, culture, and science in the fishpond (POH, 2013). The Alaska Native tribes' possess TEK about subsistence practices especially in salmon and herring fishing (Thorton, 2007). The Sealaska Heritage Institute in Juneau runs Native Tlingit and Haida language and cultural institutes year round (Throton, 2007).

The last recommendation is collaboration and cooperation between TEK holders, researchers, and government agencies. Once knowledge gaps are filled between these groups, then everyone can be included in ecosystem planning, management, and project implementation. Collaboration can lead to governments allowing local communities to self-govern or self-manage. Villages in American Samoa, in conjunction with the American Samoa Department of Marine and Wildlife Resources (DMWR) implemented a Community-Based Fisheries Management Program (CFMP) (Levine and Richmond, 2014). The CFMP allows each village to control the use of land and marine resources; the DMWR will work with the people to determine the villages' level of interest in participating in CFMP and the villages' organization (Levine and Richmond, 2014). Once the village is deemed capable of managing its own resources, CFMP representatives will work with the village to establish a fisheries management plan. In the plan villages agree to be responsible for enforcement, monitoring, and reviewing activities, while the DMWR will provide technical assistance and advice by hosting workshops and trainings to villagers on how to monitor marine resources (Levine and Richmond, 2014). The success of CFMPs in American Samoa is attributed to the collaboration and cooperation between the community and government.

Research, education, and collaboration can help achieve the goals of TEK. Research will help document TEK, identify past and current uses of TEK that have translated through the generations, and determine how TEK can be integrated into current ecosystem management and restoration practices. Education can help re-instill traditional ethics, value, and beliefs about the environment and help perpetuate indigenous culture and identity. And collaboration will encourage knowledge exchange between communities, researchers, and government agencies, which will in turn allow indigenous cultures and local communities to feel part of the process.

5.3 Summary

TEK can be integrated into modern ecosystem management and restoration practices as was demonstrated in the Ahupua□a of He□eia on O□ahu, Hawai□i, rice-fish farming in China, caribou and forestry management in Pikangikum, Ontario, Canada, and the Community-Based Fisheries Management Programs in American Samoa. TEK may be lost to changing beliefs, economies, and technologies;what is happening in South America. TEK is site specific and may not necessarily be integrated into ecosystems that have been urbanized, highly altered, and/or used for commercial practices. Therefore it is imperative to conduct more research so that TEK is not lost through the generations. Researchers and communities should be proactive in knowledge exchange so that both sides understand each other's beliefs and practices. Once TEK is documented, the next step is to educate; education is the key to perpetuating TEK and promoting collaboration. Educational programs that incorporate TEK into the curriculum should be established and endorsed. Collaboration will follow suit from research and education. Once the communities, researchers, and government understand each other, then together they can establish a collective goal of ecosystem management and restoration. TEK is not meant to be compared to Western science, but rather supplement it with rich history and culture. Ultimately TEK brings researchers and government agencies back to theirs roots, reminding the Western world how ecosystems were managed in the absence of technology, and sets the basis for future research and ecosystem management plans.

Literature Cited

Aguilar-Perera, A., C. Gonzalez-Salas, A. Tuz-Sulub, H.Villegas-Hernandez. 2009. Fishery of the Goliath grouper, *Epinephelus itajara* (Teleostei: Epinephelidae) based on local ecological knowledge and fisher records in Yucatan, Mexico. International Journal of Tropical Biology and Conservation **57(3)**:557-566.

Balee, W. 1993. Indigenous transformation of Amazonian Forests: An example form Maranhao, Brazil. L□Homme, 22e Annee **126(128)**: 231-254.

Balee, W. and C.L. Erickson. 2006. The domesticated landscapes of the Bolivian Amazon. Pages 234-278 *in* W. Balee and C.L. Erickson, editors. Time and complexity in historical ecology. Columbia University Press, New York, New York, USA.

Barooah, M. and A. Pathak. 2009. Indigenous knowledge and practices of *Thengal Kachari* women in sustainable management of *bari* system of farming. Indian Journal of Traditional Knowledge **8(1):**35-40.

Becker, C.D. and K. Ghimire. 2003. Synergy between traditional ecological knowledge and conservation science supports forest preservation in Ecuador. Conservation Ecology **8(1)**:1.

Berkes, F., J. Colding, J. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecological Applications 10(5):1251-1262.

Berkes, F. 1999. Sacred ecology. Traditional ecological knowledge and resource management. Taylor and Francis, Philadelphia and London, UK.

Calamia, M.A. 1999. A methodology for incorporating traditional ecological knowledge with geographic information systems for marine resource management in the Pacific. Knowledge Creation Diffusion Utilization 16: 2–12.

Cao, Z., Z. Liang, Y. Zhao. 2001. Symbiotic effects of cultivating in rice field in north China. Chinese Journal of Applied Ecology **12(3)**: 405-408.

Clarke, W.C. 1977. The structure of permananece: the relevance of subsistence communities for world ecosystem management. Pages 364-384 *in* T. Bayliss-Smith & R. Feachem editors. Subsistence and survival: Rural ecology in the Pacific. Institute of Pacific Studies, USP, Suva, Fiji.

University of Hawai□i College of Tropical Agriculture and Human Resources (UH-CTAHR). 2008. Taro Mauka to Makai: A Taro Production and Business Guide for Hawai□i Growers. University of Hawai□i at Mānoa.

Coordinadora de las Organizaciones Indigenas de la Cuenca Amazonica (COICA). 1989. Two agendas on Amazon development. Cultural Survival Quarterly 13(4):75-87.

Costa-Pierce, B.A. 1987. Aquaculture in ancient Hawaii. BioScience **37(5):** 320-331.

Cristancho, S. and J. Vining. 2009. Perceived intergenerational differences in the transmission of traditional ecological knowledge (TEK) in tow indigenous groups from Colombia and Guatemala. Culture and Psycholgoy **15(2)**: 229-254

Davidson-Hunt, I. and F. Berkes. 2001. Changing resource management paradigms, traditional ecological knowledge, and non-timber forest products. Pages 78-92 *in* L.C. Duchesne, J.C. Zasada, editors. Forest communities in the third millennium: linking research, business, and policy toward a sustainable non-timber forest product sector, proceedings of the meeting. Kenora, Ontarioa, Canada.

Department of Land and Natural Resources (DLNR). 1991. Conservation District Use Temporary Variance Application. 1979E. State of Hawai□i. Department of Land and Natural Resoruces, Honolulu, Hawai□i, United States.

Drew, J.A. 2005. Use of traditional ecological knowledge in marine conservation. Conservation Biology **19**:1286-1293.

Erickson, C.L. 2000. An artificial landscape-scale fishery in the Bolivian Amazon. Nature **408**:190-193.

Feyerabend, P.1987. Farewell to reason. Verso, London, UK.

Field, J.S., T.N. Ladefoged, W.D. Sharp, P.V. Kirch. 2011. Residential chronology, household subsistence, and the emergence of socioeconomic territories in leeward Kohala, Hawai□i Island. Radioacarbon, **53(4)**:605-627.

Flores-Delgadillo, L., S.L. Fedick, E. Solleiro-Rebolledo, S. Palacios-Mayorga, P. Ortega-Larrocea, S. Sedov, and E. Osuna-Ceja. 2011. A sustainable system of a traditional precision agriculture in a Maya homegarden: Soil quality aspects. Soil & Tillage Research **113**:112-120.

Gadgil, M., F. Berkes, and C.Folke. 1993. Indigenous knowledge for biodiversity conservation. Ambio 22:151-156. Conservation of biodiversity.

Giambelluca, T.W., M.A. Nullet, and T.A. Schroeder. 1986. Rainfall atlas of Hawaii. State of Hawai□i Department of Land and Natural Resources Report R76, Honolulu, Hawai□i.

Gomez-Baggethun, E. and V. Reyes-Garcia. 2013. Reinterpreting change in traditional ecological knowledge. Human Ecology Interdisciplinary Journal **41(4)**: 1-9.

Handy, E.S. and E. Handy. 1991. Native planters in old Hawai□i: Their life, lore & environment.
Bishop Museum Press. Honolulu, Hawai□i.

Henry, L.L. 1993. He□eia Fishpond = Loko I□a O He□eia: An Interpretive Guide for the He□eia

State Park Visitor. Friends of Heʻeia State Park. Kaneʻohe, Hawaiʻi.

Houde, N. 2007. The six faces of traditional ecological knowledge: Challenges and opportunities for Canadian co-management arrangements.

Huang, Y., B. Wen, J. Tang, Z. Liu. 2001. Effect of rice-azolla-fish system on soil environment of rice field. Chinese Journal of Eco-Agriculture **9(1)**: 74-76.

Huntington, H.P. 2000. Using traditional ecological knowledge in science: methods and applications. Ecological Applications 10(5):1270-1274.

Hviding, E. and G.B.K. Baines. 1994. Community-based fisheries management, tradition and the challenges of development in Marovo, Solomon Islands. Development and Change **25**:13-39.

International Union for Conservation of Nature (IUCN). 1986. Tradition, Conservation and Development. Occasional Newsletter of the Commission on Ecology's Working Group on Traditional Knowledge. No. 4. Gland, Switzerland.

Kagawa, A.K. and P.M Vitousek. 2012. The ahupuaʻa of Puanui: A resource for understanding Hawaiian rain-fed agriculture. Pacific Science **66(2)**:161-172.

Kākoʻo ʻŌiwi. 2010. Māhuahua ʻAi o Hoi: Heʻeia Wetland Restoration Strategic Plan 2010-2015. Hawaiʻi Community Development Authority, Honolulu, Hawaiʻi, United States.

Kamakau, S.M. 1976. The works of the people of old: Na Hana a ka Poʻe Hakiko. Bishop Museum Press, Honolulu, Hawaiʻi.

Kamakau, S.M. 1991. Tales and traditions of the people of old – Na moʻolelo a ka poʻe kahiko.
Bishop Museum Press, Honolulu, Hawaiʻi.

Kaneshiro, K.Y., P. Chinn, K.N. Duin, A.P. Hood, K. Maly, and B.A. Wilcox. 2005. Hawaiʻi's mountain-to-sea ecosystems: Social-ecological microcosms for sustainability science and practice. EcoHealth **2**: 349-360.

Keala, G., J.R. Hollyer, and L. Castro. 2007. Loko Iʻa: A manual on Hawaiian fishpond restoration and management. College of Tropical Agriculture and Human Resources, University of Hawaiʻi at Mānoa, Honolulu, Hawaiʻi.

King, M., and U. Faasili. 1999. Community-based management of subsistence fisheries in Samoa. Fisheries Management and Ecology **6**:133-144

Levine, A.S. and L.S. Richmond. 2014. Examining enabling conditions for community-based fisheries comanagement: comparing efforts in Hawaiʻi and American Samoa. Ecology and Society **19(1)**: 24.

Long, C. and Y. Zhou. 2001. Indigenous community forest management of Jinuo people's swidden agroecosystems in southwest China. Biodiversity and Conservation 10:753-767.

Lu, J. and X. Li. 2006. Review of rice-fish-farming systems in China – one of the globally important ingenious agricultural heritage systems (GIAHS). Aquaculture **260**: 106-113.

Madden, W.D., and C. Paulsen. 1977. The potential for mullet and milkfish culture in Hawaiian fishponds. Hawai□i Department of Planning and Economic Development. Prepared for Oceanic Institute, Waimānalo, Hawia□i. 54 pp.

Manner, H.I. 2008. Directions for long-term research in traditional agricultural systems of Micronesia and the Pacific Islands. Micronesica **40(1/2)**: 63-86.

Martin, J.F., E.D. Roy, S.A.W. Diemont, B.G. Ferguson. 2010. Traditional ecological knowledge (TEK): Ideas, inspiration, and designs for ecological engineering. Ecological Engineering **36**: 839-849.

Mueller-Dombois, D. 2007. The Hawaiian ahupua□a land use system: Its biological resource zones and the challenge for silvicultural restoration. Bishop Museum Bulletin in Cultural and Environmental Studies **3:**23-33.

The Nature Conservancy of Hawai□i. 2007. Last stand – the vanishing Hawaiian forest. The Nature Conservancy of Hawai□i & Hawai□i State Department of Land and Natural Resources, Honolulu, Hawai□i.

O'Flaherty. R.M., I.J. Davidson-Hunt, and M. Manseau. 2008. Indigenous knowledge and values in planning for sustainable forestry: Pikangikum first nation and Whitefeather forest initiative. Ecology and Society 13(1):6.

Paepae o He□eia (POH). 2013. Growing Seafood. Kamehameha Schools Bishop Estate, Honolulu, Hawai□i. Accessed April 27, 2014 (http://paepaeoheeia.org).

Poepoe, K.K., P.K. Bartram, and A.M. Friedlander. 2003. The use of traditional Hawaiian knowledge in the contemporary management of marine resources. Fisheries Center Research Reports **11:** 328 – 339.

Rai, S.C. 2007. Traditional ecological knowledge and community-based natural resource management in northeast India. Journal of Mountain Science **4**: 248-258.

Redford, K.H. and A.M. Stearman. 1993. Forest-dwelling native Amazonianas and the conservation of biodiversity: Interests in common or in collision? Conservation Biology 7(2):248-255.

Robertson, H.A. & McGee, T.K. 2003. Applying local knowledge: the contribution of oral history to wetland rehabilitation at Kanyapella Basin, Australia. Journal of environmental management 69: 275–287.

Rosendahl, P. 1994. Aboriginal Hawaiian structural remains and settlement patterns in the upland agricultural zone at Lapakahi, Island of Hawai□i. Hawaiian Archaeology **3**:14-70.

Sears, R.R., C. Padoch, and M. Pinedo-Vasquez. 2007. Amazon forestry transformed: Integreating knowledge for smallholder timber management in Easter Brazil. Human Ecology **35**: 697-707.

Schafer, A.G. and E.G. Reis. 2008. Artisanal fishing areas and traditional ecological knowledge: The case study of the artisanal fisheries of the Patos Lagoon estuary (Brazil). Marine Policy **32**:283-292.

Stab, S., and J. Arce. 2000. Pre-Hispanic raised-field cultivation as an alternative to slash-and burn agriculture in the Bolivian Amazon: Agroecological evaluation of field experiments. Pages 317-327 *in* O. Herrera-MacBryde, F. Dallmeier, B. MacBryde, J.A. Comiskey, and C. Miranda, editors. *Biodiuersidad, conseruacion y manejo en la región de la Reserva de la Biosfera Estacidn Biologica del Beni, Bolivia I Biodiversity, Conservation, and Management in the Region of the Beni Biological Station Biosphere Reserve, Bolivia*. Washington, D.C.: Smithsonian Institution, SI/MAB Biodiversity Program.

Stevenson, M.G. 2006. The possibility of difference: rethinking co-management. Human Organization 65(2):167-180.

Thaman, R.R., and W.C. Clarke. 1987. Pacific island agrosilviculture: Systems for cultural and ecological stability. Canopy International **13(1)**:6-7; **13(2)**:8-10**; 13(1)**:8-9 (three part series).

Thaman, R.R., C.R. Elevitch, and K.M. Wilkinson. 2000. Multipurpose trees for agroforestry in the Pacific Islands. Pages 1-50 *in* C.R. Elevitch and K.M. Wilkinson, editors. Agroforestry Guides for Pacific Islands. Permanent Agriculture Resources, Holualoa, Hawai□i, USA.

Thorton, T.F., and A. Maciejewski Schyeer. 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: a review. Ecology and Society **17(3)**: 6-30.

Thorton, T.F. 2007. Alaska Native corporations and subsistence. Pages 42-62 *in* C. Maida, editor. Sustainability and Communities of Place, New York, New York, USA.

Ticktin, T., H. Fraiola, and A.N. Whitehead. 2006. Non-timber forest product harvesting in alien-dominated forests: effects of frond-harvest and rainfall on the demography of two native Hawaiian ferns. Biodiversity Conservation **6**:59-77.

Tissot, B.N., W.J. Walsh, M.A. Hixon. 2009. Hawaiian islands marine ecosystem case study: Ecosystem- and community-based management in Hawaii. Coastal Management **37**:255-273.

Wilken, G. C. 1987. Good Farmers: Traditional Agricultural Resource Management in Mexico and Central America. University of California Press, Berkeley and Los Angeles, California, USA.

Williams, J.S. 1997. From the Mountains to the Sea: Early Hawaiian Life. Kamehameha Publishing. Honolulu, Hawaiʻi.