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Ways of counting in Micronesia ☆

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Abstract

In many languages in Micronesia, clever ways of extending their counting systems to numbers far beyond imagination were developed in precolonial times. Here, we provide an exhaustive overview of these systems, highlight their characteristics, and account for some of their most intriguing features. Based on a critical assessment of the available data and the in-depth analysis of both paradigmatic cases and peculiarities, we draw inferences about some more general patterns that suggest a rather long tradition of specific ways of counting both in Micronesia and the area beyond.

Zusammenfassung

In vielen Sprachen Mikronesiens wurden in vorkolonialer Zeit pfiffige Verfahren entwickelt, um die Reichweite ihrer Zahlensysteme zu erweitern – mitunter auf Zahlen jenseits jeder Vorstellungskraft. Unser Artikel bietet einen umfassenden Überblick über diese Systeme, beleuchtet ihre typischen Merkmale und erklärt ihre faszinierendsten Eigenschaften. Basierend auf einer kritischen Bewertung der verfügbaren Daten analysieren wir paradigmatische Beispiele ebenso wie auffällige Besonderheiten. Dabei werden übergreifende Muster deutlich, die auf eine relativ lange Tradition spezifischer Zählweisen hindeuten, sowohl in Mikronesien als auch darüber hinaus.

MSC: 01A11

Keywords: Micronesia; Micronesian languages; Numbers; Numeral classifiers; Specific counting systems; Counting units

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1. Introduction

A few millennia ago, a group of seafaring people began to colonize most of those far-flung atolls and islands of what is nowadays known as Micronesia. While they settled on the clusters of habitable spots that stretch across a distance of 4,000 km, they diversified in both cultural and linguistic terms. Some of the joined land masses that are home to speakers of the same language are smaller than a square kilometer, and even the largest island inhabited by Micronesian-speaking people, Pohnpei, with its 334 km^2, covers only half the size of Auckland city. Contemporary speaker populations range from about 20 for languages confined to small islands such as Tobi, to 100,000 for the language spoken on the 33 islands that constitute the Republic of Kiribati. Against this background, some of the ways in which Micronesian languages deal with numbers are mind-boggling: Most contain sets of numeral classifiers that are among the richest in the world; many include words for numbers far beyond imagination; and in a wide range of languages, clever ways of further extending the counting systems were developed.

In this paper, we aim to provide an exhaustive overview of the counting systems in Micronesia and their characteristics, highlighting why they are among the most amazing systems in the world, and accounting for some of their most intriguing features. Counting systems are essential symbolic tools for quantification and number representation, and although just one of several domains in the much broader field of ethnomathematics (Ascher, 1991, 2002; Goetzfridt, 2008, 2012; Sizer, 2000), this domain is so fundamental and rich to be worthy of examination in its own right. We begin with a brief outline of the migration paths and linguistic diversification en route, which will also serve to structure the presentation. We then characterize some general patterns in the ways of counting to be found across Micronesia, before turning to the details in which they differ, with a focus on particularly interesting cases. In so doing, we not only compile the (hitherto scattered) primary data on counting systems in individual languages, but also systematize and analyze them against the background of language history, migration, and cultural practices in the region. Because looking at sets of number words in individual languages or selected sources in isolation inevitably yields a patchy picture, our analysis considers the internal structure of counting systems in all Micronesian languages, their relationship to co-existing alternative systems in the same languages, their similarities with non-Micronesian systems in the same region, and the cultural practices linked to them whenever available. By integrating this range of data, we hope to generate the kind of compendium that will be of value to anybody interested in symbolic tools for quantification and number representation, including questions on how these tools may have evolved (e.g., Bender and Beller, submitted for publication; Bowern and Zentz, 2012; Calude and Verkerk, 2016; Epps et al., 2012).

This treatise therefore also encompasses a critical assessment of the available data and their sources (for a bibliographic study, see Goetzfridt, 2008). The earliest reports, typically from colonial times, bear witness to a rapidly changing world and provide mere snapshots of variable scope and reliability of the phenomenon under scrutiny. The first islanders in Micronesia encountered by Europeans were the Chamorro on the Mariana Islands. Discovered by Magellan in 1521, a permanent Spanish settlement on its southernmost island Guam from 1668 onwards began to dramatically alter Chamorro society. Elsewhere in Micronesia, missionary, mercantile, and colonial incursions set in later, but by the time ethnographic records were taken, decades of depopulation and sociopolitical upheaval had already transformed these societies, sometimes in radical ways (Kirch, 2000, 183). By then, several of the more intriguing specific counting systems and the contexts in which they were practiced had dropped out of use, and in some cases, even the local numerals themselves had been replaced by loanwords from Spanish or English. For various cases, the sources on which we depend therefore fall short of providing sufficient details to answer some of the most puzzling questions. In particular, they often lack details on counting practices and contexts, not to mention strategies for mental arithmetic, which is why we will have to rely heavily on the linguistic forms of number representations. However, as we are primarily interested in the counting systems and their properties, these linguistic forms are highly valuable primary data. And by taking a bird's-eye view in compiling all we

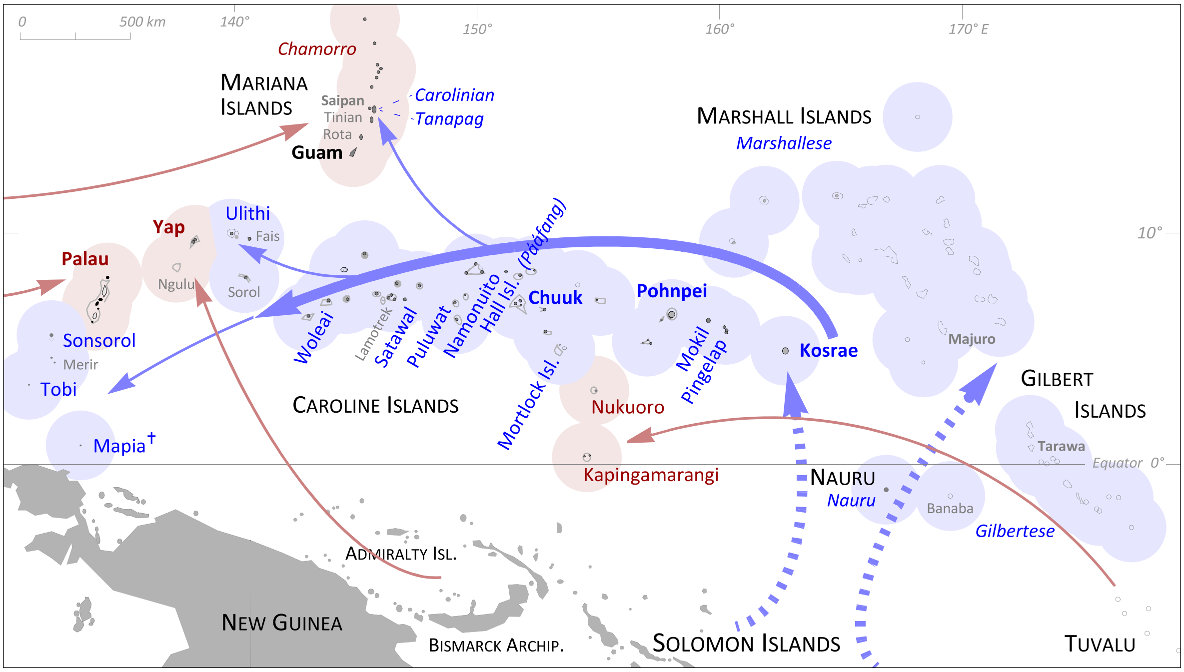

Figure 1. Micronesia in the Western Pacific: Islands and languages (Micronesian ones in blue, non-Micronesian ones in dark red). Shaded circles indicate a 100-mile radius around islands, the average distance of an overnight voyage (Marck, 1986); arrows indicate major migration paths. (For colored figures, the reader is referred to the web version of this article.)

know about the Micronesian counting systems, clear patterns emerge that do allow us to generate answers, also to broader questions, with some degree of plausibility.

2. Geographic context and historical background

Micronesia is the collective name for an array of more than 2000 islands and atolls in the Western Pacific, predominantly north of the equator. It consists of four major island groups and one isolated island (see Figure 1):

- the Mariana Islands in the North (today Guam and the Northern Mariana Islands, which are unincorporated territories of the United States)
- the Caroline Islands in the West and the Center, some of which today form the Republic of Palau, with the remainder being part of the Federated States of Micronesia (including Yap, Chuuk, Pohnpei, and Kosrae)
- the Marshall Islands in the Northeast (today the Republic of the Marshall Islands)
- the Gilbert Islands in the East (which, together with the island of Banaba and the previously mostly uninhabited Phoenix and Line Islands further east, today form the Republic of Kiribati)
- and the island Nauru in the South (today the Republic of Nauru)

This "sea of small islands" was colonized by at least five distinct groups of people, who set off from widely different areas and at different points in time.

2.1. Pathways of Micronesian settlement

Three of the five groups of colonists went ashore in *Western Micronesia*. The ancestors of the indigenous population on the Mariana Islands and on the main islands of Palau, respectively, came from the West, more specifically from insular Southeast Asia, some 4000 years ago and perhaps even earlier (Kirch, 2000, 173). Yap was colonized slightly later from the Southeast, by a group of people originating somewhere in the Bismarck Archipelago, possibly the Admiralty Islands north of New Guinea (Hurles et al., 2003; Kirch, 2000, 169; Lynch et al., 2002, 98; Matisoo-Smith, 2015).

Central-Eastern Micronesia was settled by one or several groups of people, who likely set off from the southeast Solomons and/or adjacent Vanuatu regions around 2000 to 2500 years ago. With the island groups around Kosrae being an early center, it appears that settlements soon began to spread in the region, and in a wide westwards migration movement eventually reached the island groups of the Marianas, Yap, Palau, and New Guinea. In the beginning, the high islands of Kosrae, Pohnpei, and Chuuk may have been preferred for residence. Many of the atolls were then still in a process of formation and had to be transformed during generations of intermittent usage before they could be permanently settled, the latest not more than 1000 years ago (Kirch, 2000, 167, 174f.).

Nukuoro and *Kapingamarangi*, finally, were colonized rather late, by Polynesian groups that most likely came from Tuvalu in the Southeast. Possibly reached by drift and initially used as intermittent settlements, intensive residential occupation here is documented for the last 300 years (Kirch, 2000, 179f.).

The different groups populating the islands of Micronesia were all Austronesians, but still their languages and cultural traditions differed substantially, owing to their regions of origin. Summarizing the archaeological and linguistic evidence, together with oral traditions, Kirch notes that in both of the two major parts of Micronesia, powerful chiefly polities arose, attested to inter alia by megalithic architecture, yet on high islands only, and not on all high islands (2000, 178-206). High islands include some of the Marianas, the main islands of Palau, and Yap in Western Micronesia as well as Chuuk, Pohnpei, and Kosrae in Central-Eastern Micronesia. These are the only places where sufficiently large populations – numbering in the thousands by the end of the first millennium AD (Kirch, 2000, 194) – could be sustained for considerable power concentrations to occur. At the same time, they were also undergoing fluctuations and significant changes in their sociopolitical structure. Atoll-dwelling populations, by contrast, while ranging rather in the low hundreds at most, appear remarkably stable over time and largely unchanged in sociopolitical terms, yet vulnerable to hurricanes and flooding (Kirch, 2000, 178, 194). With a vital dependence on inter-island contacts for the exchange of resources, people, and skills, the atoll-dwellers developed outstanding expertise in sailing and navigation (Gladwin, 1970; Goodenough, 1953; Hutchins, 1983, 1995; Lewis, 1994).

2.2. *Linguistic diversification*

With the exception of a few places on the fringes, Micronesian languages are spoken on all of these island groups, including Nauru, which in former times was not considered Micronesian (e.g., Bender et al., 2003), but is included in the Micronesian branch by Glottolog (http://glottolog.org/resource/languoid/id/micr1243). The exceptions are the Mariana Islands, Palau, and Yap in the West, and the atolls of Nukuoro and Kapingamarangi several hundred kilometers south of Pohnpei (Figure 1). As we are interested in the diversification of counting systems within a language family, we focus on the Micronesian languages, but include the non-Micronesian languages as their closest neighbors, especially since their speakers have maintained extensive exchange relations with Micronesian speakers for centuries.

2.2.1. *Micronesian languages*

The 21 Micronesian languages listed in Glottolog belong to the Oceanic branch of the Malayo-Polynesian part of the Austronesian language family[2] (see also Ross et al., 1998–2016). Within this branch, a first split separated *Nauru* from Nuclear Micronesian; a second split separated *Kosraean* from Central

[2] **Abbreviations for contemporary languages** follow SIL conventions (as listed in Glottolog). These include for the *Micronesian languages* NAU = Nauru, KOS = Kosraean, GIL = Gilbertese, MAH = Marshallese, PIF = Pingelapese, MKJ = Mokilese, PON =

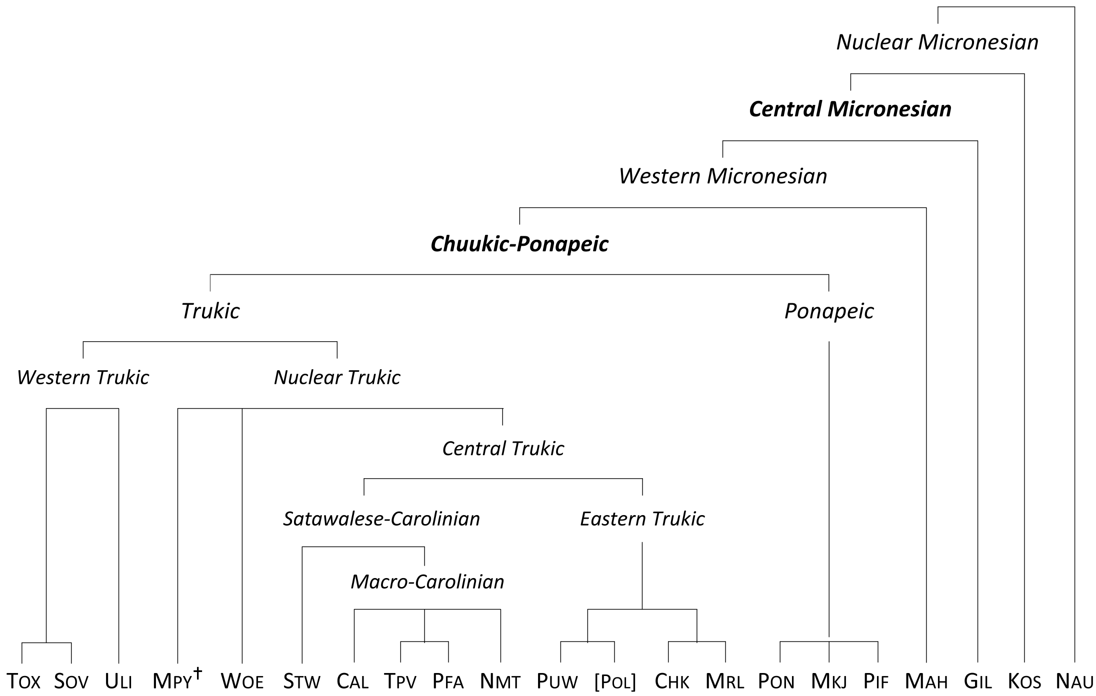

Figure 2. Phylogenetic tree of the Micronesian languages, based on Glottolog relations (time of branching not calibrated). Mapia (MPY†) is extinct; Pollapese (POL) is not considered further, as only incomplete data on its counting systems are available.

Micronesian; a third split separated *Gilbertese* from Western Micronesian; and a fourth split separated *Marshallese* from Chuukic-Ponapeic. The *Ponapeic* subbranch, in turn, consists of three languages, while the remaining 14 languages belong to the *Trukic* subbranch, stretching from Satawan in the Mortlock Islands to Tobi in the far West (Figure 2).

One of these languages, *Mapia*, was spoken on the atoll of the same name, north of the Western coast of New Guinea. Although Mapia is now considered extinct, Kubary (1895, 113) was able to collect some information on both the language and its counting system from one of its last speakers. The one Micronesian language not considered here is *Pollapese*, for which only incomplete information is available (Quackenbush, 1968); but since Pollapese and Puluwatese are highly similar, and hence often listed as one language, this gap is unlikely to affect the overall picture.

The closest common ancestor of the Micronesian languages, Proto-Micronesian, has been reconstructed from all branches in the tree except Nauru – that is, from the Nuclear Micronesian languages (Bender et al., 2003) – and is assumed to have formed in the region of Kosrae, the Gilbert and Marshall Islands, and Pohnpei, roughly 2500 to 2000 years ago (Hage and Marck, 2002; Kirch, 2000, 167). In this paper, it will be used as the background against which changes in counting systems of the daughter languages are assessed.

Pohnpeian, MRL = Mortlockese, CHK = Chuukese, POL = Pollapese, PUW = Puluwatese, NMT = Namonuito, PFA = Pááfang, TPV = Tanapag, CAL = Carolinian, STW = Satawalese, WOE = Woleaian, MPY = Mapia, ULI = Ulithian, SOV = Sonsorol, and TOX = Tobian; and for the *non-Micronesian languages* CHA = Chamorro, PAU = Palauan, YAP = Yapese, NUW = Nguluwan, NKR = Nukuoro, and KPG = Kapingamarangi.

Abbreviations for reconstructed languages (as in Bender et al., 2003; Tryon, 1995): PAN = Proto-Austronesian, PMP = Proto-Malayo-Polynesian, POC = Proto-Oceanic, PMC = Proto-Micronesian [or more precisely Proto-Nuclear-Micronesian, as it excludes Nauru], and PCMC = Proto-Central-Micronesian.

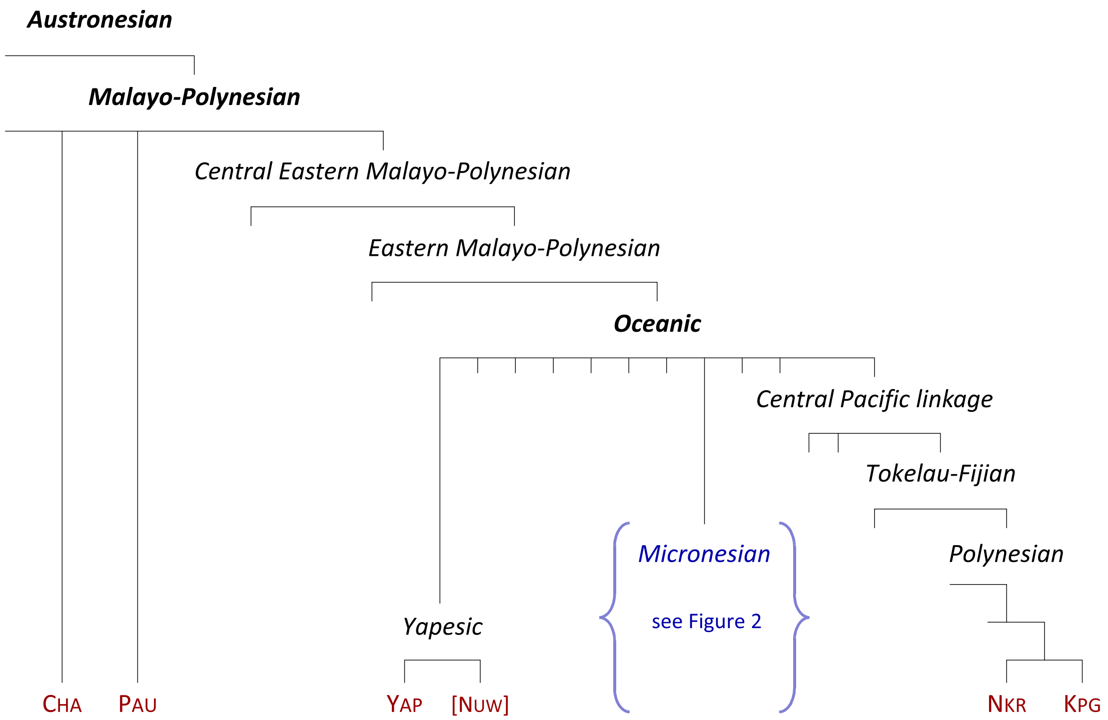

Figure 3. Phylogenetic tree of the languages spoken in Micronesia, based on Glottolog relations (not all subbranches are given, time of branching not calibrated). Nguluwan (NUW) is not considered further, as only incomplete data on its counting systems are available. **Notes:** For a slightly different tree with intermediate layers between Oceanic and the Micronesian and Polynesian branches, see Ross and colleagues (1998–2016). Most of the remaining Oceanic languages not mentioned here are found in island Melanesia and emerged from the common ancestor at an earlier time.

2.2.2. Non-Micronesian languages

Some of the languages spoken in Micronesia are of non-Micronesian origin (see Figure 3). As noted earlier, the first inhabitants of the Mariana Islands and the main islands of Palau came from insular Southeast Asia. Their languages (*Chamorro* and *Palauan*, respectively) belong to the Austronesian language family (and more specifically to Malayo-Polynesian, in which they form one independent subbranch each), but, unlike all other languages in Micronesia, are not Oceanic. The indigenous population on Yap does speak an Oceanic language, *Yapese*, the origin of which points to the Admiralty Islands north of New Guinea (Kirch, 2000, 169; Lynch et al., 2002).[3] *Nukuoro* and *Kapingamarangi*, finally, are two Polynesian outliers, with languages closely related to Samoan and Tuvaluan. The proximate common ancestor for all languages considered here (including the Micronesian languages) is thus Proto-Malayo-Polynesian, and for all except Chamorro and Palauan it is Proto-Oceanic (Ross et al., 1998–2016).

3. Ways of counting

Proto-Malayo-Polynesian already contained a base-10 counting system and a numeral for at least the first non-trivial power of the base, 10^2 = **Ratús* (Lynch et al., 2002, 72; Tryon, 1995, 1.2, 1169;

[3] The closest relative of Yapese in Micronesia, Nguluwan, is not considered here due to the inchoate description of its counting system. The language is spoken on Ngulu, an atoll roughly 100 km southeast of Yap, and those parts of the counting system that are reported appear very similar to those in Yapese, but the list of numerals ends at 600 (Eilers, 1936, 243).

N	PAN	CHA	POC	NKR	PMC	GIL	WOE
1	*a+sa, *ˀe+sá, *i+sá, *sa-, *ta+sa	hacha	*ta-sa, *sa-kai, *tai, *kai	dahi	*te-	te-[na]	se-
2	*d$_3$uSá	hugua	*rua	lua	*rua	uo-, ua-	riuwa-
3	*tĕlú	tulo, tulu	*tolu	dolu	*telu	ten-	seli-
4	*Sĕ(m)pát	fatfat	*pati, *pat	haa	*fa(a)	a-	faa-
5	*limá	lima	*lima	lima	*lima	nima-	lima-
6	*ˀĕném	gunum	*onom	ono	*wono	ono-	wolo-
7	*pitú	fiti	*pitu	hidu	*fitu	iti-	fisi-
8	*walú	gualu	*walu	valu	*walu	wan-	wali-
9	*siáw (?)	sigua	*siwa	siva	*Siwa	rua-	tiwa-
10^1	*púluq	fulu	*[sa](ŋa)puluq	[madaanga] hulu	*-ŋawulu	[te]ñaun	[se]ngaul
		manot				[te]bwi[na]	[se]ig
10^2	**PMP**: *Ratús	gatus	*Ratu(s)	lau	*-p^{w}ukiwa, *-p^{w}ukua	[te]bubua	[se]biugiuw
10^3		chalan		mano	*ŋa-ratu	[te]ña:	[sa]ngeras
10^4		manutu		[se]mada	(*kusi, *kisi)	[te]rebu	[se]n
10^5				[se]guli	(*lopwa)	[te]kuri	[se]lob
10^6				[se]loo	(*sepu, *sepi)	[te]ea	[se]piy
10^7				[se]ngaa	(*nena)	[te]tano	[se]ngit
10^8				[se]muna		[te]toki	[sa]ngerai
10^9				[se]bugi			
10^{10}				[se]baga			

Figure 4. Basic and power numerals in the reconstructed ancestors of the Micronesian languages, in two contemporary Micronesian languages (Gilbertese and Woleaian), and in two non-Micronesian languages (Chamorro and Nukuoro). **Sources:** Proto-Austronesian (PAN) and Proto-Malayo-Polynesian (PMP) numerals are taken from Tryon (1995); Proto-Oceanic (POC) from Lynch et al. (2002, 72); Proto-Micronesian (PMC) from Bender et al. (2003), complemented by Harrison and Jackson (1984); Chamorro (CHA) from Safford (1904); Nukuoro (NKR) from Carroll and Soulik (1973), complemented by Harrison and Jackson (1984, 72); Gilbertese (GIL) from Bingham (1922); and Woleaian (WOE) from Sohn (1975). **Notes:** Orthography as used in the sources, yet adding square brackets to segment suffixes (including 1 in power numerals and classifier in basic numerals). Reconstructed languages and their lexemes are shaded. One numeral reconstructed for PMP is added in the column for PAN numerals, as PMP is a common ancestor of all languages considered here. PMC numerals in round brackets are regarded as more tentative (Jackson, 1986, 209), and their precise numerical value is unclear because the value of their contemporary reflexes varies. Several languages use reflexes of different roots for 10; those not used in fast enumeration are set in grey (for more details and discussion see sections 3.2.2 and 5.3).

and see Figure 4). In addition, these ancestral languages contained a small set of numeral classifiers (Jackson, 1986; Tryon, 1995) that proliferated in some branches of Oceanic, especially in the Micronesian languages, Yapesic, and the Admiralties (Lynch et al., 2002, 39; Owens et al., 2018).

3.1. Counting systems and numeral classifiers

The sets of counting words and of numeral classifiers are largely distinct, yet related systems involved in counting. Almost all languages contain words or morphemes for numbers, but only a subset of languages use numeral classifiers. In Micronesian languages, both systems are present.

3.1.1. Counting systems and their properties

Counting systems consist of the words that denote numbers, the numerals. The way in which these words are composed define the structure of a system. Non-compositional, basic numerals constitute what is called the primary counting cycle, with the last number in this cycle being the *base* of the system. In a regular system, the next numeral after the base is a composition of the base and the first numeral of the primary counting cycle. For instance, in a base-10 or *decimal* system, the primary counting cycle ranges from 1 through 9, followed by the base (10). After reaching the base, counting continues as "10 and 1", "10 and 2", etc., until "2 times 10" is reached, which is a *multiple* of the base.[4] It then continues as "2 times 10 and 1" (21), "2 times 10 and 2" (22), and so on, until "9 times 10 and 9" (99) is reached. The next number beyond this highest possible composition so far is a *power* of the base (here the second power: 10^2). In purely decimal systems, powers of the base are each indicated by a new numeral, such as "hundred" or "thousand".

The number of power numerals in a system defines its extent, with the *limiting number* according to Greenberg (1978, 253) being the next number beyond the largest number word that can be systematically composed from the basic and power numerals in the system.[5] In the reconstructed system of Proto-Oceanic, for instance, with **Ratu(s)* = 100 as the highest power numeral, the largest number word regularly composed would have been **siwa Ratu(s) siwa(ŋa)puluq ma siwa* (= 999), hence rendering the subsequent number (1000) the limiting number of that system.

The presence of a base, its size, the number of power numerals, and the regularity of number word composition are among the defining properties of a counting system, regardless of their modality, and these properties can vary substantially (and independently) across languages (Bender and Beller, 2012, 2018; Everett, 2017; Widom and Schlimm, 2012; Zhang and Norman, 1995). Even for simple numerical tasks such as accurately assessing quantities beyond the subitizing range, counting systems are essential cognitive tools – as demonstrated in a range of empirical studies with speakers of languages that lack numerals with precise meaning for numbers greater than 3 (Gordon, 2004; Pica et al., 2004), with home-signers who lack native-speaker input on the precise meaning of numerals (Spaepen et al., 2011, 2013), or with fully numerate adults when prevented from using the numerals they in principle have at their disposal (Frank et al., 2012). Importantly, the culture-specific properties of these tools have implications for the cognitive representation and processing of numerical information. For instance, larger bases allow for a more compact (mental) representation than smaller bases, entail more extensive addition and multiplication tables, and require different algorithms even for simple calculations (Bender and Beller, 2017b; Zhang and Norman, 1995). Assuming that, over historical time periods, users of a tool gradually adjust that tool to their needs, the diversification of related counting systems can therefore be taken to reflect changes in both such needs and handling the tool (Beller and Bender, 2008; Bender and Beller, 2013).

3.1.2. Numeral classifiers

In languages that make use of numeral classifiers, the classifier is an obligatory component of words or phrases indicating number in a sentence. In such languages, nouns refer to some kind of mass only, while the classifier specifies the *unit* in which that mass would be counted (Denny, 1986). To illustrate this for a

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4 We use digits to illustrate the procedure because numerals in English are inflicted with several irregularities and are therefore ill-suited for illustration (cf. Bender and Beller, 2018). Most Oceanic languages, by contrast, by and large follow the patterns described above (Bender et al., 2015). For instance, "2 times 10 and 2" is *rieisek riau* in Pohnpeian, with *ri[au]* = 2 and *[e]isek* = 10. Note that, due to their regularity, such systems are closer to a place-value structure as implemented in present-day numerical notation, even though they differ from the latter in that they use distinct symbols for each power rather than indicating it by place only.

5 With a recursive principle in place, such as raising the base to various powers, the system can, in principle, be extended ad infinitum (for an impressive example from Papua New Guinea, see Mimica, 1988). In verbal systems, however, such extensions presuppose the invention and implementation of further power numerals.

close counterpart in English: In "three cups of sugar", the sugar is the mass to which the *cup* provides the unit for counting.

Numeral classifiers are not normally a direct part of the counting system. Still, they will be considered here insofar as they sometimes also convey numerical information. While most classifiers simply refer to an individual instance of the mass (e.g., in "three cups of sugar", the total amount of items is 3), some specify the unit to be parts, groups, or multiples of the item referred to. The latter include a few that, besides the type of entity, also specify a precise quantity (Bender and Beller, 2006b; Benton, 1968), in much the same way that *brace* in "three braces of pheasants" specifies the counting unit to be pairs, thus rendering a total of 6 (rather than 3) pheasants.

3.2. *Ways of counting in the Micronesian languages*

All counting systems in the Micronesian languages share three properties that they inherited from Proto-Oceanic: They are base-10 systems; they employ numerals for at least one higher power of the base; and they contain numeral classifiers, or have done so until very recently. Despite these structural similarities, however, Micronesian counting systems also differ substantially in a number of details.

3.2.1. *Basic numbers*

As explained above, the primary counting cycle in a regular system consists of non-compositional, basic words. In almost all Micronesian languages, these are reflexes of the Proto-Micronesian numerals from 1 through 9 (see Figure 4). The most notable exception is the system in Marshallese, which adopts a 'sub-decimal' structure for some of its basic numerals (Figure 5(a)). Specifically, the words for the numbers 6 through 9 are compositional, with, for instance, 6 translating as 3 + 3 and 7 as 3 + 3 + 1 (Erdland, 1906; for more details, see section 4.2.2).

Potentially a second exception is that in most of the Central Trukic languages and in at least one Western Trukic language, one of those numerals in use for referring to 4 does not follow the typical pattern, but appears to involve a component alluding to 2 (Figure 5(b)). For instance, Elbert (1947, 23) reports Chuukese *ruanü* as indicating 4 in the general form, whereas in combination with numeral classifiers and higher powers, it is rendered by a reflex of the Proto-Micronesian **fa* / **faa* (as in *fa-chö* = 4 flat objects, or *fä-*

(a) Marshallese		
Value	**Numeral**	**Numerical transcription**
1	*júon*	[1]
2	*rúo*	[2]
3	*jilu*	[3]
4	*emen*	[4]
5	*lalim*	[5]
6	*jil-jino*	**[3] [3]**
7	*jil-jil-im-júon*	**[3] [3] + [1]**
8	*rua-lidök*	**[2] [4?]**
9	*ruad-im-júon*	**[2] [4?] + [1]**
10	*jo-ñoul*	[1] [10]

(b) Chuukese				
Value	***Counting objects***			
	general	*animate*	*flat objects*	…
1	*eü*	*e-men*	*e-chö*	
2	***ru***	***rue**-men*	***rua**-chö*	
3	*ününgat*	*ünü-men*	*ünü-chö*	
4	***ruanü***	***fö**-men*	***fa**-chö*	
5	*nimu*	*nim-men*	*nima-chö*	
…	…	…	…	
10	*e-ngon*			
40	***fä**-ik*			
400	***fö**-pükü*			

Figure 5. Irregular patterns (in boldface) in the numerals for basic numbers in (a) Marshallese (Erdland, 1906) and (b) Chuukese (Elbert, 1947); hyphens added to facilitate segmentation.

	NAU	KOS	GIL	MAH	Ponapeic			Trukic												
					PIF	MKJ	PON	MRL	CHK	PUW	NMT	PFA	TPV	CAL	STW	WOE	MPY	ULI	SOV	TOX
(a) Power numerals																				
10^1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10^2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10^3	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10^4	(+)		+		+	+	+	+	+	+	+			+	+	+	+	+	+	
10^5	(+)		+		+	+	+		+	+				+	+	+		+	+	
10^6	(+)		+		+	+	+			+				+	+	+		+	+	
10^7			+		+	+	+			+					+	+		+		
10^8			+		+	+	+			+					+	+		+		
10^9					+	+	+													
(b) Numerals for base 10																				
**ŋawulu*		1	1, 2	1, 2	1[2]	1[2]	1, 2	1	1	1	1	1				2		2		
**itaki*	(?)		2		1	1	1, 2													
**ik[ae]*			2				1	[1]	[1]	1	[1]	[1]	1	1	1	1	1	1	1	1
**yafi*								2	2	2				2		2				
other	(?)		1	2																
*(c) Numerals for the powers 100 (*púkua) and 1000 (*ŋaratu)* [a]																				
**púkua*	(?)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
**ŋaratu*	(?)		+					+	+	+	+	+	+	+	+	+	+	+	+	+

[a] In Nauru (NAU), as with *ata* = 10, the numerals for 100 (*aibu*) and 1000 (*aranga*) may be cognates of the Nuclear Micronesian numerals, but this is yet to be assessed.

Figure 6. Distribution of power numerals in the Micronesian languages, indicating (a) the range of powers covered in each language, (b) the PMc root of the numeral(s) used to denote base 10, and (c) whether the numerals for 100 and 1000 reflect the respective PMc root (according to Bender et al., 2003; Harrison and Jackson, 1984). **Notes:** Generally, a shaded cell with "+" indicates that the respective numeral is attested. In (b), existence is further specified as occurrence in the primary counting system ("1"), in some multiples of 10 but not all ("[1]"), or in a specific counting system ("2"). For more details, see sections 3.2.2 to 3.2.4. The dataset containing the actual power numerals (Bender and Beller, 2021) is available at https://doi.org/10.5281/zenodo.4696262.

ik = 40). While Dyen (1965, 56) declares this general numeral for 4 to be an unanalyzable portmanteau morph, the similarity between the numerals for 4 and 2, *ruanü* and *ru(a)*, respectively, rather points to a shared meaning.

3.2.2. Numerals for 10

Among the numerals inherited from ancestor languages is the numeral for base 10: **púluq* in Proto-Austronesian (Tryon, 1995), **[sa](ŋa)puluq* in Proto-Oceanic (Lynch et al., 2002), and **ŋawulu* in Proto-Micronesian (Bender et al., 2003, 63). Interestingly, though, in contemporary Micronesian languages, there is considerable variability regarding which lexeme is chosen for this pivotal number (Figure 6(b); and see Harrison and Jackson, 1984). Of the twenty languages considered here, only eleven adopt a reflex of **ŋawulu* as a prime lexeme for 10; seven adopt it also, or exclusively, as a lexeme in alternative ways of counting (for an example, see Figure 12). Gilbertese and the languages of the Chuukic-Ponapeic branch use reflexes of **itaki* and **ik[ae]* instead or in addition (Bender et al., 2003, 63; Jackson, 1983, 52, 375), and in the eastern part of the Trukic branch, a reflex of **ŋawulu* is used for 10 itself and for some of its multiples, yet a reflex of **ik[ae]* is used for other multiples (for an example, see Figure 5(b)). In addition, a reflex of *yafi* ("a bunch of ten") is widely used in the Trukic subbranch (Bender et al., 2003, II, 354); and Gilbertese makes use of altogether four different numerals for 10, one of which, *[te]bwi[na]*, occurs only here.

3.2.3. Number of power numerals

As noted above, the number of power numerals in a system defines its extent. Compared to earlier ancestor languages, this was already rather high in Proto-Micronesian, with reliably reconstructed numerals for 100 and 1000 (Bender et al., 2003, 63; Figure 6(c)) and more tentative reconstructions for even greater powers (Figure 4). In contemporary Micronesian languages, the number for power numerals is one of the most widely varying properties (Figure 6(a)), which is also one of the reasons why the numerical value of the reconstructed forms is more difficult to establish than their existence. The number of powers ranges from only two in contemporary Kosraean, in which 1000 is indicated with a loanword from English (Lee, 1975, 123-125), to as many as nine in the Ponapeic subbranch (Rehg, 1981, 139). Interestingly, besides the enumeration of words for basic numbers (or "unit counting"), there was a distinct way of counting out the series of the power numerals (i.e., 1, 10, 100, 1000, etc.), for which slightly different numerals were occasionally used (e.g., in Mokilese, 1 is indicated as *oahd-* in unit counting, yet as *ehd-* when enumerating the power series; Harrison, 1976; Harrison and Jackson, 1984, 76, n12).

3.2.4. Composition of power numerals

In a regular base/power system, a new lexeme is assigned to every new power level. English, by contrast, combines two power numerals for referring to 10,000 and 100,000 (i.e., "ten thousand" and "hundred thousand"), which actually makes it a system with two main bases, 10 and 1000 (Bender and Beller, 2018). The majority of Micronesian languages, however – and in fact related languages in other parts of Oceania – do adopt distinct lexemes for each power of the base. Two languages deviate from this regular pattern. Composition of power numerals similar to "ten thousand" and "hundred thousand" is reported for Nauru as early as the beginning of the 20th century (Kayser, 1993 [1936]) and for a modern variant of Satawalese (Roddy, 2007), whereas the traditional variant of Satawalese followed the regular, Oceanic pattern (Damm, 1935). In both cases, the most likely explanation is that the irregular pattern was adopted from the colonial European languages, in which it is widespread.

3.2.5. Variability in numeral classifier systems

While all Micronesian languages have, or until recently had, systems of numeral classifiers, these systems vary substantially in terms of both the principles for classification and the number of classes thus distinguished. As a consequence, the extent of classifier systems ranges from two in contemporary Kosraean to more than a hundred in Chuukese (Benton, 1968) and Gilbertese (Jackson, 1983, 371). Although contemporary Marshallese has given up on them, until recently at least three different classes were in use there too (Erdland, 1906). Some of these involved classifiers with a precise numerical value different from 1 and hence generated specific counting systems.

3.2.6. Specific counting systems

Specific counting systems are characterized by a combination of two features: They only apply to certain objects, and they are based on counting units larger than 1. So far, such systems have been described predominantly for Oceania, and in particular for the Polynesian languages (e.g., Beller and Bender, 2008; Bender, 2013; Bender and Beller, 2006a,b, 2007, 2014, 2017a), but are likely more widespread, both within and beyond the Pacific (e.g., Bellamy, 2018; Hill and Unger, 2018).

Available data on Micronesia directly point to the existence of such systems in about half of the Micronesian languages, most of them adopting pairs and/or tens as their counting unit, typically for food items such as coconuts, breadfruit, or fish (Figure 7). The fact that instances of such systems are spread

Language	***Counting unit*** 2	4	5	8	10	20	***Objects counted specifically***
Nauru	+				+		coconuts and non-lagoon fish by 2, young *ibia* fish by 10
Kosraean	(?)				(?)		breadfruits by bunches of 10, with 2 bunches per pole
Gilbertese	+				+		coconuts by 10; no object information for counting by 2
Marshallese	+				+	+	coconuts by 10; no object information for counting by 2 and 20 (see section 4.2.2)
Pohnpeian	+	+			+		coconuts by 10; no object information for counting by 2 and 4 (see section 4.1.1)
Mortlockese					+		coconuts and clams by 10
Chuukese	+		+		+	+	fish by 5, coconuts by 10, breadfruit by 10 and 20; no object information for counting by 2
Puluwatese	+				+		fish, breadfruit, and coconuts by 2; alternatively, coconuts by 10
Carolinian					+		coconuts by 10
Woleaian				+	+		coconuts by 10, yet during funerals by 8 (see section 4.1.2)
Ulithian					+		coconuts by 10
Sonsorol	+						[reported for Merir]: counting of all things also by 2 (see section 4.2.3)

Figure 7. Specific counting systems in the Micronesian languages, with counting unit(s) implemented and type of objects to which they apply. **Sources:** Data for Nauru as reported by Kayser (1993 [1936]); Kosraean by Vesper (1970); Gilbertese by Bingham (1922); Marshallese by Hernsheim (1880); Mortlockese by James (n.d.); Chuukese by Benton (1968), Dyen (1965), and Elbert (1947); Puluwatese by Elbert (1974) and Bender et al. (2003), respectively; Carolinian by Jackson and Marck (1991); and Ulithian by Sohn and Bender (1973). **Notes:** A shaded cell with "+" indicates attested occurrence, "(?)" indicates tentative evidence.

across the entire language tree, from Nauru to Western Trukic, suggests that they would actually have been in use in all Micronesian languages, albeit with a substantial degree of variation. Lack of evidence in some languages should therefore not be taken as implying that the phenomenon was lacking (the possibility that such systems were indeed used more widely is assessed in section 5).

3.2.7. Numerical notation

In general, languages in Micronesia were exclusively oral in pre-colonial times, and no notational system was applied for numbers before the introduction of the Hindu-Arabic digits in the course of colonial and mercantile incursions. One exception is the invention of writing systems on some of the Caroline Islands in post-contact times. For instance, the Faraulep script, designed by a local chief, Saueeru, includes a notational system for numbers that was supposed to be employed during copra trading with the Japanese (Damm, 1938, 212f.; see Figure 8).

However, other methods for externally representing quantities were in more frequent use, and may have already been so before contact. For instance, on Nauru, the number of a specific type of fish when caught was registered by placing a pebble, and when counting coconuts, larger numbers were registered by a nick on a stick (Kayser, 1993 [1936], 74). In some instances, such as in Gilbertese, fingers were utilized to help keep track of numbers (Bingham, 1922, 17). The enumeration of knots in ropes seems to have been involved in counting more widely, as attested to by the correspondence of Proto-Micronesian **p^wukiwa / *p^wukua* (referring to "units of hundreds") with **p^wuku(a)*: "node, joint, knot, knee" (Bender et al., 2003, 75f.; Jackson, 1986, 209). This points to a more general, yet poorly documented pattern of external representations in Micronesian languages, and perhaps also in the neighboring languages, as suggested by similar evidence for Palauan (Krämer, 1926, 155f.).

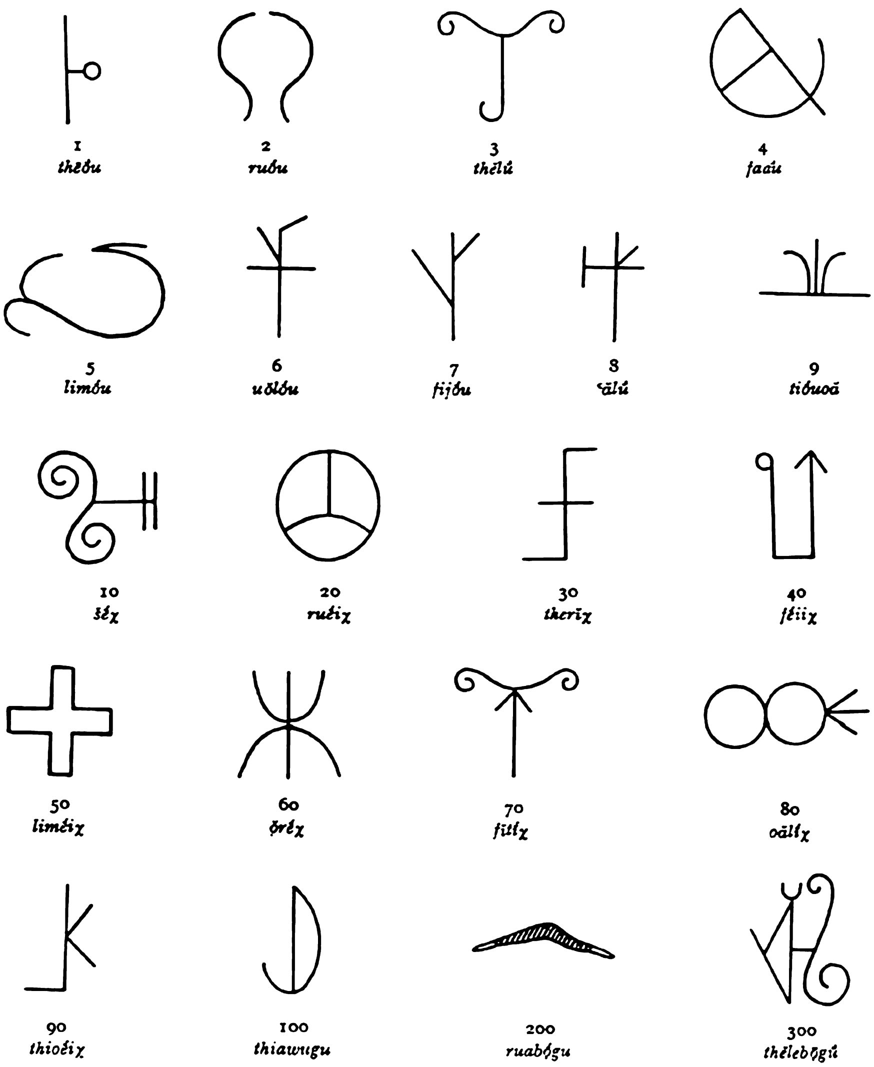

Figure 8. Part of the notation system in the Faraulep script, developed by Chief Saueeru in post-contact times. **Source:** Damm (1938, 212f.).

3.3. Non-Micronesian languages in Micronesia

As mentioned before, Micronesia is also home to several groups of people speaking non-Micronesian languages. Two of these languages form independent branches at a very high level in the Austronesian language tree (see Figure 3), another one descended directly from Proto-Oceanic, and the remaining two are Polynesian. They all inherited the same properties as the Micronesian languages: a base-10 system, a power numeral for at least 10^2, and most likely a set of numeral classifiers.

3.3.1. Chamorro

By the beginning of the last century, the Austronesian set of numerals in Chamorro had already been replaced with Spanish ones (Safford, 1904, 97), but some information on its traditional counting system was still available at that time. This Chamorro system was decimal, with specific numerals for several powers of the base up to 10^4, the word for which also indicated the "end of counting" (Safford, 1904, 100).

Interestingly, a cognate of the Proto-Oceanic word for 10, *fulu*, was used to refer to the multiples of 10 only in numbers from 20 onwards, whereas 10 itself and the numbers from 11 to 19 were composed from the numeral *manot*, literally meaning "a set" (Safford, 1904, 97f.). Chamorro also contained numeral classifiers that distinguished between animate entities, inanimate entities, and ways of measuring length, as well as at least one specific counting system: For fish, the counting unit was a pair, with 10 such pairs making a score (Safford, 1904, 97-101).

3.3.2. Palauan

The counting system in Palauan is also decimal, but less extensive than the one in Chamorro, with power numerals reportedly ending at 10^3 (Krämer, 1919). Palauan also makes use of numeral classifiers, but descriptions differ somewhat with respect to the content of these classes (Josephs, 1975, 470-477; Krämer, 1919, 331f.). While none of the sources explicitly mention a specific counting system, the distinction between a counting class that includes bananas and a separate class for bunches of bananas may point in this direction. Notably, Palau is one of two island groups in Micronesia, where several types of valuables reminiscent of money were already in use in pre-colonial times (Krämer, 1926, 156-160; Kubary, 1895). And, as in some Micronesian languages, knotted cords served the external representation of numerical information (Krämer, 1926, 155f.).

3.3.3. Yapese

Like its neighbors, Yapese has a decimal system reaching a power level of 10^3, but the words for the numbers 7 through 9 are composed, defined by their distance from 10 (i.e., $7 = 10 - 3$, $8 = 10 - 2$, and $9 = 10 - 1$), akin to the "Manus type" found in most of the Admiralty languages off the northeastern coast of New Guinea (Owens et al., 2018). Yapese also contains numeral classifiers, and it has traditionally made use of specific counting systems. Especially coconuts and fish, the latter threaded on strings, were counted in units of 10 (Müller, 1917, 125f.). The practice of collecting items on strings appears to have been reasonably widespread in counting, as indicated by the word for counting itself, which refers to the rib of a type of pandanus used as string (Müller, 1917, 126).

3.3.4. The Polynesian vicinity and the Outlier languages Nukuoro and Kapingamarangi

Central-Eastern Micronesia was in contact with speakers of Polynesian languages on a somewhat regular basis. This included visits by Polynesian voyagers from Tuvalu and presumably Samoa to the Gilbert and the Eastern Caroline Islands (Bender et al., 2003, I, 2; Kirch and Green, 2001, 75) as well as permanent settlements on Nukuoro and Kapingamarangi, south of Pohnpei. These two northernmost Polynesian Outliers were colonized by people speaking variants of the Ellicean-Outlier branch, closely related to Tuvaluan and Samoan (Kirch, 2000, 179). Nukuoro and Kapingamarangi have almost identical counting systems up to 10^3, which by and large preserve the Polynesian pattern. Yet, while the system in Kapingamarangi allegedly ends there, Nukuoro has developed the most extensive system in the entire region, with the highest numeral indicating 10^{10} (see Figure 4). Interestingly, some of the higher power numerals here appear to derive from Micronesian ones, specifically from Gilbertese (rather than Pohnpeian, which would be geographically closer). They also follow the Micronesian pattern of prefixing power numerals with the basic numeral for 1 for the higher powers, whereas in Polynesian languages this is common only for the lower powers (cf. Harrison and Jackson, 1984, 73). With regard to specific counting systems, non-generic vocabulary is reported for certain entities: in Nukuoro one each for humans, a few food items including breadfruit and coconuts, and pieces of coconut frond thatching in units of 10 (Carroll, 1965, 207), and in Kapingamarangi one for counting ripe coconuts in pairs and one for bunches of coconuts in units of 10 (Elbert, 1948, 253) whereas fish and taro are said to not be counted with special systems (Elbert, 1948, 30).

4. Assessing selected cases

In the previous sections, we explained the most characteristic properties of counting systems and highlighted their variability across the Micronesian languages. To some extent, though, this variability may be exaggerated due to poor descriptions or because data were collected after a system had deteriorated. Here, therefore, we look at some examples in more detail, first to illustrate the features of greatest interest and then to account for puzzling cases. This will also provide the background against which we try to assess (in section 5) how widespread the pattern of counting things in different ways was.

4.1. Paradigmatic examples

Three paradigmatic examples will be presented here: Pohnpeian serves to illustrate one of the most extensive counting systems in the region; for Woleaian, we have detailed descriptions of how a specific counting system was actually used; and Yapese is included as an instance of extensive exchange networks and their possible impact on counting.

4.1.1. Pohnpeian: Extending the system

When the Oceanic languages began to differentiate out of their ancestral language, they were inclined to extend their counting systems in one or more of three dimensions: in length by generating numerals for higher powers, in breadth by adding numeral classifiers, and in level by introducing a counting unit greater than 1 (Bender and Beller, 2017a).

Pohnpeian adopted all three of these options. Its counting system is among the most extensive systems in Micronesia, with power numerals as high as 10^9. In terms of breadth, the system has been extended in two related senses: by a set of close to 30 numeral classifiers (Rehg, 1981, 139), and by dividing them further into three subsets that differ in which form for 10 they employ: *e-hk*, *e-isek*, or *ngoul* (Rehg, 1981, 126-135). Finally, Pohnpeian also contains at least one clear instance of a specific counting system, in which the counting unit was 10, thereby further extending its range by the order of a power (Figure 9). Gulick (1872–1880) reports that the application of this specific system depended on how valuable objects were, with the numerals for the valued objects indicating smaller amounts, whereas Rehg (1981) explicitly refers to coconuts as being counted in units of 10.

Pohnpei is one of the three high islands in Central-Eastern Micronesia. As the island with the greatest land mass in the region, it has also been able to sustain the largest population, estimated at several tens of thousands in pre-colonial times (Kirch, 2000, 195). It gave rise to powerful chiefs and at one point in time was unified under a single dynastic rule seated in Nan Madol – an impressive megalithic architecture, the building of which is dated to between 1200 and 1600 AD (Kirch, 2000, 195-201). Contact with Polynesian-speaking regions, most likely Samoa, is attested to by linguistic evidence, kava consumption, and certain types of tools (Kirch, 2000, 200). Trading relationships may have also existed towards the west, indicated by shell 'money' that appears to have circulated all the way between the high islands of Western Micronesia and Pohnpei (Kubary, 1895, 3). Even though, against this backdrop, an interest in great numbers does not come as a surprise, the highest powers reached in the Pohnpeian system would nonetheless be hard to account for by practical purposes. Still, Pohnpeian is not exceptional in this regard. Almost identical power numerals are also to be found in Mokilese and Pingelapese, the languages most closely related to Pohnpeian. Systems one power level short of the Pohnpeian system are documented for Gilbertese and several languages of the Trukic branch (see Figure 6(a)). And in some Polynesian languages, including Nukuoro south of Pohnpei, even more extensive systems were in use. As noted above, this extent was expanded further in Pohnpeian by the counting unit of 10 in the specific counting system for coconuts.

With the exception of an additional numeral for the counting unit itself, the specific system uses the same power numerals as the regular system, yet in the former case they refer to ten times as many items as in the

Value	**Abstract counting**
1	*eh-d*
2	*a-ri*
3	*e-sil*
…	…
10	*koadoa-ngoul*

Value	***Counting objects (general), some examples:***				
	animate beings	*leaves or sheets*	*bundles on a string*	*round objects*	*yams & bananas*
1	*e-men*	*e-te*	*o-dun*	*eh-u*	*o-umw*
2	*rie-men*	*rie-te*	*ria-dun*	*ria-u*	*rio-umw*
3	*sili-men*	*sili-te*	*sili-dun*	*silu-u*	*silu-umw*
…	…	…	…	…	…
10	*e-hk*		*e-**isek***		***ngoul***
20	*rie-hk*		*rie-isek*		*rie-ngoul*
30	*sili-akan*		*sili-isek*		*silin-ngoul*
…	…		…		…
10^2	*e-pwiki*				
10^3	*kid*				
10^4	*nen*				
10^5	*lopw*				
10^6	*rar*				
10^7	*dep*				
10^8	*sapw*				
10^9	*lik*				

Specific counting	**Value**
*e-**isek***	10^1
rie-isek	
sili-isek	
…	
ngoul	10^2
e-pwiki	10^3
kid	10^4
nen	10^5
lopw	10^6
rar	10^7
dep	10^8
sapw	10^9
lik	10^{10}

Figure 9. Pohnpeian ways of counting: abstract, using classifiers, and in the specific counting system. **Notes:** Examples are taken from Rehg (1981); hyphens are added to facilitate segmentation. The classifier generating the counting unit of 10 in the specific counting system (*-isek*) is set in boldface, and so is *ngoul* as the first power numeral with shifting value (additionally shaded).

latter case. Let us illustrate this principle for coconuts, which require the classifier *-u* as long as only small quantities are involved (Figure 9). For larger quantities, the main counting unit is a set of 10, indicated by *-isek*. Ten of these units (or 100 single ones) are denoted by *ngoul*, a numeral that in other cases refers to 10 objects. Counting then proceeds with *-pwiki* (for 100 of these units), *kid* (for 1000 of them), and so on. That is, where coconuts are concerned, the general power numerals indicate a value that is ten times higher than the value they have when referring to ordinary objects.

Doane (1894, 439) describes a similar pattern, yet based on a counting unit of 4, in which the numerals of abstract counting are used to refer to multiples of 4 (with the word for 1 referring to 4, the word for 2 referring to 8, and so on). This counting pattern is said to be followed until the tenth number is reached (which refers to 40), and is then repeated to reach $40 + 40 = 80$, repeated again to reach $80 + 40 = 120$, and so on. Other than the high-power numerals or the specific counting of coconuts, however, this pattern has no parallel in Micronesia. A possible counterpart in Hawaiian is unlikely to be derived from a shared ancestral system, as claimed by Doane, as there is no known relationship between Hawaiian and Pohnpeian, either in terms of linguistic descent (beyond both being Oceanic languages) or in terms of culture contact. Yet, units of 4 are nothing other than pairs of pairs, and given the relatively widespread pattern of pair counting in Micronesia, it is not inconceivable that speakers of Pohnpeian simply developed such a system on their own. The fact that pair counting is (or was) employed in Pohnpeian itself (Doane, 1860, 11) – as well as in Nauru, possibly Kosraean, Gilbertese, Marshallese, and some of the languages in the Trukic branch – does lend plausibility to this hypothesis. Further support comes from the fact that in some of the latter languages,

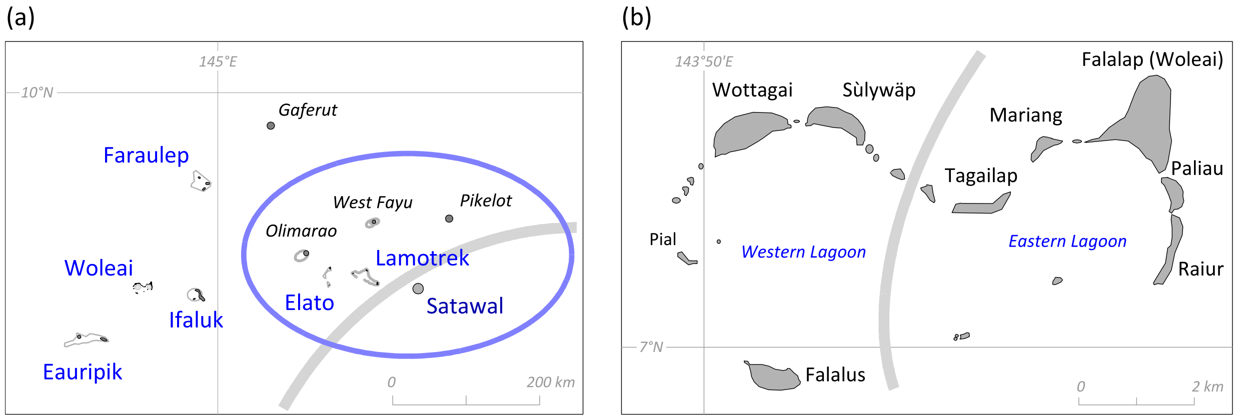

Figure 10. Geographical distribution of Woleaian. (a) Atolls with Woleaian-speaking populations. The grey arc demarcates the boundary between Woleaian- and Satawalese-speaking areas; the exchange network of "Greater Lamotrek" is indicated by the ellipse. (b) Islands of Woleai atoll. Here, the grey arc indicates the boundary between Western and Eastern Lagoon.

the numeral for 4 appears to allude to 2 (see section 3.2.1 and Figure 5(b)), hence possibly indicating two pairs.

4.1.2. *Woleaian: Specific counting systems in use*

Woleaian is spoken on several islands – the islands of Woleai atoll itself and the islands of Faraulep, Eauripik, Ifaluk, Elato, and Lamotrek (Figure 10(a)). For four of these islands, one distinct list of numerals each was provided by the *Hamburger Südsee-Expedition*: for Faraulep, Eauripik, and Ifaluk by Hambruch and Sarfert, as reported in Damm (1938), and for Lamotrek by Krämer (1937). In addition, information on counting in contemporary Woleaian as spoken on Woleai proper is provided by Alkire (1970) and Sohn (1975). These reports list similar entries for the power numerals up to 10^5 only, but differ with regard to both the existence and the form of the numerals beyond (Figure 11). For instance, a variant of *[se]ngit* indicates 10^7 on Woleai and Faraulep, but 10^6 on Eauripik, Ifaluk, and possibly Lamotrek. As the authors did not comment on these differences, it is hard to decide in hindsight whether they are due to errors in

Power level	**Woleai atoll**		**Faraulep**	**Eauripik**	**Ifaluk**	**Lamotrek**
	Alkire (1970)	*Sohn (1975)*	*Hambruch & Sarfert, reported in Damm (1938)*			*Krämer (1937)*
10^1	*se-g / se-ig*	*se-ig*	*še-χ*	*sa-ch*	*sa-k*	*se-g*
10^2	*su-pagui*	*se-biugiuw*	*thia-wugu*	*sa-wugu*	*sä-wugu*	*së-bugul*
10^3	*so-ngaras*	*sa-ngeras*	*thia-ṅeras*	*sa-ṅäras*	*sa-ṅaläs*	*sa-ngaras*
10^4	*se-n*	*se-n*	*the-n*	*sa-n*	*sa-n*	*se-l*
10^5	*se-lop*	*se-lob*	*thia-rouf*	*se-lowu*	*se-lop*	*(so-llop)*
10^6	*sú-pi*	*se-piy*	*thia-aṅarei*	*sa-ṅit*	*sa-ṅit*	*(se-ngit)*
10^7		*se-ngit*	*thia-ṅit*	*ṅarauli maṅeraul*	*sa-ṅalau*	*(sa-ngarai)*
10^8		*sa-ngerai*	*naroida-maṅeroid*	**jarot*	*ṅalaul maṅalaul*	*(sé-met)*
10^9					**jalot*	*(*kaimus)*

Figure 11. Power numerals reported for different atolls with Woleaian-speaking populations. **Notes:** Orthography has been simplified and hyphens are added to facilitate segmentation. Higher-power numerals for Lamotrek are set in brackets, as it is not entirely clear whether Krämer (1937, 411f.) intended to report these items also for Lamotrek or only for Fais. Numerals with an asterisk are reported to terminate the counting. The power numeral used as example in the text is shaded.

Power level	Ordinary counting		Specific counting			
	numerals	literal translation	numerals	literal translation	ordin. value	ritual value
10^1	***se-g / se-ig***	1 “unit of 10s”	***se-iäf***	1 “set of 10 coconuts”	10	8
10^2	*su-pagui*	1 “unit of 100s”	***sa-ngoal, se-g / se-ig***	1 “unit of 10s” [of a set of 10 coconuts]	100	80
10^3	*so-ngaras*	1 “unit of 1 000s”	*so-ngaras*	1 “unit of 1 000s”	1 000	800
10^4	*se-n*	1 “unit of 10 000s”	*se-n*	1 “unit of 10 000s”	10 000	8 000
10^5	*se-lop*	1 “unit of 100 000s”				
10^6	*sú-pi*	1 “unit of 1 000 000s”				

Figure 12. Woleaian ways of counting, exemplified for counting coconuts (Alkire, 1970). **Notes:** Hyphens are added to facilitate segmentation (illustrating that the initial *s* with subsequent vowel indicating 1 is replaced by other basic numerals in multiples of the respective power). The classifier generating the counting unit of 10 in the specific counting system (*-iäf*) is set in boldface, and so is the power numeral with shifting value, *se-g*/*se-ig* (additionally shaded). The numerals beyond appear to resume the values in ordinary counting (set in grey).

data collection and/or reporting, due to individual variability among informants (a possibility alluded to in Alkire, 1970, 8), or due to genuine regional differences.

The main reason, however, for showcasing Woleaian lies in the relatively detailed description of a specific counting system in use. Woleaian contains a rather large set of numeral classifiers, with the list reported by Sohn and Tawerilmang comprising 57 distinct entries (1976, 284f.). One of these classifiers, *-yaf* (in the spelling of Sohn and Tawerilmang, 1976) or *-iäf* (in Alkire, 1970), establishes a specific counting system for coconuts, chickens, and eggs, normally defining the counting unit as “groups of ten”. This system was also employed in the ceremonial collection and redistribution of coconuts as part of all funeral rites, yet with the modification that in this context, the counting unit comprised only 8 items (Alkire, 1970; and see Figure 12).

The inhabited islands of the Woleai atoll are assigned to two groups, Western Lagoon and Eastern Lagoon (Figure 10(b)), and are engaged in different types of exchange: The least formal, yet most frequently evoked ties existed within lagoon, whereas more formal ties connected the islands of one lagoon to the islands of the other. These links ensured a reciprocal exchange of gifts, particularly food, and the permission to exploit a partner’s reef and lagoon areas (Alkire, 1970, 6f.). For all funerals, coconuts were collected on the island of the deceased and the island’s partners in the same lagoon. Their redistribution then depended on whether or not the deceased was a chief. If the deceased was a commoner, the redistribution of the coconuts took the form of a (symbolic) exchange among those islands that were involved in collecting them. During such a funeral in 1965, a total of 12,232 coconuts (denoted as 1,529 *seiäf*, each of which comprises 8 coconuts) had been collected in each of the places involved (i.e., on Wottagai and Súlywäp on the one hand and Falalus on the other, all located in the Western Lagoon) and were symbolically exchanged between them. In practice, the coconuts were redistributed afterwards, predominantly to the homesteads on each island on an equal base, and some to those who had presented gifts (Alkire, 1970, 13). If the deceased was a chief, the coconuts were redistributed to delegations from the other lagoon, with an additional share to the specific inter-island partner there; to the neighboring islands Faraulep, Eauripik, Ifaluk, and Fais; to the islands of Elato, Lamotrek, and Satawal; and to Mogmog on Ulithi, which is senior in rank to Woleai. Part of these latter relations arose from joint participation in several nested levels of exchange networks. One of these networks, called the “hook” (also known as “Greater Lamotrek”) connected Elato and Lamotrek with Satawal (Alkire, 1965, 1970, 6); another one, detailed below, linked Yap in the West with all of the inhabited islands eastward up to the Puluwat area and Namonuito (Alkire, 1970, 1980).

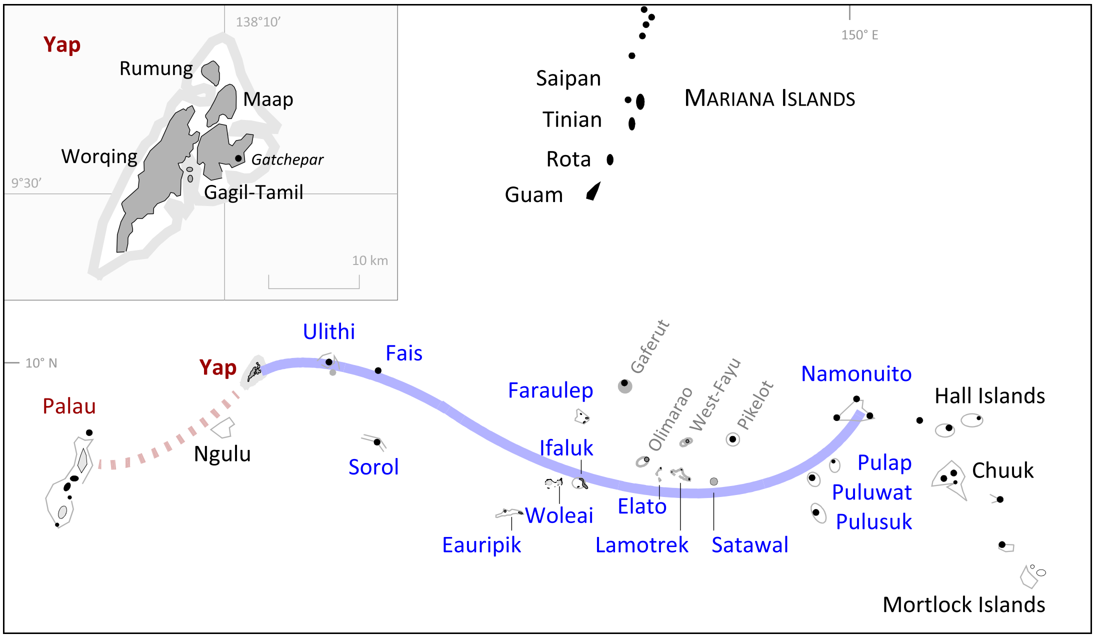

Figure 13. The greatest exchange network in Micronesia, *sawei*, linking Yap with Palau in the West and with a chain of 14 inhabited Caroline Islands in the East.

4.1.3. Yapese: The possible influence of exchange networks

In pre-colonial times, Yap was divided into villages and districts that formed two war parties. Different types of valuables, interpreted as money by Europeans (e.g., Kubary, 1895), were instrumental for maintaining the balance of power between these war parties and for negotiating political alliances (Berg, 1992). None of the material of which these valuables consisted was found on Yap itself, but had to be imported from other high islands in Western Micronesia or from the central and eastern Caroline Islands. This need for trading resulted in the largest overseas exchange system in Oceania, stretching across an overall distance of 1500 km from Palau in the Southwest to Namonuito in the East (Figure 13).

The first type of valuable, called *fei* or *palang*, consisted of huge wheels of aragonite, measuring up to several meters in diameter. In former times, the stone material may have come from the Mariana Islands, but in recent centuries was quarried on Palau (Kubary, 1895, 4; Kirch, 2000, 191). To some extent, this ‘stone money’ was used to offset the prevalence of the valuables obtained by other districts through their relationships with the islands to the east (Berg, 1992, 155). The second type of valuable or ‘shell money’, called *gau*, consisted of discs of Spondylus shell, which were imported from Etal atoll (in the Mortlock Islands), Eauripik atoll, and Udot island (in Chuuk Lagoon), presumably since the 12th century (Berg, 1992, 150f.; Kirch, 2000, 193). While these two types of valuables were either hard to move or inalienable on more principal terms (Kubary, 1895, 3), this differed for a third type, the *yar*, which consisted of mother-of-pearl shells on strings. In addition, turmeric powder and other valuables were occasionally used to cover expenses (Kubary, 1895, 6).

The exchange system enabling this long-distance trading was called *sawei* (Alkire, 1977, 52; Hunter-Anderson and Zan, 1996; Lessa, 1950; Sudo, 1996). It linked Gatchepar village in the Gagil district on Yap to all of the inhabited atolls and islands from Ulithi to Namonuito (Figure 13). These islands were organized almost linearly in a ranked hierarchy descending eastwards, with Yap being the most senior (Lingenfelter, 1975; Petersen, 2000). Yet, all parties benefited from the *sawei* (Alkire, 1980). For the atoll-dwellers, who controlled the navigational skills and sailing technology essential for sustaining the exchange, it served as an “insurance policy for survival” (Alkire, 1977, 52), providing them with access to high island resources and with shelter in times of hardship. For their partners in the Gagil District, both the goods they received and the very fact that they were able to muster them, combined with the prestige linked to being generous in return, were instrumental in negotiating their position within Yap (Petersen, 2000).

Notably, the *sawei* involved six languages (Yapese, Ulithian, Woleaian, Satawalese, Puluwatese/Pollapese, and Namonuito) – even seven if we consider Palau – but none of the other languages seem to have had any influence on the Yapese counting system (Bender and Beller, submitted for publication). Its extent is one of the smallest in all of Micronesia (with the highest power numeral indicating 10^3), apparently unaffected both by the extent of the overseas exchange network and by the presence and salience of money. However, the specific counting systems in Yapese and the practice of counting objects bundled on strings (Müller, 1917, 125f.) open up the possibility that the use of such counting units were shared when trading.

4.2. *Puzzling cases*

In several cases, a closer look at the described peculiarities is warranted to distinguish which of the reported elements are genuine characteristics of a system in that language, and which were more likely introduced in colonial times. To highlight a diverse set of issues, we focus on Kosraean as an instance of a presumably collapsed system, Marshallese as an instance of a distinctive system structure, and Merir as an instance of a confusing description.

4.2.1. *Kosraean: A presumably collapsed system*

Despite its position close to the joint common ancestor of the Micronesian languages, contemporary Kosraean stands out by deviating from the shared patterns in various ways: It contains the lowest number of indigenous power numerals, the lowest number of numeral classifiers (if we disregard contemporary Marshallese), and is one of the few languages that appear to lack specific counting systems,[6] which otherwise are spread across the language tree including Nauru. This is particularly noteworthy given that Kosrae is one of the few high islands in Central-Eastern Micronesia, which at times sustained a population of several thousand people and a powerful and arguably centralized chiefly polity, and which maintained inter-island ties to the Marshall Islands, the Gilbert Islands, and Pohnpei, as well as presumably to Polynesian settlements further south (Bender et al., 2003, I, 2; Kirch, 2000, 201-206). This raises the question of how accurately the current system actually reflects the traditional counting.

Unfortunately, information on the Kosraean ways of counting is sparse. The only available sources are a reference grammar from the 1970s (Lee, 1975) and a brief analysis of linguistic structures in present-day number expressions (Vesper, 1970), while the reports from the *Hamburger Südsee-Expedition*, which for many of the other islands do contain valuable information on numbers, are not forthcoming in this case (Sarfert, 1919, 1920). The main reason for both the paucity of information and for a putative depletion of the counting system may lie in the devastating consequences of introduced diseases. In the late 19th century, Kosrae was severely depopulated (numbers had gone down from several thousand in the past to a few hundred); the capital Lelu, once an impressive site of megalithic architecture, had become an abandoned ruin; and the sociopolitical structure had collapsed (Kirch, 2000, 201f.; Sarfert, 1919, 7). It is thus highly likely that the traditional ways of counting had been richer and more extensive than the contemporary system and even older reports suggest.

4.2.2. *Marshallese: A distinctive structure*

Marshallese is special in several ways. It has adopted a sub-decimal structure for numbers 6 through 9, while at the same time using a decimal system that extends to 10^4 and containing, at least in pre-colonial

[6] Vesper (1970) describes a couple of distinct "measures" for whole breadfruit as well as cut breadfruit that appear to share characteristics with specific counting systems, but her description lacks sufficient details for a conclusive assessment.

times, one of the largest collections of specific counting systems in Micronesia. These systems alternatively adopted pairs, tens, and even scores as counting units (Erdland, 1906; Hernsheim, 1880, 24), which further extends the value of the highest power numeral by factor 20.

While the latter properties are consistent developments characteristic of Micronesia, the sub-decimal structure (Figure 5(a)) is rather puzzling. It introduces irregularities into an otherwise regular system, which are cognitively taxing and make it more cumbersome to handle. Even if one wanted to give up basic numerals, there are more regular and more parsimonious ways of doing this than creating terms such as "$3 + 3 + 1$". In light of the fact that Marshallese continued to employ general Micronesian words for 10 and 100 – and has developed its own words for 1000 and even (pairs of) 10,000 – it appears highly unlikely that the numbers between 5 and 10 fell out of use at some point and needed to be reinvented later. In fact, in two of the specific counting systems, even the counting unit itself exceeded the numerical range referred to by these compositional numerals of the primary counting cycle. Despite their residence in the northeastern corner of Micronesia, speakers of Marshallese were not isolated populations either, which may otherwise have accounted for a decreasing interest in numbers; rather, they were expert sailors, frequent voyagers to at least Kosrae and Pohnpei (Bender et al., 2003, I, 2; Finney, 1998; Hage and Marck, 2002; Lewis, 1994), and also in contact with people in the central Caroline Islands (Jackson, 1983, 130).

Given its position in the language tree – and the fact that both the languages that split earlier and those that split later have retained Proto-Micronesian basic numerals – the change in Marshallese must have occurred *after* the settlement of Eastern Micronesia, and was most certainly a late local innovation. One possibility is that the numerals for 6 through 9 originate from one of the specific counting systems, presumably one that employed pair as its unit.

The structure of the numerals in question point in this direction, despite little consensus on how exactly they should be segmented: According to Erdland (1906), these words refer to $3 + 3$ for 6, $3 + 3 + 1$ for 7, $2{\cdot}4$ for 8, and $2{\cdot}4 + 1$ for 9. In a later publication, Erdland (1914, 149) translates 8 and 9 as $2{\cdot}5 - 2$ and $2{\cdot}5 - 1$, respectively. Hernsheim (1880, 24) interprets the words for 8 and 9 as $10 - 2$ and $10 - 2 + 1$, respectively, and so does Zewen (1977, 114) in translating 8 as "give two [more to complete 10]" and 9 as 8 [i.e., "give two"] $+1$. Under all of these interpretations, 6 and (presumably) 8 would be arrived at by pair counting, and 7 and 9 by adding a single to the preceding pair. Importantly, a tradition of counting things in pairs in Marshallese has been described by both Doane (1860) and Erdland (1906).

If this hypothesis is correct and the composed numerals indeed originated from a pair counting system, the question remains why this substitution would have happened. The fact that the descriptions of Hernsheim (1880) and Erdland (1906) differ in several regards may point to actual differences between regional variants, to a blending of previously distinct systems, perhaps as a consequence of foreign influence, or to imprecise observations. Whereas regional differences seem rather unlikely, as there is otherwise very little dialectal variation within Marshallese (Marck, 1986, 256), the intrusion of elements from one counting system into another – either in actual practice or in mistaken reports from outside observers – has happened repeatedly (compare the instances in section 3.2.2; and see Bender, 2013).

Interestingly, the pair counting system described by Erdland (1906) also used a sub-decimal structure, yet of an entirely different type: While pairs for 1 through 4 are counted with the ordinary numerals from 1 through 4, the numeral for 5 pairs is distinct (*jabejet*), and is used as subbase to produce composite numerals for 6 through 9 pairs (i.e., *jabejet-im-juon*: $5 + 1$, *jabejet-im-ruo* = $5 + 2$, etc.). The numeral for 10 (pairs) is again a distinct lexeme (*jo-kor[en]*), to be then counted with the *ordinary* numerals from 1 through 9. The numeral for 100 (pairs) is the same as that for 10 single items, suggesting that the prime counting unit in this system was actually 20 rather than 2. The numerals for 1000 and 10,000 pairs were then again distinct: *ji-kit* and *ja-ñar*, respectively.

Finally, a system employing the 'original' decimal set of numerals seems to have survived alongside the two sub-decimal patterns. This set (which is reported to be very similar to the Pohnpeian ones) was used when "the *knots*, into which a cocoanut leaf or pandanus may be tied, are counted—counted for the purpose of foretelling the future" (Doane, 1860, 10; italics in original). Yet, the numerals from 6 to 9 were each shifted by one position: the numeral commonly used for 6 referred to 7 in this Marshallese system, the one for 7 referred to 8, 8 to 9, and 9 to 6. In other words, while Marshallese clearly started off with the common set of basic numerals, an obvious concern with specific counting systems seems to have resulted in a range of language-specific modifications.

4.2.3. *Merir (Sonsorol): A confusing description of pair counting*

On Merir, a small island south of Palau where a variant of Sonsorol is spoken, Eilers (1935, 380) observed a method for pair counting that, as she states, was used uniformly for all things. The description of the method is somewhat confusing, though, and basically consists of the list of numerals presented in Figure 14.

The most obvious peculiarity is that entries for 6 through 9 pairs and for 20 pairs are missing. Leaving some entries out in the interest of saving space is a common practice and justified when the principle for composing the missing numerals is reasonably obvious. But why, then, drop 6 through 9 while mentioning those for 60 through 90? And even more puzzling, why mention all multiples of 10 except for the first one in this list, 20?

What aggravates matters further is that the composition principle implied in the description is by no means trivial: Composing numerals for 6 to 9 pairs in line with the pattern described would appear to be cumbersome at any rate, and composing a numeral for 20 pairs virtually impossible. Almost all numerals used in pair counting are contractions of two numerals, the latter of which points to the value to which the numeral refers.[7] Now, for the entries in the left half of Figure 14, this relevant numeral seems to indicate the total amount of single items counted. For instance, *tiu-ẓeik* (literally "9...10") is reported to indicate 10 *items* (or 5 pairs). For the numerals in the right half of the figure, however, the latter numeral seems to indicate the amount not of single items, but of pairs counted: *tio-ẓauoki* ("9...100") is now reported to indicate 100 *pairs* (or 200 items).

This description leaves us with three divergent possibilities. The first possibility is that what Eilers described might simply have been common practice at the time she observed it. This would suggest that, at some point in the past, an originally consistent system had partly collapsed, resulting in a hybrid system whose users would not be bothered by the apparent inconsistencies. The other two possibilities share the

Unit	***Numerals***	***Composition***	***… re-coded as***
1 Paar	*ta-luie*	1…2	2 (pairs [= 4])
2 Paar	*aruuaiṅ* [a]	?	4 (pairs [= 8])
3 Paar	*rim-oor*	5…6	6 (pairs [= 12])
4 Paar	*fiẓi-uar*	7…8	8 (pairs [= 16])
5 Paar	*tiu-**ẓeik***	9…10	10 (pairs [= 20])
10 Paar	*tiu-liek*	9…20	20 (pairs [= 40])

[a] The numerals for 3 and 4 would be *ẓor* and *fā* (see also section 3.2.1 and Figure 5(b)).

Unit	***Numerals***	***Composition***	***… coded as***
30 Paar	*tiu-ẓeriek*	9…30	30 (pairs)
40 Paar	*tio-feik*	9…40	40 (pairs)
50 Paar	*tio-rimeik*	9…50	50 (pairs)
60 Paar	*tio-orok*	9…60	60 (pairs)
70 Paar	*tio-fiẓiek*	9…70	70 (pairs)
80 Paar	*tio-uariek*	9…80	80 (pairs)
90 Paar	*tio-tineik*	9…90	90 (pairs)
100 Paar	*tio-**ẓauoki***	9…100	100 (pairs)

Figure 14. Complete list of Merir numerals to be used when counting objects in pairs ["Paar"], as reported by Eilers (1935, 380; orthography simplified), with composition of numerals and suggested reinterpretation (shaded) being added. The regular numerals for 10 (*ẓeik*) and 100 (*ẓauoki*) are printed in boldface; hyphens are added to facilitate segmentation.

[7] The one exception is the second numeral in this system, *aruuaiṅ*, which – instead of being composed from *ẓor* (3) and *fā* (4) – appears to contain an older variant of the lexeme for 2, thereby reflecting a pattern also observed in other Trukic languages (see section 3.2.1 and Figure 5(b)).

assumption that the system was consistent, but its description mistaken. In either case, the unit for the numerals in the left half of Figure 14 would have to be re-coded – as suggested in the shaded part – as 2, 4, 6, 8, 10, and 20 (instead of 1, 2, 3, 4, 5, and 10), respectively. What remains open is the value of the unit to which these numbers refer: If we consider the meanings rendered in the *left* half of Figure 14 as the correct ones, then the numbers should refer to *single* items (e.g., *tiu-ẓeik* would then indicate 10 single items, or 5 pairs, as stated by Eilers); if, by contrast, we consider the meanings rendered in the *right* half of Figure 14 as the correct ones, then the numbers should refer to *pairs* of items (e.g., *tiu-ẓeik* would then indicate 10 pairs of items, or 20 single items, as indicated by Eilers for numerals from 30 onwards).

Either way, the re-coding addresses two issues simultaneously: It renders a consistent system of pair counting, and it dissolves the gaps in Eilers' description. Even if the first of the three possibilities mentioned above were true, and what Eilers described was common practice by the early 20th century, we would still have strong reasons to assume that one of the other two possibilities gives a more accurate picture of the original system in the past. What we cannot decide, based on the available information, is which of the two readings is correct: the one according to which the numerals refer to the *value* of the pair, or the one according to which the numerals refer to the *name* of the pair.

The former reading would be a basic form of pair counting, involving only a practical simplification by taking two items at a time, while still referring to them by the two numbers involved; for instance yielding 2 pairs of bananas referred to as 4 bananas. An instance of this pattern was described for Puluwatese, in which objects such as fish, breadfruit, and coconuts were counted in twos: *yét-é-rúúw* (1...2), *yel-u-fáán* (3...4), *lim-o-woon* (5...6), *fús-u-waal* (7...8), and *ttiw-é-heeyik* (9...10) (Elbert, 1974, 111f.).

The latter reading would be an amplified form of pair counting in that it extracts factor 2 from the quantity referred to (just as the system for coconuts extracts factor 10). In fact, by providing numerals for *even* numbers of pairs only, it in practice increases the counting unit to 4, which renders this the most fascinating possibility. Yet, this also begs the question of how likely such a system would be. With Doane's (1894, 439) claim of Pohnpeian containing a system that adopts 4 as its counting unit (section 4.1.1), there would be one more instance of a similar type in Micronesia, even though separated from Merir in both space and time by a range of languages that entirely lack respective evidence (for even more remote instances in Eastern Polynesia, see also Bender and Beller, 2006a,b, 2014). Some of the Trukic languages in between, however, do use a numeral for 4, similar to the one in Merir, which is not derived from the Proto-Micronesian root for 4 but appears to involve a component alluding to 2 (see section 3.2.1 and Figure 5(b)).

5. Reconstructing general patterns

In section 3, we began with presenting some general features that are characteristic of the ways of counting across Micronesia, and then zoomed in to discuss single instances that deviate from the general pattern. Here, we zoom back out in an attempt to reconstruct, from patchy evidence in today's languages, more general patterns and principles in pre-colonial times. In so doing, we focus on two features that can be considered hallmarks of counting systems in this region: their range of power levels and their specific counting systems. Key to the understanding of both are the numeral classifier systems, which provide a rich and easily expansible set of counting units.

5.1. The numeral classifier system as the source of counting units

As mentioned earlier, number words in classifier languages typically consist of two components: a basic numeral and a classifier. Basic numerals refer to the numbers of the primary counting cycle. They stand by themselves only in abstract or serial counting, in which enumeration proceeds until the base is reached and then restarts from 1. When counting concrete objects or quantities, these numerals are prefixed to a second morpheme, traditionally denoted as numeral classifier. In Micronesian languages, power numerals behave

Quantity		Numeral compound (components)	Literal translation
1	bird	*se-* ***mal***	one [unit of animates]
2	birds	*riuwe- mal*	two [units of animates]
10	birds	*se-* ***ig***	one [unit of 10s]
12	birds	*se- ig me riuwe- mal*	one [unit of 10s] and two [units of animates]
20	birds	*riuwe- ig*	two [units of 10s]
100	birds	*se-* ***biugiuw***	one [unit of 100s]

Figure 15. The typical pattern of number word composition, illustrated for counting birds in Woleaian. A basic numeral (e.g., *se-* or *riuwe-*) is prefixed to a 'countable sort', here *-mal* for animates, and *-ig* and *-biugiuw* for 10 and 100, respectively (Sohn, 1975, 80).

in many ways like classifiers rather than like the basic numerals (for illustration, see Figure 15). They do not stand by themselves, but are suffixed to a basic numeral (including 1), that is, they are entities to be counted, whereas the basic numerals are the entities with which to count. This is why both power numerals and conventional classifiers are jointly categorized by scholars of Micronesian, alternatively as "classifiers" (Sohn, 1975), "numerative bases" (Dyen, 1965), "countable bases" (Harrison and Jackson, 1984), or simply "bases" (Benton, 1968). To avoid confusion with the linguistic category of (numeral) classifiers and with the mathematical base of numeral systems, we tentatively treat this category as "countable sorts".

Their divergent semantics warrant further distinction into those operating on *qualitative* grounds (i.e., the bulk of classificatory or *sortal* classifiers) and those operating on *quantitative* grounds (i.e., the *mensural* classifiers): The former basically pool items into classes, while the latter (also) specify a unit of measurement or quantity (Harrison and Jackson, 1984, 62f.; Sohn, 1975, 59). All of these countable sorts serve the same function in that they provide a unit to the entities that are to be counted, yet they differ in what they explicate: The sortal classifiers exclusively specify the entity, setting the counting unit to 1, whereas the mensural classifiers specify the unit of counting or measurement, typically regardless of entity. Frequent instances of mensural classifiers are "finger length", "parts of", "bundle", or "handful". In the specific case of the power classifiers, the unit corresponds to the respective power level (e.g., for *-biugiuw* in Figure 15, this would be "units of 100s").

Some of the mensural classifiers, however, combine numerical information with a specification of entity, such as when indicating "pairs of breadfruit" or "a set of 10 coconuts", thereby generating a *specific counting system* (Bender and Beller, 2013, 2017a). While boundaries between these categories may occasionally be blurred, the differences in value and scope are critical for how counting systems are structured, which is why we treat them distinctly in the remainder of this discussion.

5.2. *Power numerals*

One of the hallmarks of counting systems in the Micronesian languages that has fascinated and bewildered researchers time and again is the power numerals that refer to numbers far beyond imagination (cf. Figure 6(a)). Yet, even if some of these numerals appear breathtaking, it seems unwarranted to dismiss them as "fanciful" translations of lexemes that indicated great numbers only in a "poetical" sense (Elbert and Pukui, 1979, 160f.). Rather, in agreement with Harrison and Jackson (1984), we argue that even the higher powers should be considered as genuine numerals, for several reasons.

First, the power numerals compiled here were provided by native speakers as part of counting sequences. Notably, some languages contain a distinct counting sequence for the power series alongside the counting sequence for basic numbers, indicating that both the existence and the order of the power numerals were subject to convention. Agreement on the fact that a numeral is the tenfold of the one immediately preceding it in this sequence is the very definition of a power numeral.

Admittedly, data collected at different points in time and in different locations do not always render a coherent picture of the local ways of counting. Variability in the range of power numerals and their precise form or value is considerable, sometimes even for different speaker populations of the same language, as in the case of Woleaian (see section 4.1.2). Still, variation is much less pronounced than one would expect had the elicited numerals been spontaneous inventions. While the power numerals up to 10^4 are widely shared across languages, several of those in the higher ranges appear to be local innovations, yet they often have semantic meaning in common, and others do recur in related languages (see also Harrison and Jackson, 1984). Since most of the higher power numerals refer to quantities that are not needed on a daily basis, variability in this regard may be unsurprising. For all we know, high-power numerals might have been inherited from an ancestor language and might have dropped out of use at some point in time, only to be replaced by a novel word later on when in renewed demand. Given how simple it is in Micronesian languages to just add another classifier to an existing set, expanding the extent of the counting system along this dimension may well have happened repeatedly (Bender and Beller, 2017a; Harrison and Jackson, 1984).

Second, large quantities did play a key role in the economic, political, social, and ceremonial activities of Micronesian speakers. As described earlier for Woleai, a total of 12,232 coconuts, meticulously counted, was collected on each of two rather small islands on the occasion of a commoner's funeral. While the population size on these islands was confined to less than a dozen homesteads, it numbered in the tens of thousands on Pohnpei. Assuming that similar practices as on Woleai were also in place in other parts of Micronesia, the quantities required on larger islands and/or for social events involving people of higher and chiefly rank would be even greater. Likewise, the redistribution of yields gained in joint efforts is reported to have involved counting to high numbers: The need for numerals up to 10^7 on Fais and potentially Lamotrek, for instance, was attributed by Krämer (1937, 412) to the quantities of a specific type of fish counted during redistribution after village hauls. In addition to these local practices, inter-island ties such as the *sawei* described earlier involved the exchange of tributes and gifts on an even larger scale (Alkire, 1970; Lessa, 1950).

A third reason to assume an inherent interest in high numbers among Micronesian speakers is the diversity in practices revolving around counting. The chances are that it was not so much the amount of items per se that was important in many contexts, but rather an accurate assessment of this amount. This possibility is attested to by both the counting process itself and the external representations of its results by way of pebbles, nicks on a stick, or knotted strings (Bender et al., 2003; Jackson, 1986; Kayser, 1993 [1936]; Krämer, 1926). The desire to record quantities culminated in local inventions of numerical notations in the 19th century (Damm, 1938, 212f.). In pre-colonial times, keeping track of large numbers and the calculations involved in compilation and redistribution were arguably the responsibility of specialists (Hughes, 1982). Yet, counting exercises were more widespread, as suggested by counting games, an instance of which is described by Hambruch (1914) for Nauru.

To sum up, despite considerable variation in power numerals, there is ample evidence for the conclusion that large power levels were a widespread feature of Micronesian counting systems, certainly as local innovations after settlement, but possibly already available in ancestral languages within the Micronesian branch. In fact, the systematic patterns across the language tree suggest that the initial system was of considerable extent and may have diversified through both contractions and expansions, perhaps even repeatedly, in the process of migration, settlement, partial isolation, and reconnecting. At any rate, a genuine interest in large numbers in the region is attested to both linguistically and ethnographically. While socioeconomic purposes, such as keeping track of great amounts of tributes and gifts, may have contributed to this interest, they need not have been its only source. The very prestige linked to large quantities, and hence to great numbers, may occasionally have been sufficient to maintain the counting sequence of power numerals and keep it productive. All that was needed to extend it to ranges beyond practical usefulness was a system of 'countable sorts' that included power numerals alongside the numeral classifiers. The most remarkable of these extensions led to the generation of specific counting systems.

5.3. Specific counting systems

The second and arguably even more fascinating hallmark of Micronesian ways of counting is the specific counting systems that add another level to the means for extending already extensive systems. Here, we briefly recount the principles for generating such systems, before mustering evidence on their distribution and discussing the two subtypes prevailing in Micronesian languages.

5.3.1. Principles for generating specific counting systems

Specific counting systems are implemented by introducing a new counting unit. This can be achieved without marking. For instance, pair counting could be conducted by simply using the exact same numerals as in counting singly, with the counting unit being implicitly understood (for such an instance in Tahitian, see Henry, 1928; Lemaître, 1985). Still, all Micronesian systems used linguistic markings for most of their specific counting systems. The principle for generating these is best illustrated for Chuukese, which is the language in Micronesia with the most extensive system of numeral classifiers (Benton, 1968; and see Elbert, 1947). These include a set of classifiers that specify both the counting unit and the entity to be counted: *-yáf/-yef* denoting 10 coconuts, *-ttit* denoting 10 breadfruit, and *-ccoc* denoting 10 packages of breadfruit pudding, as well as *-fóc* denoting respectively 5 fish or 20 or more breadfruit, and *-sópw* indicating half the quantity of *-fóc* applied to breadfruit (hence 10 or more). While we lack more detailed information on the other languages of the Trukic branch, at least one of these classifiers is sufficiently widespread there to be reconstructed as Proto-Trukic **yafi* (Bender et al., 2003), attested to at least in Mortlockese, Chuukese, Puluwatese, Carolinian, and Woleaian (Figure 6(b)). In all instances where it occurs, it serves to establish a counting unit larger than 1, reflecting a more general pattern of counting coconuts in units of 10 (or 8 during funerals on Woleai). Additional practices involve counting coconuts and/or other items in pairs, and/or adopting other counting units, as possibly 4 in Pohnpeian, and 20 in Marshallese (see Figure 7).

5.3.2. Evidence on the distribution of specific counting systems

The fact that the specific counting systems occur across the language tree, from Nauru to Merir, suggests that such systems may also have been used in the remainder of languages, and that apparent gaps may simply be instances of undiscovered occurrences. Tentative evidence for this assumption is provided by the following considerations (see also Figure 16):

(a) First, reconstruction of the classifier **yafi* for Proto-Trukic implies that a counting unit of 10 would have been in place, at some point in the past, in all languages of the Trukic subbranch, including those for which we do not have confirmatory evidence. Usage of such a system would be particularly likely for

	Nau	Kos	Gil	Mah	Ponapeic			Trukic												
					Pif	Mkj	Pon	Mrl	Chk	Puw	Nmt	Pfa	Tpv	Cal	Stw	Woe	Mpy	Uli	Sov	Tox
(a) *yafi								+	+	+	(+)	(+)	(+)	+	(+)	+	(+)	(+)	(+)	(+)
(b) alter	(?)		+	+	+	+	+	+	+	+	+	+		+		+		+		(?)
(c) pairs	+	(?)	+	+			+		+	+									+	

Figure 16. Indicators for the existence (or previous existence) of specific counting systems in the Micronesian languages: (a) a reflex of **yafi* for units of 10, mostly for coconuts; (b) different numerals for the same number used in parallel; and (c) pair counting. **Notes:** A shaded cell with "+" indicates attested occurrence, "(+)" indicates inferred occurrence, "(?)" indicates tentative evidence.

Satawalese and Ulithian, as speakers of these languages keep formal exchange relations with Woleai, where this system is used and from where they receive gifts that are counted in this very unit, certainly during chiefly funerals and perhaps at other occasions as well (Alkire, 1970).

(b) Second, existence (or previous existence) of specific counting systems is also highly likely for languages that employ two or more distinct lexemes for 10 in parallel, as is the case, for instance, in Pingelapese, Mokilese, and Ulithian. A specific case can be found in those five Trukic languages that use a reflex of **ŋawulu* for 10 itself, yet a reflex of **ik[ae]* for its multiples, a pattern that potentially results from blending two systems. The very same languages also use two distinct numerals for 4, one of which may arise from pair counting, hence providing further evidence for specific counting systems in these languages. An alternative possibility is that these languages already inherited the hybrid system from a common ancestor. However, while they are geographical neighbors at the Eastern end of the Trukic language chain, they do not belong to the same linguistic subbranch, which points to a later, shared innovation in the region rather than to linguistic inheritance.

(c) Third, pair counting is explicitly mentioned for seven languages, yet interestingly enough based on divergent principles for how numerals are mapped onto quantities: Nauru is reported to speed up counting by using even numbers only (Kayser, 1993 [1936]); Gilbertese basically employs the same numerals for 1 through 5 for referring to the amount of alternatively single items or pairs of items (Bingham, 1908), and so does Marshallese, which, however, from 5 onwards applies number words composed from subbase 5 (Erdland, 1906); Chuukese and Puluwatese contract two subsequent numbers for indicating the pairs (Elbert, 1974; Krämer, 1932), and so does Sonsorol, yet with modifications (Eilers, 1935; and see section 4.2.3). Pohnpeian might be added here as an instance of counting not only in pairs, but possibly also in pairs of pairs (see section 4.1.1).

Merging the substantive and the tentative evidence of indicators for the existence, or previous existence, of specific counting systems suggests that such systems were indeed in use in each of the Micronesian languages, at least at some point in time (for the exceptional status of Kosraean, see section 4.2.1).

Another, more general piece of evidence for a pan-Micronesian pattern of specific counting is the shift of value in the power numeral **ŋa-ratu*. While clearly originating from Proto-Oceanic **Ratu(s)*, which referred to 100, the Proto-Micronesian reflex already refers to 1000 (Bender et al., 2003; Harrison and Jackson, 1984). This shift points to the possibility that an additional counting unit of 10 became inserted in the power series early on. Specific counting systems likely predated even the diversification of the Oceanic, if not the Malayo-Polynesian language branch, as attested to by the presence of such systems also in neighboring Polynesia and Melanesia (Bender and Beller, 2006a, 2007, 2014; Churchward, 1941; Hill and Unger, 2018) and in non-Micronesian languages in Micronesia such as Chamorro and Yapese.

To sum up, in spite of the variation in specific counting systems, the available evidence warrants the conclusion that this tool was shared widely across the Micronesian (and even Oceanic) languages, with most certainly a joint system for counting coconuts in units of 10 and arguably a pattern of pair counting for coconuts and/or other important fruit items. The observation that similarity of these systems is greater in Micronesia than in Polynesia (Bender and Beller, 2006a, 2014) suggests that the Polynesian languages inherited the principle, but implemented it in distinct manners, whereas the Micronesian ones more likely inherited one system in toto and then developed it further locally.

5.3.3. Subtypes of specific counting systems and their putative origins

As we have seen, the most widespread if not ubiquitous specific counting system (besides the general one) operates on a counting unit of 10, followed by one operating on pairs. These two types of system share a number of characteristics, but they also differ in remarkable ways. These differences, we propose, arise from how the counting units originated: the former as a *conceptual* innovation in support of calculation, the latter as a *practical* innovation for counting. While a unit of 10 almost naturally falls off a decimal system, this is not true for the unit of 2, which by contrast is easier to 'handle'. Taking two objects in one hand (or one in each hand) works well for most types of objects, including coconuts. It works less well for counting things in units of 10, and is impossible for coconuts, to which almost all systems based on a unit of 10 were applied.

If pair counting arose out of practical rather than conceptual considerations, then the variety in mapping numerals onto quantities is easier to account for: There is simply no single, self-suggesting way in which pairs should be counted; distinct inventions of pair counting would therefore be unlikely to come up with the exact same convention.

The pattern for counting units of 10 is much more consistent, simply because these units are derived from the existing linguistic structure. All Micronesian languages inherited a set of numeral classifiers, some of which specify measurement and/or quantity, including a substantial number of power numerals. With such a system already in place, inserting a new counting unit emerges almost as a natural step (Harrison and Jackson, 1984), especially when looking for means to facilitate mental arithmetic (Bender et al., 2015). Such a conceptual link of the specific counting system with the decimal structure of the main system is supported by several pieces of evidence. First, almost all classifiers that instantiate a new counting unit do so for units of 10 (the most notable exception being Chuukese discussed further below). Second, in the one instance where the value of the counting unit is reported to shift depending on context (Woleaian), it shifts from 10 (the decimal 'default') to 8 (the ceremonially valued number; cf. Biggs, 1990). And third, usage of the counting unit 10 is always lexically codified and is done so in similar ways, even if not with the exact same classifier, across the Micronesian languages.

The three instances in which additional counting units were employed most likely derived from either of the major units. Chuukese uses five classifiers to specify new counting units: three of these for units of 10, the other two for units that almost definitely arose from halving or duplicating this unit, hence involving 5 and 20 as the counting unit. Interestingly enough, none was employed for 2 although pair counting was practiced. The single, albeit somewhat debatable, instance of a counting unit of 4 in Pohnpeian, on the other hand, was more likely arrived at by counting pairs in pairs.

Finally, while the unit of 20 in Marshallese may appear similar to the one in Chuukese, as they share the same value, these two actually differ in important aspects. The lexeme denoting this unit is a classifier in Chuukese (*-fóc*), but a power numeral in the case of Marshallese (*[jo]koren*). More importantly still, the respective units are arrived at based on divergent principles: In Marshallese, it clearly results as 10 times the unit of a pair, whereas the Chuukese instance is more likely a result of duplicating the unit of 10. Despite these differences, however, the Marshallese instance also demonstrates that – even if the two main types of specific counting systems originated from distinct sources, a conceptual and a practical one – they did not remain distinct, but could be elegantly integrated to extend the existing system further.

6. Conclusion

The diverse ways of counting in the Micronesian languages almost infallibly captured the interest of those that encountered them, yet the scope, comprehensiveness, and quality of available descriptions varies substantially. After centuries of foreign incursions, systems had eroded, undergone structural changes, or simply dropped out of use. This is why we only have a patchy and incomplete picture of the richness and conceptual coherence of the traditional systems. Still, by taking a bird's-eye view in compiling all we know about counting in Micronesia, we hope to have summoned sufficiently convincing evidence of some overarching patterns.

Micronesian languages have had mostly regular and extensive counting systems with high-power numerals, presumably as early as the emergence of the language family. They have also had rich numeral classifier systems that facilitated the generation of specific counting systems, which operate on counting units different from 1. In line with the decimal structure of the main system, most of these specific counting systems were based on counting units of 10, predominantly for counting coconuts and occasionally other important food items. At least the underlying principle, if not the system as a whole, may be older than the Micronesian languages themselves. In addition to this conceptual feat, some groups also implemented pair counting as a practical advancement for speeding up the counting process. Practices of pair counting exhibit more substantial variability and most likely were later, local innovations.

In many (Indo-)European languages like English, 1000 was such a substantial threshold for such a long time (possibly due to the limits of the Roman numerals used as notation) that it was turned into a new base when the system had to be extended, hence the auxiliary compound numerals "ten thousand" and "hundred thousand". Micronesian speakers, by contrast, appreciated their counting systems as purely decimal, adding a distinct new numeral for every new power level required. The only way in which they modified its structure was by inserting counting units with cardinal values other than 1, thereby generating novel systems. As the preferred unit for these systems was 10, these new systems also remained perfectly decimal, though.

When settling their "sea of small islands", Micronesian seafarers demonstrated exceptional sailing and navigational skills that also enabled them to subsequently maintain large-scale exchange systems. Linked to these accomplishments was a genuine interest both in high numbers and in systems for keeping track of these numbers that were highly regular, conceptually coherent, and cognitively efficient. The largest of these numbers defy any attempts to be accounted for by practical purposes. Yet, a lack of imagination on our part regarding what these numbers may have been used for is no justification for dismissing them as a topic worthy of scientific investigation in its own right. Even if counting systems are just one aspect of the much richer world of ethnomathematics (Goetzfridt, 2012), being some of the most amazing systems in the world, the ways of counting in Micronesia and the cultural context in which they arose clearly deserve more attention from researchers across disciplines.

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