Online supplementary material

Weapons of war? Rapa Nui *mata'a* morphometric analyses

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Our measured outlines are composed of 200 points evenly spaced along the outline of 423 object (Figure S1). *Momocs* interpolates between points to locate distances from centroids at even intervals. Further, as measurements are based on georeferenced coordinates, a planimetric measure (such as width or length) can be calculated. Additional image-analysis techniques to isolate object outlines point to the strong potential for automation of the measurement process, thereby greatly increasing the ability to characterise substantial assemblages. With large numbers of measures of radial distances made relative to the *mata'a* centroids, we then calculated a statistical summary for each angle to assess variability in relative dimensions.

<FIGURE S1, 13.5cm wide, colour>

In morphometrics, elliptical Fourier treats outlines as series of overlapping closed curves. Elliptical Fourier analysis then decomposes the description of the outline into a series of closed curves known as harmonics that vary in size, shape and orientation, and that are generated by a known mathematical function. The sum of all harmonics needed to fully characterise the outline depends on the complexity of the shape.

Elliptical Fourier series, however, work on continuous functions. In practice, shape is measured on a finite number of discrete points on a plane, such as the distance of any point on the outline to the centroid of the shape, the variation of the tangent angle for any point, or x/y coordinates. Thus, in our case, a discrete equivalent to Fourier series is used to analyse a given number of points called pseudo-landmarks that are sampled along the outline. Elliptical Fourier decomposition of these data results in a harmonic sum of trigonometric functions associated with harmonic coefficients. They are (usually) normalised to remove homothetic, translational or rotational differences between shapes. Two or four coefficients, depending on the approach used, are obtained for each calculated harmonic and can then be considered as quantitative variables. The geometrical information contained in the outlines is thus quantified and can be analysed with classical multivariate tools.

To conduct Fourier analysis, we must estimate the number of necessary harmonics after examining the spectrum of harmonic Fourier power. The power is proportional to the harmonic amplitude and can be considered as a measure of shape information. As the rank of the harmonic increases, the power decreases and adds less and less information. We can evaluate the minimum number of harmonics required to best approximate the shape. In the case of the *mata'a*, and using the x/y position for points on the outline as the data set, 12 harmonics provide a good reconstruction of the overall shape (Figures S2–4).

<FIGURE S2, 13.5cm wide, colour>

<FIGURE S3, 13.5cm wide, colour>

<FIGURE S4, 13.5cm wide, greyscale>

Tables S3, S4 and S6 show the multivariate analysis of variance (MANOVA) results of *mata'a* shapes grouped by site location, obsidian source and island, respectively.

References

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Figure captions

Figure S1. Sample size and mata'a *parameter estimation. We evaluated sample size through bootstrap resampling with replacement and with an increasing number of samples; for each sample size, we calculated the 95% confidence intervals for length and width; based on the changes to the 95% confidence intervals, it appears that the sample size used in our study (N = 423, shown via the dotted lines) is sufficient to characterise shape variability; increasing the number of samples beyond N does not appear to dramatically improve our characterisation of overall* mata'a *metrics.*

Figure S2. Mata'a *included in the current analyses; the five colours indicate the collection locations on Rapa Nui (Blue = Ahu Tautiri, Green = Orito, Yellow/Green = Orongo, Orange = Rano Kao, Red = location only known to the level of the island, Yellow = Parcela).*

Figure S3. Mata'a *reconstructed from different numbers of harmonics; 12 harmonics provide a satisfactory reconstruction.*

Figure S4. Cumulated harmonic Fourier power calculated from Rapa Nui mata'a*; the first 12 harmonics gather nearly 100% of the harmonic power; maxima, minima and medians are also plotted.*

Table S1. Rapa Nui *mata'a* included in analyses by site and by repository (N = 423).

		Site					
		Ahu Tautira	**Orito**	**Orongo**	**Rano Kau**	**Parcelas**	**Unknown**
Collection	Bishop Museum	0	0	0	0	0	291
	P. Sebastian Englert Museum	25	31	29	33	0	0
	Heyerdahl & Ferdon 1961a	0	0	0	0	0	8
	Field surveys (Hunt & Lipo 2006)	0	0	0	0	6	0

Table S2. *Mata'a* included in analyses by obsidian source and collection.

	Collection	
		Bishop
Obsidian source	Motu Iti	5
	Orito	279
	Rano Kau	7

Table S3. Results of MANOVA for Rapa Nui *mata'a* shapes grouped by site location.

Comparison	**Pillai statistic**	**Approximate F**	**Degrees of freedom**	**p-value**
Ahu_Tautira—Orito	0.06193215	0.2420769	22	0.957466644
Ahu_Tautira—Orongo	0.05560218	0.1962527	20	0.974104678
Ahu_Tautira—Parcela	0.2504351	0.5011609	9	0.793418058
Ahu_Tautira—Rano_Kau	0.35941869	2.1508146	23	0.08600363

Ahu_Tautira—Unknown	0.06921958	1.9211541	155	0.080653113
Orito—Orongo	0.20782605	0.9619464	22	0.473111612
Orito—Parcela	0.35290287	0.9998323	11	0.471607994
Orito—Rano_Kau	0.34630248	2.2073313	25	0.076044588
Orito—Unknown	0.1189607	3.5331059	157	0.002621205
Orongo—Parcela	0.24543826	0.5963331	11	0.728110499
Orongo—Rano_Kau	0.38662672	2.6263692	25	0.040967992
Orongo—Unknown	0.11393999	3.3648169	157	0.003790983
Parcela—Rano_Kau	0.4768608	1.9749971	13	0.142954022
Parcela—Unknown	0.04653588	1.1795064	145	0.320454247
Rano_Kau—Unknown	0.11683632	3.4837141	158	0.00291422

Table S4. Results of MANOVA for Rapa Nui *mata'a* shapes grouped by obsidian source.

Comparison	Pillai statistic	Approximate F	Degrees of freedom	p-value
Motu_Iti—Orito	0.009766345	0.2702371	137	0.928722366
Motu Iti—Rano Kau I	0.558319438	0.7584478	3	0.633804963
Motu Iti—Unknown	0.06662441	0.9136648	64	0.477938757
Orito—Rano Kau I	0.05378207	1.5801239	139	0.169585655
Orito—Unknown	0.099580026	4.4237147	200	0.000764068
Rano Kau 1—Unknown	0.038861611	0.5013679	62	0.774053529

Table S5. Stemmed lithic tools from island locations in the Pacific (N = 24).

Island	Number	Source
Chatham	8	Jones 1981
New Britain	12	Torrence 2009, 2013
New Zealand	2	Jones 1981
Pitcairn	2	Heyerdahl & Ferdon 1961b

Table S6. Results of MANOVA for Rapa Nui *mata'a* shapes grouped by island.

Comparison	Pillai statistic	Approximate F	Degrees of freedom	p-value
Chatham—New_Britain	0.60145264	0.188639	1	0.9497193
Chatham—Rapa_Nui	0.04067497	1.091789	206	0.3701949
New_Britain—Rapa_Nui	0.05319146	1.460673	208	0.1733617

Table S7. Wilcoxon rank-sum test of Rapa Nui *mata'a* shapes grouped by island.

Comparison	W score	p-value
New Zealand—New Britain	17	0.4108
New Zealand—Chatham	14	0.1497
New Zealand—Pitcairn	4	0.3333
New Zealand—Rapa Nui	725	0.0819
Chatham—New Britain	39	0.5116
Chatham—New Zealand	2	0.1497
Chatham—Pitcairn	16	0.04949
Chatham—Rapa Nui	1606	0.08065