Calendar Plants in Southern Vanuatu

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Abstract: Pacific peoples maintain strong traditional ties to their local environments. One noteworthy example of these is the use of "ecological calendars," in which natural cycles are observed as guides in time-reckoning. In southern Vanuatu, what we here call "calendar plants" represent the majority of signals used in these systems. We recorded 111 distinct scientific species of calendar plants, which correspond to 159 folk species drawn from eight linguistically and culturally distinct communities in the area (on Aneityum, Futuna, and Tanna, the three southernmost islands of Tafea, the southernmost province of Vanuatu). These plants are indicators for various temporal events, including when to harvest certain sea creatures, the best time to plant various crops, and when to conduct garden rituals. By describing, comparing, and contrasting calendar plants among these different cultures, we suggest that these systems are fine-tuned to particular ecological, cultural, and personal contexts. Rather than being rigid, formalized calendars, ecological calendars are flexible frameworks for a particular kind of time-reckoning. This quality allows them to be adaptable to changes to the local climate or biota. There is evidence that knowledge of traditional calendars is eroding. Because of their role in supporting resilience among diverse populations (e.g., in maintaining productive gardens and anticipating cyclones), it is critical that they are recorded, and revitalized, before Indigenous knowledge systems are lost across the world.

Key Words: Vanuatu, calendar plants, Pacific ethnobotany, Pacific botany, ethnography of Oceania, linguistics, climate change

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Introduction

For most of Western society, calendars rule people's lives. They allow for organization of our days, weeks, and months, remind us of future appointments, conversations, and deadlines, helping us to map out our activities, both work and personal. Printed calendars may hang on walls or sit on our desks, and increasingly, they are stored on our computers and mobile phones. This important tool developed and evolved over a long period of human history, often originating from folk traditions derived from natural phenomena. The earliest known calendar, thought to date to ca. 8,000 BCE, was recently discovered in Scotland by a team of archeologists (Gaffney et al. 2013). It consisted of a series of 12 pits aligned with the phases of the moon. The authors of that study believe that the prehistoric people who designed the structure used it to track changes in the seasons, guiding them in their hunt for game and in gathering food plants. This system may have been the first to use precise observations of celestial bodies—in this case, the moon—to organize people's livelihoods. Five thousand years later, along the Nile River Valley, the ancient Egyptians developed a calendar based on movement of the sun, dividing the year into 12 months and 365 days (Neugebauer 1983). Throughout history, this calendar was adjusted and refined, most notably by Julius Caesar, whose Julian calendar took effect in 45 BCE, and again by Pope Gregory XIII in 1582, whose Gregorian calendar is still used today (Dershowitz and Reingold 2008). Focusing only on the evolution of physical lunisolar calendars, however, leaves out a large and diverse range of time-reckoning practices that can also be described as types of "calendars." In this paper, we concentrate on time-reckoning practices in the Pacific Islands, focusing on our first-hand observations from Vanuatu, which reveal how local communities use plants as cues for diverse subsistence and ritual practices, as well as indicators of other recurring natural cycles. We refer to any species used in such time-reckoning practices as "calendar plants."

Mondragón (2004: 290), discussing non-Gregorian systems of time-reckoning, writes that "the experience of temporality in Melanesia and elsewhere cannot be reduced to a question of 'calendars, clocks, and cyclic rhythms.'" Indeed, to Indigenous groups across the globe, "weaving weather, plant [cycles], and animal cycles into a complex annual calendar is a common strategy and an alternative or complement to the lunar model" (Harrison 2007: 85). Time-reckoning systems in which people use patterns in their local environments to organize time are what we here call "ecological calendars." Ecological calendars are rather well represented through short discussions in broader works (i.e., ethnologies, ethnobotanical inventories, anthropological articles, and dictionaries), but the term itself was not established or thoroughly defined until quite recently. Kassam et al. (2018) provide the following definition: "Traditional ecological calendars are based on context-specific phenological knowledge generated by communities that have inhabited particular landscapes for multiple generations. Therefore, each of these calendars is unique because it is embedded in the relationships of people to their own ecosystem." Bakar and Franco (2015) detail the ties between ecological calendars and biocultural heritage:

> Local ecological calendars (LECs) such as the Kedayan calendar [of Bruneian and Malaysian Borneo] are not mere instruments to determine time. For local communities, they are ecocultural frameworks that link temporal and spatial scales, contributing to resilience and adaptive management of natural resources and landscapes. As ecocultural frameworks, they also facilitate management, access and withdrawal of provisioning ecosystem services through fishing, foraging, hunting, etc., a role that is often overlooked. LECs utilize changes in the skyscape and landscape, including biological rhythms of flora and fauna as temporal markers which is then linked to the social and cultural rhythms of the community. Folklores in local languages transmit calendric knowledge, while local languages also possess lexemes with layers of meanings to denote the event-based time intervals. Thus, LECs also form important components of biocultural diversity (2).

In the broader context of ecological calendars, especially in the Pacific Islands, calendar plants are often significant time-reckoning elements. Over generations, Indigenous groups have observed the phenology (timing of flowering, fruiting, senescence, etc.) of these plants and established temporal links between such events and other natural cycles (which may not be so easily observed). The only previous record of the term "calendar plant" that we have found describes two plants that Nggela people of the Solomon Islands use as indicators of seasonal fish behavior (Foale 1998). In other accounts across the region, plants are recorded as being used to guide people's activities, ranging from agriculture and foraging, to fishing and even resting.

Among the earliest descriptions of the phenomenon to which we refer as calendar plants is Codrington's (1891) discussion of the time-reckoning system of Mota Island, in northern Vanuatu. In this ecological calendar, the behavior of animals, the winds, and a variety of plants are used as signals for different stages in the agricultural cycle. The "spring" of *magoto*, a particular grass (species not cited), signals the end of winter, and as it withers, the gardens are prepared for yams (*Dioscorea* spp.). When *Erythrina* spp. (*rara* in the Mota language) begin to flower, this phenomenon signals to local people that it is time to plant the yams. Planting continues as *gavinga* (*Syzygium malaccense* (L.) Merr. & L.M. Perry) flowers and the south-east wind blows, and ends when the *Erythrina* flowers fall. The months that follow are named after the palolo worm (*Palola* spp., or *un* in the Mota language), and each appearance of the worm signals a different stage of yam harvest. During the month that follows the yam harvest, people note that reeds (species not cited) make flowers. The production of seeds by these reeds then signals the beginning of hurricane season. After this comes *Lamasag Noronoro*, the month of rattling reeds and return of fresh grass, when the wind blows strongly and steadily, and the work of clearing the gardens can begin again.

Other references to calendar plants span the Pacific region, although few sources give comprehensive descriptions of ecological calendars. Malinowski (1927: 207–208), writing on the Trobriand Islands of Papua New Guinea, explains that "[t]he division of the seasons is associated with the growth of vegetation, which starts its new lease with the beginning of the wet season. The trade winds, on the other hand, is [*sic*] the dry season, in which many fruits and plants ripen, while in bad years there occur droughts and stagnation." Beattie recorded information provided by Teone Taara Tikao (see Tikao and Beattie 2013 [1939]: 46), who was among the last of the Waitaha Māori to receive a traditional Māori education, sharing that "the seasons can be foretold by observing the trees and shrubs flowering, though I was never taught this lore."

Later writings concerning calendar plants reveal the rich variety of phenomena for which plants have become signals across the Pacific. The Inonda of Papua New Guinea detect the start of the dry season by the flowering of *huvira* (*Erythrina variegata* L.), and the beginning of the wet season by the ripening of different nuts and the flowering of the *garepa* tree (species not cited). In addition, "the *pasiro* (a variety of *pitpit*, *Saccharum* sp.) ripens about March, which is a time of more moderate rainfall" (Crocombe and Hogbin 1963: 6). A number of calendar plants are used on Takuu, a Polynesian outlier within Papua New Guinea, including *hano* (*Guettarda speciosa* L.), the flowering of which signals an abundance of tuna (Moyle 2011), and speakers of the Futuna-Aniwa language of Vanuatu use the flowering of *naregai*, a type of yam, to indicate that the hot season is approaching (Capell 1984). Much farther north in Vanuatu, on Vanua Lava, Chiefs Hosia Waras and Eli Field Malau of Vetuboso have recorded a local calendar based on plants, detailing their relationships to weather and human health. "The calendar is based on developmental stages of the Indian coral tree (narara [in Bislama], *rar* [in the local Vurës language]… *Erythrina* spp.), a wild cane [likely *Miscanthus floridulus* (Labill.) Warb. ex K. Schum. & Lauterb.] and yam (*dëm*… *Dioscorea alata*). For each period, the important times for crop planting and harvesting were added, such as for breadfruit (*bieg*… *Artocarpus altilis*), bush nut (navele, *wotag*… *Barringtonia edulis*) and native almond (nangae,

ēne… Canarium indicum)" (Caillon and Malau 2002: 224).

As on Mota, the people of Samoa eagerly await the annual spawning of the palolo worm, a highly valued delicacy, and "several natural clues that preceded the palolo rising enabled islanders to predict the correct timing for palolo swarming" (Itano 2009: 33). These include the flowering of the *moso'oi* tree (*Cananga odorata* (Lam.) Hook.f. & Thomson), an introduced species, and the closing of the *pālulu* flower (several flowers of the family Convolvulaceae, for which the botanical species is not given in Itano [2009] but was later determined using Whistler [2000]). Whistler (2000) records that *gatae* (*Erythrina variegata*) attracts birds when flowering and, citing Christophersen (1935), that its flowering indicates that whales are "running" and yams are ready for harvest. Whistler (2000) also records a number of other plants known by Samoans for attracting birds and fruit bats (which can then be hunted) when in fruit or flower.

In Fiji, Gatty (2009) records the flowering of *drala* (*Vitex trifolia* L. and/or *Erythrina variegata*) as a calendar plant that attracts *kula* birds (*Vini solitaria* [Suckow, 1800]), while also being used as a traditional signal to plant yams. Flowering of *gasau* (*Miscanthus floridulus*) signals a time of increasing fly populations and higher risk of conjunctivitis. Tuisavusavu's (2017) survey of traditional Fijian farming practices adds to the variety of calendar plant uses. The flowering of *viliyawa* (*Decalobanthus peltatus* (L.) A.R. Simões & Staples) warns that drought will soon be experienced, while signs of an impending cyclone include trees bearing more fruits than normal, bends in the leaves of banana trees (*Musa* spp.), and plantain suckers pointing straight up into the sky. Tuisavusavu recorded that the ecological calendar of Fiji is, in fact, much more complex than this. It also utilizes signs such as frog vocalizations, insect behavior, fish behavior, body pain, star visibility, and the sighting of birds. This calendar system has always been a critical tool to Fijians, but "the use of environmental indicators as an early warning system [also] increases their capacity to adapt to extreme weather conditions," such as those now experienced more frequently due to climate change (Tuisavusavu 2017: 61). This suggests that calendar plants are merely one category of inputs in ecological calendar systems. Drawing from literature documenting Pacific cultures, there are also records of other peoples making use of animal phenology, celestial bodies (the sun, moon, stars), weather phenomena (e.g., winds, rain), and human health as signals for other natural events and human activities. While our discussions in Vanuatu have also touched on some of these other time indicators, plants seem to be the largest category of inputs there.

In collaboration with many local experts in southern Vanuatu, we have recorded the use of plants as signals for a diversity of other natural and cultural events. In this paper, we discuss the importance of these plants individually, and the broader importance that ecological calendars have in general to both local peoples and a global audience. References to calendar plants and their uses are abundant in the Pacific anthropological literature, but few studies (Bakar and Franco 2015; Cochran et al. 2015; Haag et al. 2017; Kassam et al. 2018, 2021; Tuisavusavu 2017) have intentionally investigated ecological calendars, and none have attempted to systematically record a region's calendar-plant inventory. In this paper, we attempt to remedy that gap in the literature through a long-term study that includes an investigation into locally recognized calendar plants.

Research Questions

Primarily, we were interested in learning what kinds of activities are informed by plant phenology or development, how these plant species are used to organize time in southern Vanuatu, and how widely this information is known across the population. The diversity of cultural groups in Vanuatu, a language hotspot with an estimated 138 vernacular tongues (François et al. 2015; Harrison 2018), allowed for comparisons of interpretations of natural phenomena across cultures. We were also interested in how different language groups identified the same or different plants for similar activities, for example, species in different areas that indicated that it was time to plant gardens or harvest a specific crop. At the same time, we were interested in seeing whether there were specific plants that

had similar ecological cues across these areas, in the same way that a widely known plant used in primary health care might be known across a broad spectrum of people, sometimes at a global scale. Finally, as this is a long-term study, we talked to people about how climate change might be impacting these traditional practices based on phenological patterns of calendar plants that are currently changing or that people felt might do so in the future, and whether different species might take their place in directing the trajectory of their activities.

Methods

The *Plants mo Pipol blong Vanuatu* (Plants and People of Vanuatu) project is a biocultural conservation endeavor with an interdisciplinary approach. The work, ongoing since 2014, involves a diverse group of botanists, ethnobotanists, mycologists, linguists, governmental agencies, cultural organizations, local communities, traditional leaders, and cultural specialists (some of whom are coauthors on this paper). To date, the project has been focused in Tafea Province, the southernmost part of this Y-shaped archipelago, carrying out fieldwork on the islands of Tanna, Futuna, and Aneityum (Fig. 1) in communities representing eight ethnolinguistic groups: Anejom̃, Futuna-Aniwa, Nafe, Naka, Narak, Netwar, and the Southwest Tanna dialect chain (including Neuai and Nahual, among others). This is a long-term project in Vanuatu, and one for which we plan to move northward to other provinces during the next decade or so.

Initial interviews were conducted with local community members at or close to the area where the plants were collected (e.g., a nearby village close to the forest). In our field notes, we recorded the date, location, and habitat of each plant, along with its physical description (size, color, etc.) and a list of the names of all people (with age and gender) who participated in making the collection (totaling 127 people for plant uses relevant to the present study). We also made in-situ photos of the living plants prior to collecting. After collecting, we conducted follow-up interviews in which specimens were brought into the community to record ethnographic data in a group setting. These data included the vernacular name of each plant (also recording the name of the local language) and any uses or beliefs associated with that species. Questions posed during the interview process were open-ended, inviting anyone in the community to share any information that they wished to contribute. Using this approach, only a small portion of plant uses elicited during these discussions involved time-reckoning. The cultural data gathered at these interviews are linked to physical collections of each species in the form of herbarium-specimen vouchers, which serve as permanent records for current and future research. After recording calendrical uses for plants in these group settings, in which the physical specimens were present, we conducted additional, later rounds of in-depth ethnographic interviews with those members of the community who were identified to us as being plant experts. During these interviews, participants were shown our in-situ photographs of the plant collections and asked to contribute additional information specifically regarding ecological calendars. At times, this process resulted in correction, modification, or expansion of the initial data collected.

Herbarium vouchers were deposited at the Vanuatu National Herbarium (PVNH) in Port Vila and at other institutions with important collections of Pacific plants, including the New York Botanical Garden (NY) and the South Pacific Regional Herbarium (SUVA) in Fiji, among others (herbarium codes follow Thiers 2023). Data and field-based images from these collections are being uploaded to the Vanuatu National Herbarium's *Flora of Vanuatu Website* (https://pvnh.net), and all specimens deposited at NY are being imaged and made available at the C.V. Starr Virtual Herbarium (http://sweetgum.nybg.org/science/vh/).

Our project collects only general knowledge about plants, defined as any uses that could be expected to be known by a broad cross-section of knowledgeable participants. To catalog this information, we followed a series of protocols that ensured that permissions were obtained from traditional leaders, state and national officials, village leaders, and family members. Before each interview, the team members explained the purpose and goals of the study and what type of information we sought to document. Following this, Prior Informed Consent was obtained.

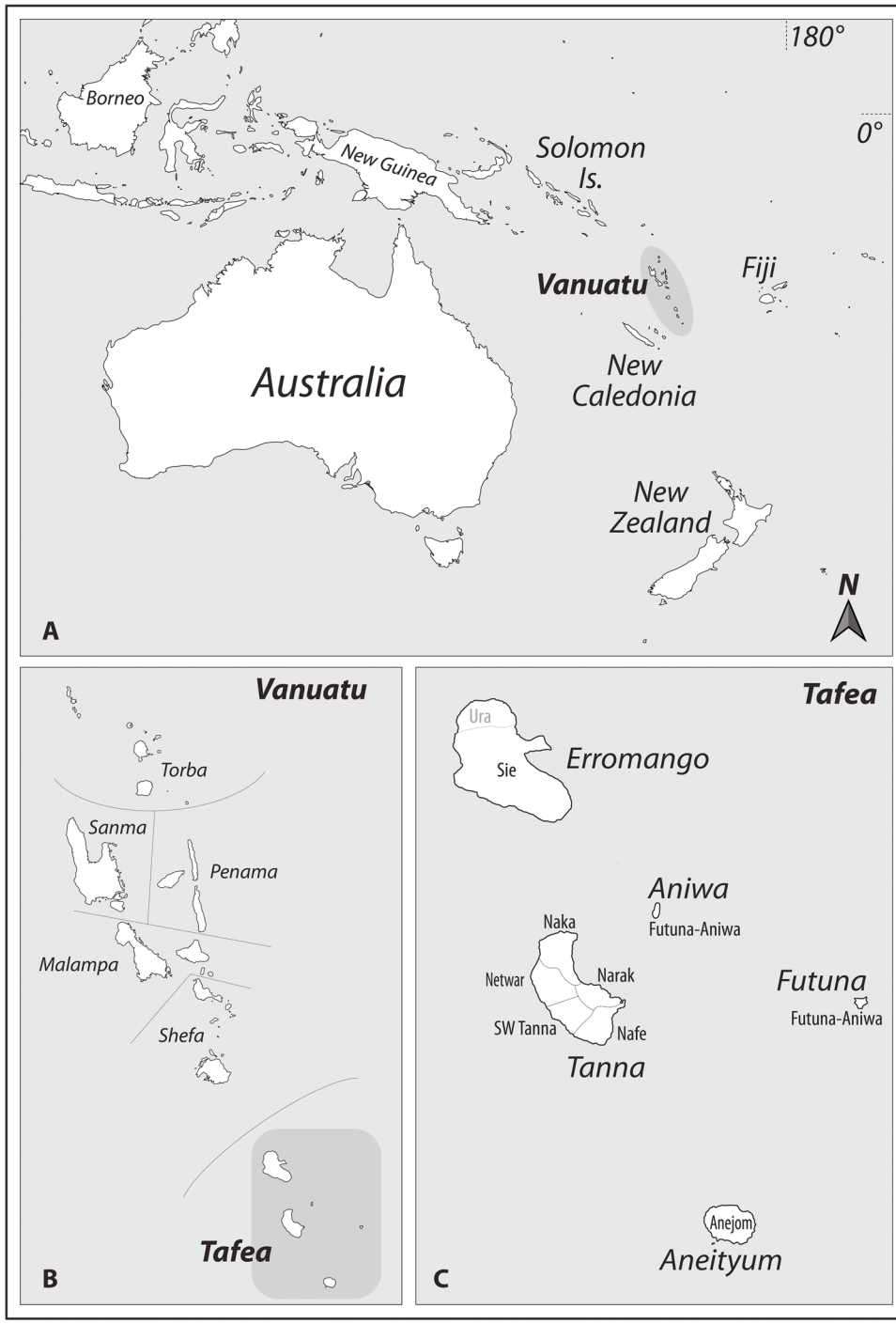

Fig. 1. **A.** Map of the Southwest Pacific region showing the location of Vanuatu (highlighted in darker ellipse), **B.** map of Vanuatu and its six provinces (Tafea Province highlighted in darker square), **C.** the five islands that comprise Tafea Province: Erromango, Aniwa, Tanna, Futuna, and Aneityum; language groups and their approximate boundaries are shown on each island. The area labeled "SW Tanna" represents the full area occupied by a chain of several closely related dialects. We worked with speakers of Neuai and Nahual, though the area also includes Nahuat and Nahuar.

Ni-Vanuatu (the Indigenous people of Vanuatu) who participated in this project were involved in plant collection and interviews, and were trained early during the project, including on the use of the "permission to participate and consent" form. This form specifically instructs signatories that "we are seeking general information on uses of plants as part of this study and do not wish you to reveal anything that is not intended for general knowledge of the community." People shared the most common knowledge and kept family or clan secrets to themselves. Participants often reported that stemming the loss of the traditional knowledge was a major benefit of this program. They perceived that this benefit is contributing to the maintenance of traditional ways of life in Vanuatu (known as *kastom*), along with other objectives, such as the preservation of cultural memory relating to plants and language diversity, and conservation goals—benefits shared by all citizens.

We have compiled the botanical, linguistic, and cultural data in Appendices 1–8. These tables are arranged by language and thus cultural groups, and include vernacular and scientific names, cultural practices, and the names of collectors and local experts. Every community member present during discussions is listed, but it may have been the case that only one or two provided the cited information. In general, most individuals listed for a given calendar plant use provided acknowledgment of the information if they were aware of it. In addition, for some collections, we worked with a single expert who was assigned by the community or volunteered to work with us that day. Because field identifications are provisional, the scientific name assigned to a specimen is often updated over time, especially as we develop a greater understanding of plant relationships and have the opportunity to have taxonomic experts in particular plant groups review these determinations. Therefore, in Appendices 1–8, we include not only the species name of each collection, but also the collector name + collector number (a unique identifier) for each specimen on which the interview was based, to allow for any future changes in species determinations to be tracked. To save space, collectors' names in the Appendices are abbreviated by their initials: Kate Armstrong (KA), Michael J. Balick (MB), Ashley A. McGuigan (AAM), Gregory M. Plunkett (GMP), and Tom A. Ranker (TR). The names of local experts who provided cultural information are provided in the right-hand column of each table. While we discuss some simple statistics and devote a small section of the present study to comparison among cultures, statistical or quantitative analyses were not a part of our methodology because this is a primarily descriptive study.

The collection of field data was sometimes enhanced through the use of audio and video recordings made during the interviews. These have also been used to create a series of "Talking Dictionaries" that help to preserve names, pronunciations, and uses (where known) of biological organisms (not only plants, but also fishes, birds, and other animals), as well as cultural artifacts. The *Nafe [Kwamera] Talking Dictionary* (http://talkingdictionary.swarthmore.edu/kwamera/) is one example of these online resources, which currently contains 3233 entries, 3212 audio files, and 1236 images. In many cases, cultural information, such as the uses of plants to direct the trajectory of human activities, is embedded in these resources. Because the online Talking Dictionaries are freely available, access to these data by local community members is facilitated through use of mobile devices (smart phones, tablets, etc.), which are becoming increasingly common in Vanuatu.

Results and Discussion

During our fieldwork, one domain of knowledge that was particularly impressive in its sophistication is the way in which local people continue to use observations of the natural world to determine the trajectory of their daily activities (although these practices seem to be waning). Elsewhere in the Pacific (see the "Introduction" section above), the phenology of flowering or fruiting times of different plant species provides an indication of the change of seasons and cues for certain activities, such as gardening, hunting, and fishing. Our work on the islands of Tafea included gathering information on the flowering and fruiting patterns of many different species of plants, both in and around villages and from natural habitats (e.g., rainforests, mangroves, and grasslands), along with information about how these plant-based

events direct certain human activities, both on land and at sea.

The Diversity of Calendar Plants

In collaboration with 127 local experts in Tafea Province, the project identified 111 scientific taxa (including a few without species determinations), which corresponded to 159 folk species (Appendices 1–8). Of the plants that serve as environmental or cultural cues, most by far (66 scientific names and 98 folk species) involve plant signals that relate to hunting birds and fruit bats, largely due to the fact that a large number of flowering and fruiting plants serve as food sources for these animals. These cues provide local people with information regarding the most successful times and places for hunting. Next in abundance—though more culturally important than those associated with flying animals—are cues for agricultural practices, such as planting and harvesting crops, and gathering wild plants and fungi (41 scientific names and 47 folk species), along with the harvesting of marine animals (17 scientific names and 19 folk species). Nine plants (nine botanical and folk species) have fruiting or flowering times that indicate anticipated changes in the weather, either rainfall or temperature, and thus help to guide people with their seasonal routines (e.g., mandating rest at certain times in the day in the hottest seasons). Interviews also revealed that some plants are used to schedule semi-magical garden games, which are observed to ensure the success of crop plants, most especially the culturally significant yam.

Calendar Plants and Livelihoods in Tafea Province

Ethnographic interviews on Tanna reinforced the importance of calendar plants in the area, which comprise the majority of indicators in these ecological calendars. Other calendrical elements in the region include animals, celestial bodies (the sun and moon, stars), the winds, and other weather events.

In southern Vanuatu, a variety of critical livelihood activities depend on cues from calendar plants. We recorded one plant, *Bambusa vulgaris* Schrad. ex J.C. Wendl. (referred to using the Bislama *bambu* by Naka speakers), which is used to identify the best time for collecting mushrooms in the forest. The timing of many agricultural activities, such as clearing, planting, and harvesting gardens, is often determined by the phenological cycles of plants found outside of the garden. To the Netwar speakers of western Tanna, various plants indicate that it is time to establish new gardens, for example, when the leaves of *kautuhwé* (*Pterocarpus indicus* Willd.) start to fall from the tree. This is also the time when children play the game called *sayé*, which is viewed as a semi-magical means of improving the yam harvest. In *sayé*, players throw stems of *nuig* (wild cane: *Miscanthus floridulus*) as spears in a way that they bounce when touching the ground (rather than sticking into the ground). The one who sends his reed the furthest wins, and the further the reed goes, the larger the yams in that year's harvest will be. Similar games that are said to improve harvest are scheduled based on the further development of the yam crop.

In some cases, other natural cues are used in conjunction with plants to aid in agricultural planning. For example, if *nepalap* (the cooler, southern wind) blows at the time for clearing gardens, it signals that the following year will experience a poor yam harvest. Most garden rituals are the special purview of men holding the rank of *tupanas* (who may be defined as "workers" with particular responsibilities, often endowed with spiritual powers used in completing their work). These men also use calendar plants to schedule their activities, which are considered critical to the success of certain crops. They are often those who first observe natural signs, then announce in the village that these signs have appeared. Each *tupanas* has the power to deal with a single crop, such as yams, taro, kava, etc., while others may deal with aspects of the environment (a wind from a particular direction, rain, sunshine, etc.). As such, the *tupanas* may be viewed as garden and weather magicians on Tanna, who protect crops and people through rituals and physical work in their dedicated, *tabu* gardens. Like people everywhere, Tannese people recognize and follow signs in the skies to prepare for inclement weather, but they also look to plants to identify certain times of the year that require special preparation for cyclones, or to avoid garden work due to excessive heat.

Plants that signal different kinds of animal behaviors are also quite important, informing people when and where to find both terrestrial animals (e.g., fruit bats and birds) and marine animals (e.g., turtles, urchins, fish, and the palolo worm). The palolo worm is especially important in northern Vanuatu (and elsewhere in the Pacific), as its remarkable annual swarms are also associated with various rituals and feasts, and is itself a highly prized food source. The worms' arrival at the reef can be predicted by the flowering of the two native legume species of the genus *Erythrina* on the island of Pentecost (Penama Province), or by the senescence of the branchlets of *Casuarina equisetifolia* L. on Vanua Lava (Torba Province) (see Kelso et al., 2023), but in Tafea Province, the practice of harvesting palolo worms seems to be a recent introduction, and we have not recorded any data suggesting calendar plants associated with its appearance. On Aneityum, however, calendar plants do play a role in the sustainable management of other marine organisms. For example, the color change and abscission of the leaves of *Terminalia catappa* L. provides a signal that lobsters are sufficiently numerous to be harvested during this period, which lasts approximately 1.5 months. In the past, conforming to this rule served to reduce pressure on the lobster populations, which allowed stocks to replenish and flourish during the remaining ~ 10.5 months each year. Elders have observed that abandonment of this practice has led to overharvesting of lobster populations on Aneityum, and the depletion of this important food source. On Tanna, Netwar speakers observe the color of the fruits of *nekvitu* (*Lepidocupania brackenridgei* (A.Gray) Buerki, Callm., Munzinger & Lowry) to preserve populations of *tapatapa*, a local lobster species (*Parribacus caledonicus* Holthuis, 1960). When the fruits of this plant are red, it is *tabu* to harvest this particular kind of lobster. People on Tanna also report using the fruiting and flowering of plants favored by birds and fruit bats not only for scheduling hunting, but also at times to enforce *tabu* restrictions on harvesting those animals, helping to avoid depleting populations.

The relative abundance of plant cues related to birds and fruit bats (representing more than half of our recorded calendar plants) reflects the relationship of plants to the animals that feed on their fruits or nectar. Having observed this, local people have thus learned that hunting near these trees during the time of fruiting or flowering results in improved harvest of their prey. It might take only a few observations of a bat-flower feeding event to confirm a direct association between those organisms (though a longer period of observation will reinforce the strength of the association). Other categories of calendar-plant cues do not have such an immediate connection with the organisms and the events with which they are associated. For example, in the Nafe-language area of southern Tanna (Fig. 1), the flowering of *Melochia odorata* L. f. (Fig. 2) and another unspecified plant flower is the best time to harvest a local shellfish known as *bari* (species not determined during interview). It would likely take several seasons or more of close observation to first notice this association.

Comparisons of Calendar Plants Between Different Cultures and Communities

Categorizing plants by ethnolinguistic groups allows for comparisons of these calendar plants among different groups, understanding that floras and other factors are not necessarily the same for each environment. For example, on Aneityum, Tanna, and Futuna, the appearance of fruits in several different species of *Ficus* serves as a cue to prompt hunters to look for birds and flying foxes (or fruit bats) as prey. In some cases, different phenological events for the same plant indicate different things. When Netwar speakers in western Tanna observe *Urena lobata* L. (Fig. 2) seedlings sprouting, it is a sign for garden activities (viz., that various crops should be planted), while on Aneityum, the fruiting and flowering of *U. lobata* indicates a seasonal weather shift (viz., that the cyclone season has passed). In other cases, the same phenological event has different meanings to different people. Both Aneityumese people and Nafe-speakers on Tanna know that the flowering of *Metrosideros vitiensis* (A. Gray) Pillon (Fig. 2) can be used to tell when taro is ready to be harvested. However, on Aneityum, it is also used in a completely different way: to signal a good time for fishing. Even neighboring peoples on a single island, over centuries

Fig. 2. *Melochia odorata*, Appendix Tables 1, 3, and 6 (upper left); *Metrosideros vitiensis*, Tables 1, 2, 3, 5, and 8 (upper right); *Urena lobata*, Tables 1 and 6 (lower left); *Hedycarya dorstenioides*, Tables 3 and 4 (lower right). Photos by G. M. Plunkett and W. Law.

of observing their land, find very different associations between plant phenology and the local ecosystem of their area. On Tanna, Naka speakers know that it is a good time to hunt birds when *Hedycarya dorstenoides* A. Gray produces fruits (Fig. 2), while Nafe speakers look to the same plant's flowering as a signal that sea urchins are fat and ready to be harvested. It may be that the latter association is shared more broadly on Tanna, but in the Naka-speaking area of the island, we only worked with people who lived further inland. In our future work, a more concentrated effort to conduct interviews on ecological calendars in different ecological niches will enable us to make stronger statements about the distribution and abundance of different categories of calendar-plant associations (Fig. 3).

The Importance and Adaptive Nature of Calendar Plants

Due to local differences in climate, geography, biota, language, and culture, each community's set of interpretations of calendar plants is unique. This suggests that ecological calendrical frameworks are fluid, with individuals adapting their knowledge and applications of local natural cycles not only to the

Fig. 3. *Casuarina equisetifolia*, Appendix Table 1 (upper left); *Commersonia obliqua*, Table 1 (upper right); *Amyema artensis*, Table 3 (lower left*), Boehmeria virgata*, Tables 3, 4, 7, and 8 (lower right). Photos by G. M. Plunkett.

peculiarities and changes in their environment, but also to their specific needs. Our time frame (8 years of fieldwork) did not allow for detection of changes in phenological patterns due to climate change, and while Pacific islanders everywhere recognize climate change as a tangible phenomenon, no one we interviewed was able to provide a specific example of how a formerly recognized calendar plant required "updating" or switching to a different species.

One possibility is that people have become less attuned to their environments, and as a result, activities such as hunting, fishing, housebuilding, and gardening have become less important to their daily, seasonal, and annual cycles. Because of this loss of connection to biodiversity and habitats, it may be that people maintain the older associations of plant cues, even if the temporal connection has been weakened. Evidence of this type of ossification can be found in another Pacific ecological calendar. On the island of Futuna (of Wallis and Futuna), 2 months are named after the palolo worm even though it does not occur there today, and it is unclear whether it ever did (Kirch 1955). Its persistence in Futunan time-reckoning is likely due to the fact that, elsewhere in Polynesia, the worm was maintained as a key part of ecological calendars throughout the Polynesian expansion: it is both precisely

predicted using natural indicators and used as an indicator itself (Kelso et al., 2023).

Another possibility is that calendar-plant associations may be fading in the collective memory as lifestyles change. In many places, the names used for plants are clearly shifting from local languages to Bislama, especially among the younger generations. During our group interviews, a consensus for the local names for plants was reached only after extensive discussions with knowledgeable elders, and in a few cases the Bislama name was all that was recorded (such as *bambu* [bamboo] for Naka speakers). Furthermore, some calendar plants—particularly those used for gardening—are still relatively widely known in these communities, but many others were reported only by one person. Despite these shifts, the potential utility of traditional knowledge in adapting to global climatic threats is a topic in which ni-Vanuatu are keenly interested, and we suspect that as our long-term research effort continues, some patterns of change and adaptation may be observed.

As the islands of southern Vanuatu adapt to changes in climate and other global forces, cross-cultural comparisons can lead to collaborative efforts, serving to maintain the effectiveness of local ecological calendars. Recent research highlights the diverse set of strategies that Pacific Islanders have developed for survival in an often-dangerous region (Inamara and Thomas 2017; Lefale 2010). In the nearby Melanesian region of the Torres Strait Islands of Australia, Green et al. (2010: 351) discuss "a large body of knowledge of environmental indicators and weather observations in the memories of many Island elders" with "the potential…for forecasting the impacts of climate change and planning anticipatory adaptation activities." The authors note that while recognition of this knowledge is valuable, it must be followed by the development of concrete adaptation strategies appropriate for a climate changing more rapidly than Indigenous peoples have contended with before.

Other researchers claim that ecological calendars specifically can serve as effective, adaptable tools that foster resilience in the face of climate change. Kassam et al. (2021: 521) state: "Because human knowledge derives from engagement and performance in the fluidity of spatial and temporal dimensions of climatic and ecological cycles, co-generated articulation of seasonal rounds [i.e., ecological calendars] facilitates adaptation to the evolving reality of anthropogenic climate change. The process generates empirically rich Indigenous or local knowledge which has the potential to inform gaps in the biological, physical and social sciences." In the Netwar language area of Tanna, 2022 was an abnormal year in terms of precipitation. It was very wet, and a number of calendar plants gave their sign later than usual, so people planted gardens later than usual and the crops did well. This is evidence towards plant-based calendars being adaptable to climatic changes and lending a level of resiliency compared to the Gregorian calendar. Rather than conducting a particular agricultural activity on the same Gregorian date each year, calendar plants serve as reliable guides as they respond to peculiarities in weather that also affect crop plants.

Ecological calendars, perhaps more than any other time-reckoning strategy, require a deep and constant connection to the local environment. The maintenance of these systems is not only critical for traditional livelihood practices, such as agriculture, but also keeps people aware of changes in their environments generally. Many of the local people we spoke with during this study have expressed concern about recent changes in weather patterns, plant phenology, and reduction in the abundance of certain plant and marine organisms, and they are concerned about how such changes will affect them in the future. As in the past, the current lifestyles of most ni-Vanuatu in Tafea Province remain biodiversity-dependent, and among the people of this province, there is great interest in preserving and transferring knowledge about local traditions to the next generations. Evidence of this interest can be seen in the recent development of local "Kastom Skuls" (Customary Knowledge Schools) that are being conducted in Tafea Province, which provide curricula designed to teach and pass down

traditional knowledge to younger generations of local people (Balick and Plunkett 2019).

Conclusion

Without doubt, there are many additional calendar plants to be documented, not only in Vanuatu but across the whole of Oceania. The goal in writing the present paper has been to draw attention to an important but neglected body of biocultural information that is rapidly being lost. As global cultural and economic forces result in changes to lifestyles among ni-Vanuatu, we can ask how calendrical knowledge can be shared and perpetuated in their communities, and what are the most effective means of doing so, given modern pressures. In addition, like so much of life in the Pacific Islands, traditional lifestyles are increasingly threatened by climate change. The relatively small data set presented here is merely a snapshot, yet it raises some very interesting questions for future research. While ecological-calendar frameworks are highly adaptable tools specially tuned to local ecological niches, their futures are uncertain. With changes to the patterns of plant distribution and abundance, including flowering and fruiting times, can ni-Vanuatu find a reliable guide for the timing of their subsistence activities, such as planting and harvesting crops? How far into the future will ni-Vanuatu be guided in regulating their lobster-harvest season by the reddening of *Terminalia catappa* leaves (Fig. 4)? As phenologies shift, how can such harvest schedules be

Fig. 4. *Terminalia catappa* (Appendix Tables 1, 3, 4, and 6) with some reddened leaves, during the process of leaf senescence and abscission. Photo by Dominik M. Ramík.

adjusted? Will new calendar plants be chosen for activities that are no longer reliably guided by the flowering and fruiting of traditionally used calendar plants, or will the loss of such connections lead to the degradation of natural resources? These are only some of the reasons to be concerned about the impacts of global climate change on people around the world, and especially in the archipelago of Vanuatu, with its rich cultural and biological diversity.

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Authors' Contributions

Balick: project management, fieldwork, specimen preparation, data analysis, and preparation and submission of manuscript.

Plunkett: project management, fieldwork, specimen preparation and identification, data analysis, photography, and contributions to preparation of manuscript.
Harrison: project management, literature survey, fieldwork, linguistics, data analysis, and contributions to preparation of manuscript.
Kelso: literature survey, data analysis, linguistics, and preparation of manuscript.
Wahe, M.: fieldwork, specimen preparation, linguistics, and follow-up interviews with community members.
Ramik: fieldwork, specimen preparation, construction of database, photography, and contributions to preparation of manuscript.
Dovo: project management and liaison to National Government, fieldwork, specimen preparation, and ethnobotanical interviews.
Nasauman: fieldwork, interviews, and review of data and follow-up interviews with community members.
Neriam: liaison to traditional chief on Aneityum Island, fieldwork, interviews, and review of data and follow-up interviews with community members.
Keith: liaison to Forestry Department on Aneityum Island, fieldwork, interviews, and review of data and follow-up interviews with community members.
Ranker: fieldwork, interviews, and review of data and participation in the preparation and review of manuscript.
Wahe, J-P.: liaison to Tafea Kaljoral Senta, fieldwork, interviews, and review of data and follow-up interviews with community members.

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Data Availability

Herbarium specimens (collected in sets of up to 6) with associated data were deposited at PVNH, NYBG and up to four other institutions having significant collections from the Pacific Islands. Information on language names of plants is available through the Vanuatu Talking Dictionaries: https://talkingdictionary.swarthmore.edu/vanuatu.php). Requests for information and material should be directed to the corresponding author.

Declarations

Ethics Approval This project collects only general knowledge about plants, defined as any uses that could be expected to be known by a broad cross-section of knowledgeable participants. To catalog this information, we followed a series of protocols that ensured that permissions were obtained from traditional leaders, state and national officials, village leaders, and family members (see "Methods" section for full details). The research and methodology for this project was reviewed by the Institutional Review Board of Swarthmore College (where

co-author Harrison was affiliated from 2016 to 2023) and an exemption from further review was granted.

Competing Interests The authors declare no competing interests.

Literature Cited

Bakar, N., and F. Franco. 2022. The fading popularity of a local ecological calendar from Brunei Darussalam Borneo, Journal of Ethnobiology and Ethnomedicine 18: 33. https://doi.org/10.1186/s13002-022-00525-9.

Balick, M. J., and G. M. Plunkett. 2019. Tanna's first *Kastom Skul*: Helping to sustain culture and identity into the future. Island Life 35: 76–79.

Caillon, S., and E. F. Malau. 2002. Coconuts and taro from the west coast of Vanua Lava (Vanuatu): An ethno-agronomic inventory. Orléans, France: Research Institute for Development [Institut de Recherche pour le Développement].

Capell, A. 1984. Futuna-Aniwa dictionary with grammatical introduction. Canberra: Dept. of Linguistics, Research School of Pacific Studies, The Australian National University.

Christophersen, E. 1935. Flowering plants of Samoa. Bishop Museum Bulletin 128: 1–221.

Cochran, F. V., N. A. Brunsell, A. Cabalzar, P. van der Veld, E. Azevedo, R. A. Azevedo, R. A. Pedrosa, and L. J. Winegar. 2016. Indigenous ecological calendars define scales for climate change and sustainability assessments. Sustainability Science 11: 69–89. https://doi.org/10.1007/s11625-015-0303-y.

Crocombe, R. G., and G. R. Hogbin. 1963. Land, work, and productivity at Inonda. Canberra: New Guinea Research Unit, Australian National University. https://ehrafworldcultures.yale.edu/document?id=oj23-014.

Codrington, R. H. 1891. The Melanesians: Studies in their anthropology and folk-lore. Oxford, UK: Clarendon Press.

Dershowitz, E., and E. M. Reingold. 2008. Calendrical calculations, 3rd edition. Cambridge: Cambridge University Press.

Foale, S. 1998. What's in a name? An analysis of the West Nggela (Solomon Islands) fish taxonomy. SPC Traditional Marine Resource Management and Knowledge Information Bulletin 9: 3–19.

François, A., M. Franjieh, S. Lacrampe, and S. Schnell. 2015. The exceptional linguistic density of Vanuatu: Introduction to the volume. In The languages of Vanuatu: Unity and diversity, eds. A. François, S. Lacrampe, M. Franjieh, and S. Schnell, 1–21. Canberra: Asia-Pacific Linguistics.

Gaffney, V., S. Fitch, E. Ramsey, R. Yorston, E. Ch'ng, E. Baldwin, R. Bates, C. Gaffney, C. Ruggles, T. Sparrow, A. McMillan, D. Cowley, S. Fraser, C. Murray, H. Murray, E. Hopla, and A. Howard. 2013. Time and a place: A luni-solar 'time-reckoner' from 8th millennium BC Scotland. Internet Archaeology 34. https://doi.org/10.11141/ia.34.1.

Gatty, R. 2009. Fijian-English dictionary: With notes on Fijian culture and natural history. Suva, Fiji: R. Gatty.

Green, D., J. Billy, and A. Tapim. 2010. Indigenous Australians' knowledge of weather and climate. Climatic Change 100: 337–354. https://doi.org/10.1007/s10584-010-9803-z.

Haag, I., K-A. Kassam, and C. Samimi. 2019. Ecological calendars in the Pamirs: Adapting to climate change on the top of the world [Ökologische kalender im Pamir: Anpassung an den klimawandel auf dem dach der welt]. Geographical Review [Geographische Rundschau] 71(12): 26–31.

Harrison, K. D. 2007. When languages die: The extinction of the world's languages and the erosion of human knowledge. Oxford: Oxford University Press.

———. 2018. Vanuatu's wealth of languages. Island Life 34: 62–64.

Inamara, A., and V. Thomas. 2017. Pacific climate change adaptation: The use of participatory media to promote indigenous knowledge. Pacific Journalism Review: Te Koakoa 23(1): 113–132. https://doi.org/10.24135/pjr.v23i1.210.

Itano, D. 2009. Palolo swarming. In: Natural history guide to American Samoa, 3rd ed., ed. P. Craig, 32–33. Pago Pago, American Samoa: National Park of American Samoa.

Kassam, K-A. S., M. L. Ruelle, C. Samimi, A. Trabucco, and J. Xu. 2018. Anticipating climatic variability: The potential of ecological calendars. Human Ecology 46(2): 249–257. https://doi.org/10.1007/s10745-018-9970-5.

Kassam, K-A, M. Ruelle, I. Haag, U. Bulbulshoev, D. Kaziev, L. Louis, A. Ullmann, I. Edwards, A. A. Khan, A. Trabucco, and C. Samimi. 2021. Engaging transformation: Using seasonal rounds to anticipate climate change. Human Ecology 49(5): 509–523. https://doi.org/10.1007/s10745-021-00269-2.

Kelso, N., G. M. Plunkett, P. Dovo, C. B. Paul Vusqal, K. D. Harrison, and M. J. Balick. 2023. The palolo worm as a cornerstone of Pacific ecological time-reckoning. Ethnobiology Letters 14(1): 24–35. https://doi.org/10.14237/ebl.14.1.2023.1815.

Kirch, P. V. 1994. The pre-Christian ritual cycle of Futuna, western Polynesia. Journal of the Polynesian Society 103: 255–298. https://www.jstor.org/stable/20706578.

Lefale, P. F. 2010. Ua ‘afa le aso Stormy weather today: Traditional ecological knowledge of weather and climate The Samoa experience. Climatic Change 100: 317–335. https://doi.org/10.1007/s10584-009-9722-z.

Malinowski, B. 1927. Lunar and seasonal calendar in the Trobriands. The Journal of the Royal Anthropological Institute of Great Britain and Ireland 57: 203–215. https://doi.org/10.2307/2843682.

Mondragón, C. 2004. Worms and *mana*: The traditional calendar of the Torres Islands Vanuatu. Oceania 74(4): 289–308. https://doi.org/10.1002/j.1834-4461.2004.tb02856.x.

Moyle, R. M. 2011. Takuu grammar and dictionary: A Polynesian language of the South Pacific. Canberra: Pacific Linguistics, Research School of Pacific and Asian Studies, The Australian National University.

Neugebauer, O. 1983. Astronomy and history: Selected essays. New York, New York: Springer.

Thiers, B. 2023. Index Herbariorum. https://sweetgum.nybg.org/science/ih/ (10 December 2022).

Tikao, T. T., and H. Beattie. 2013 [1939] Tikao talks: Traditions and tales of the Canterbury Maori as told by Teone Taare Tikao to Herries Beattie. Christchurch, NZ: Cadsonbury Publications.

Tuisavusavu, A. R. 2017. Analysis of traditional farming practices in Vanua Levu, Fiji: Implications for building local community resilience in climate change adaptation M.D. dissertation. University of the South Pacific.

Whistler, W. A. 2000. Plants in Samoan culture: The ethnobotany of Samoa. Honolulu, Hawai‘i: Isle Botanica.