Terevaka Archaeological Outreach (TAO) 2017/2018 Field Report: Archaeology Provides Future Opportunities

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Since 2003, Terevaka Archaeological Outreach (TAO, founded by Dr. Britton Shepardson) has offered unique experiential learning activities for Rapa Nui high school students to raise awareness regarding cultural and natural resources on the island, to promote conservation initiatives, and to conduct original research regarding the island's prehistoric human-environment interactions. Since incorporating as a 501(c)(3) organization in 2014, TAO has redoubled its efforts to include more high school students, incorporate advanced non-destructive research technology, and design projects that offer unique potential to combine archaeological studies with sustainable development efforts within the island community. Over the last two years, TAO students focused on three distinct projects: (1) three-dimensional ortho-corrected photogrammetry; (2) use-wear analysis of matā or obsidian blades; and (3) design and construction of vertical hydroponic gardens.

Introduction

Since 2003, Terevaka Archaeological Outreach (TAO) has provided educational opportunities for nearly 200 local high school students within the Rapa Nui community. While the curriculum has evolved, TAO's three primary goals have remained the same: (1) to offer experiential learning opportunities specific to cultural and natural resources that surround the local community; (2) to promote awareness and expertise in conservation measures and sustainable development; and (3) to document and study both cultural and natural phenomena of the past and today.

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TAO projects are all designed to be non-invasive, reinforcing the notion of sustainable development on the island, and promoting resourcefulness and expertise in a wide variety of professional careers (Shepardson et al. 2004, 2009, 2010, 2011, 2012, 2013, 2014, 2015; Torres & Shepardson 2005; Shepardson 2006a, 2010; Rutherford et al. 2008; Shepardson & Torres 2009; Petney et al. 2015; Sullivan et al. 2018).

Equally important, TAO projects are designed specifically to use cultural and scientific knowledge about ancient lifeways on Rapa Nui to address, and provide solutions to, modern obstacles in the island community's efforts to develop sustainably.

Three-Dimensional Photogrammetry

As a continuation of the project started in 2016, during 2017 and 2018 TAO students photographed artifacts curated by the Museo Antropológico Padre Sebastián Englert (MAPSE), as well as megalithic statues and other *in situ* cultural features at archaeological sites around the island. The digital photographs compiled by local students were later used to make digital and physical three-dimensional replicas (Shepardson et al. 2016).

Students employed three-dimensional orthogonally-corrected photogrammetry, which required them to take photos of each feature or artifact from a variety of angles, in order to capture each natural face of the object from a distinct perspective. Students photographed objects with two types of cameras, a Canon EOS-6D DSLR body with a Canon EF 24-105 mm f/4L IS USM lens and a Canon EOS Rebel T6 DSLR body with a Canon EF 18-55 mm f/3.5-5.6 IS II lens, used to photograph small artifacts.

Teams of students photographed artifacts curated by MAPSE in the museum's collections storage area, with enhanced lighting. Objects were flipped and rotated to capture all sides and textures. In order to comprehensively photograph features at archaeological sites, students moved around the objects, taking photos with a handheld camera, and at times with the help of an extendable monopod (Fig. 1).

Next, the photos were imported to Agisoft PhotoScan Professional Edition software (www.agisoft.com). While the software and a mobile workstation computer have the capabilities of aligning digital photographs without any post-processing of the images, "masking" of areas peripheral to the artifacts of interest greatly reduced computation time and failed attempts to align multiple photographs. Following alignment, a series of processing steps in the program allow the user to create a point cloud and finally a realistic, three-dimensional model of the object. Digital models are available to the public through various portals, including the TAO website (www.terevaka.net), SketchFab (www.sketchfab.com/terevaka), and TAO's Facebook page (https://www.facebook.com/TAOrapanui) (Figs. 2 and 3).

Finally, the digital models created by TAO students were converted to stereolithographic files (.stl) and printed at the Cline Library's MakerLab at Northern Arizona University (NAU) in Flagstaff, Arizona. The MakerLab printed the models on a MakerBot Replicator Z18 three-dimensional printer, which provides up to 0.1 mm resolution. Models are printed in polylactic acid (PLA), a biodegradable thermoplastic made from renewable resources such as cornstarch or sugarcane. Once printed, the models are painted with acrylic paints by NAU fine arts students. The printing of the models was partially funded by the NAU College of Social and Behavioral Sciences Research Support Award, awarded to Shepardson in 2017 (Figs. 4 and 5).

In 2018, thirteen models produced by TAO students between 2016 and 2017 were donated to MAPSE in the creation of the island's first educational replica collection, which

Fig. 1. TAO student photographing a *hare paenga* in the field.

Fig. 2. Digital 3D models available for viewing on TAO's website, www.terevaka.net.

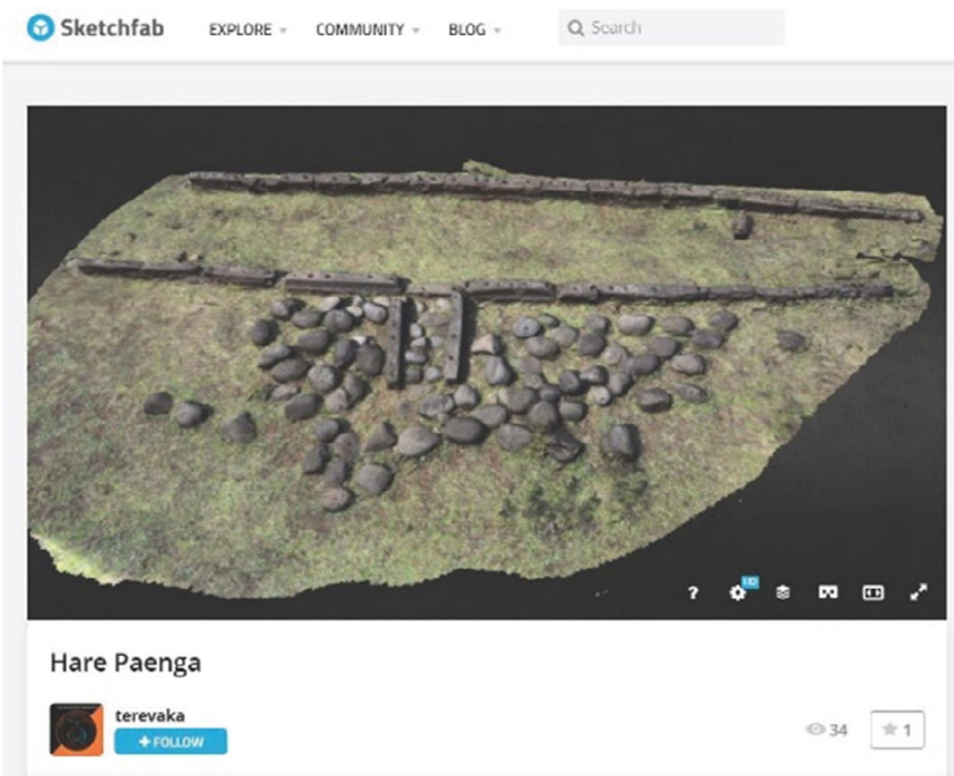

Fig. 3. Digital 3D models available for viewing on SketchFab, www.sketchfab.com/terevaka.

will allow for enhanced visibility of the artifacts, typically stored away in the museum's deposit, and launch new learning opportunities for local students and other visitors to the museum (Fig. 6).

Matā Research

Matā, tanged obsidian tools, are found in abundance in prehistoric contexts across Rapa Nui. Historic accounts and oral histories describe *matā* as "spears" and "weapons," used in episodes of prehistoric violence (Routledge 1919; Flenley & Bahn 2002; Ruiz-Tagle Eyzaguirre 2004). Other researchers have questioned this narrative and explored features of form and evidence of use-wear on *matā* (Church & Rigney 1994; Church & Ellis 1996; Church 1998; Lipo et al. 2016). Results from these studies suggest that these tools served a range of utilitarian functions, such as plant and animal processing and may have been used periodically as weapons.

In order to contribute to the understanding of this important artifact type, TAO students undertook a two-part research project to analyze and catalog the collection of *matā* stored at MAPSE and to understand the development of use-wear. Through the documentation process, TAO students contributed greatly to the future research potential of this collection of artifacts. Following the documentation and curation stage, students conducted a series of

Fig. 4. Side-by-side comparison of the printed 3D model (above) and the original artifact, curated by MAPSE (below).

use-wear experiments, through which they examined the development of edge damage, while producing a comparative collection, useful for future research into the use of prehistoric obsidian tools.

Documentation and Cataloguing

In order to document and catalog *matā*, students collected metrics and took photographs of each artifact. Within this step, four stations delineated the documentation process. The stations included metric data collection (Fig. 7), low-powered digital microscopic (20-40×) photography of edge damage (Fig. 8), digital photography of the dorsal and ventral surfaces, as well as the profile of each *matā*, and finally data entry into a Microsoft Excel spreadsheet before the bagging and tagging of each artifact. Each station had a minimum of two TAO researchers processing artifacts at a time. Over the course of five work days, TAO researchers processed 180 *matā*. This documentation led to the curation of individual artifacts to be stored in the collections storage area at MAPSE (Table 1).

This project creates a foundation for future research opportunities to compare microscopic photos of the experimental flakes and known types of accretional edge damage (Tringham et al. 1974) to microscopic edge damage observed on the *matā* documented by TAO 2017 students at MAPSE.

Fig. 5. TAO Founder and Director Britton Shepardson with MAPSE employees Valeska Chavez Pakomio (left) and Marlene Hernández Vázquez (right) in March 2018 with four of the 3D models from the educational replica collection, produced and donated to MAPSE by TAO.

Fig. 6. The printed 3D model, held by collections manager Mario Tuki, now offers hands-on learning experiences for local high school students at MAPSE.

Fig. 7. TAO students recording metrics of *matā* for curation at MAPSE.

Fig. 8. TAO students using the digital microscope to capture photos of microscopic edge damage on *matā* at MAPSE.

Table 1. Measurements and image records of *matā* generated for the MAPSE catalog by TAO students.

Catalog	Max. Length (mm)	Max. Width (mm)	Max. Depth (mm)	Weight (g)	Microscope Images	Camera Images
17-00-01605	57.83	46.7	15.51	29.33	6	3
17-00-01608	49	49.7	11.9	19.97	4	3
17-00-01612	67.4	54.4	14.8	33.05	5	3
17-00-01613	48.86	42.98	13.22	19.17	5	3
17-00-01620	77.3	33.92	15.45	30.87	7	3
17-00-01626	31.39	65.4	12.29	21.18	4	3
17-00-01634	62.9	38.8	11.7	24.21	4	3
17-00-01636	63.70	39.40	8.50	22.23	4	3
17-00-01638	75.8	39.4	22.2	42.43	5	3
17-00-01639	68.80	55.50	20.00	41.73	4	3
17-00-01640	68.9	33.8	11.6	24.89	6	3
17-00-01641	70.80	61.60	12.20	32.58	6	3
17-00-01642	60.22	63.57	12.32	34.45	4	3
17-00-01643	58.77	48.97	13.33	31.06	4	3
17-00-01644	74.28	58.40	17.96	54.74	5	3
17-00-01646	53.7	45.80	16.90	32.53	4	3
17-00-01647	71.3	48.73	12.19	29.74	7	3
17-00-01648	75.43	53.84	11.46	41.83	7	3
17-00-01649	58.10	57.70	15.90	47.16	4	3
17-00-01650	57.10	39.90	11.80	16.30	5	3
17-00-01651	71.30	52.30	21.20	47.58	6	3
17-00-01652	57.04	56.93	14.7	37.87	4	3
17-00-01653	69.43	51.78	16.25	37.39	4	3
17-00-01654	87.78	84.61	14.95	75.19	4	3
17-00-01655	81.9	46.6	12.9	40.41	6	3
17-00-01656	57.3	46.22	17	30.21	4	3
17-00-01657	78.40	45	13.60	36.66	4	3
17-00-01658	59.4	50.1	15.07	35.49	4	3
17-00-01659	47.3	37.9	5.5	11.61	2	3
17-00-01660	59.7	40.5	9.8	20.4	7	3
17-00-01661	69.3	60.4	16.7	49.88	3	3
17-00-01662	94.6	65.4	24.5	104.55	5	3
17-00-01663	71.06	49.51	17.55	43.34	2	3
17-00-01664	74.26	49.64	12.66	33.19	2	3
17-00-01665	62.04	47.21	10.93	21.13	3	3
17-00-01666	72.48	48.6	17.65	32.06	2	3
17-00-01667	70.56	54.94	14.04	40.77	4	3
17-00-01668	80.13	38.51	19.11	52.62	4	3
17-00-01669	78.50	50	17.40	43.56	4	3

TABLE 1 (*Continued*)

Catalog	Max. Length (mm)	Max. Width (mm)	Max. Depth (mm)	Weight (g)	Microscope Images	Camera Images
17-00-01671	59.80	75.30	12.10	43.75	5	3
17-00-01672	63.3	37.7	75.7	20.26	4	3
17-00-01673	60.4	40.1	12.9	21.77	4	3
17-00-01674	66.2	52.2	15	38.94	5	3
17-00-01675	78.5	44.8	17.8	42.72	4	3
17-00-01676	75.30	62.50	17.40	54.88	4	3
17-00-01677	43.8	55.3	9.8	15.8	4	3
17-00-01678	96.3	52.3	18.3	57.53	5	3
17-00-01679	58.8	64.3	17	37.19	5	3
17-00-01680	62.8	52.5	12.8	30.66	5	3
17-00-01681	70.9	54.2	15.5	42.99	6	3
17-00-01682	107.9	63.2	26.2	122.42	6	3
17-00-01683	49.7	55	10.7	18.4	4	3
17-00-01684	85.5	92.9	91.3	92.32	7	3
17-00-01685	63.6	47.1	14.8	30.74	4	3
17-00-01686	60.2	60.5	12.5	35.13	5	3
17-00-01687	78.4	56.1	74.3	37.33	6	3
17-00-01688	60.7	66.5	75.3	43.03	3	3
17-00-01689	65.2	56	17.1	46.89	3	3
17-00-01690	66.6	50.44	10.9	25.51	4	3
17-00-01691	79.6	57.3	15.3	50.65	5	3
17-00-01692	62.75	56.48	14.74	25.03	5	3
17-00-01693	49.9	65	12.8	28.53	7	3
17-00-01694	66.9	55.3	15	46.79	4	3
17-00-01695	65.21	26.99	13.91	20	5	3
17-00-01696	61.3	48.4	18.1	52.34	6	3
17-00-01697	36.6	66	11.9	25.63	4	3
17-00-01698	71.7	53.9	11.7	36.05	4	3
17-00-01699	57.7	38.5	15.8	31.5	3	3
17-00-01700	54.7	63.8	14.8	40.24	6	3
17-00-01701	81.8	52.2	12.9	44.56	8	3
17-00-01702	68.1	51.8	17	50.32	5	3
17-00-01703	57.8	47	11.7	23.99	5	3
17-00-01704	76.1	38.7	8.9	19.9	4	3
17-00-01705	66.5	46.3	13.7	30.2	4	3
17-00-01706	79	58.5	14.8	42.35	4	3
17-00-01707	75.5	31.8	15.5	26.5	4	3
17-00-01709	76.7	48.7	15.6	41.61	6	3
17-00-01710	49.3	61.5	14	30.38	4	3
17-00-01711	63.3	54.8	12.9	33.06	4	3
17-00-01712	57.7	51.5	16.1	29.48	4	3

TABLE 1 (*Continued*)

Catalog	Max. Length (mm)	Max. Width (mm)	Max. Depth (mm)	Weight (g)	Microscope Images	Camera Images
17-00-01713	69.73	54.92	9.52	26.56	4	3
17-00-01714	68.03	55.53	11.99	31.69	4	3
17-00-01715	73.92	60.97	18.22	44.45	5	3
17-00-01716	74.79	42.85	13.13	35.1	4	3
17-00-01717	67.67	50.07	10.72	26.32	4	3
17-00-01718	56.53	51.68	14.23	27.1	4	3
17-00-01719	61.85	62.75	13.86	40.78	4	3
17-00-01720	60.37	38.18	15.33	25.35	4	3
17-00-01721	83.02	56.78	13.33	36.63	4	3
17-00-01722	69.33	59.23	15.74	46.57	4	3
17-00-01723	87.89	66.86	16.48	78.43	4	3
17-00-01724	55.71	51.04	12.98	19.5	4	3
17-00-01725	57.01	60.67	16.86	46.79	4	3
17-00-01726	47	54.1	11.2	23.74	4	3
17-00-01727	59.4	44.7	12.3	24.65	4	3
17-00-01728	69	53	11.5	38.16	5	3
17-00-01729	64.96	55.47	11.66	28.66	4	3
17-00-01730	67.07	53.06	13.31	35.02	4	3
17-00-01731	63.12	44.25	14.44	26.68	4	3
17-00-01732	44.34	34.88	10.83	13.96	4	3
17-00-01733	57.03	38.14	10.83	18.07	3	3
17-00-01734	59.38	40.73	13.47	25.84	4	3
17-00-01735	60.75	33.81	10.95	15.64	4	3
17-00-01736	54.07	43.36	8.27	16.24	4	3
17-00-01737	49.65	44.16	6.69	12.9	4	3
17-00-01738	49.95	37.34	13.66	18.07	5	3
17-00-01739	59.04	49.46	15.46	40.35	5	3
17-00-01740	43.18	39.02	12.18	12.15	4	3
17-00-01741	52.81	36.47	11.86	17.69	5	3
17-00-01742	73.58	46.78	13.99	32.94	5	3
17-00-01744	62.8	47	11	22.5	6	3
17-00-01745	55	43.4	11.6	20.26	4	3
17-00-01746	54.7	35.6	11.1	12.47	5	3
17-00-01747	53.8	56.1	11.4	21.83	9	3
17-00-01748	51.1	56.9	10.5	21.59	3	3
17-00-01749	64.7	59.9	12.4	35.3	4	3
17-00-01750	63.1	55.2	11.8	18.05	4	3
17-00-01751	73.12	35.37	13.3	35.75	5	3
17-00-01752	85.3	45	13.6	35.13	4	3
17-00-01753	78.9	60.2	20.8	57.05	3	3
17-00-01754	68.2	59	16.9	42.12	3	3

TABLE 1 (*Continued*)

Catalog	Max. Length (mm)	Max. Width (mm)	Max. Depth (mm)	Weight (g)	Microscope Images	Camera Images
17-00-01755	56	39	20.8	23.99	3	3
17-00-01756	57.53	67.38	12	33.8	5	3
17-00-01757	59.01	66.85	11.15	36.1	6	3
17-00-01758	63.54	58.37	13.55	37.12	4	3
17-00-01759	72.31	68.65	26.2	65.07	4	3
17-00-01760	67.1	59.93	14.27	40.77	5	3
17-00-01761	53.21	43.16	8.96	15.19	4	3
17-00-01762	85.11	79.76	18.4	83.69	8	3
17-00-01763	72.91	64.12	16.49	43.84	3	3
17-00-01764	79.77	76.36	19.5	76.22	5	3
17-00-01765	80.78	86.93	19.06	74.27	4	3
17-00-01766	53.3	51.38	10.93	22.41	4	3
17-00-01767	44.77	39.5	8.42	12.42	4	3
17-00-01768	73	57.3	17.7	47.53	5	3
17-00-01769	69.66	51.63	16.07	41.53	6	3
17-00-01770	65.39	42.45	14.18	25.47	3	3
17-00-01771	53.19	57.97	16.07	31.92	4	3
17-00-01772	60.59	42.59	12.01	27.1	4	3
17-00-01773	52.45	52.4	11.6	23.88	4	3
17-00-01774	63.96	56.74	17	42.43	5	3
17-00-01775	90.53	49.44	17.54	51.48	4	3
17-00-01776	74.58	73.15	20.76	71.03	4	3
17-00-01777	76.76	93.32	13.72	79.31	4	3
17-00-01778	61.65	54.81	12.2	26.63	5	3
17-00-01779	53.01	30.47	9.7	15.15	4	3
17-00-01780	71.13	58.95	13.93	46.72	4	3
17-00-01781	77.62	55.39	16.33	52.08	4	3
17-00-01782	67.62	42.34	11.3	22.57	4	3
17-00-01783	70.91	86.39	22.27	96.39	6	3
17-00-01784	72.52	56.51	16.5	45.26	5	3
17-00-01785	84.14	80.23	18.36	91.2	3	3
17-00-01786	65.46	54.81	14.37	51.12	4	3
17-00-01787	46.91	42.28	11.81	17.48	3	3
17-00-01788	52.67	65.31	16.02	48.86	4	3
17-00-01789	68.19	57.93	16.4	47.9	5	3
17-00-01790	75.78	52.97	10.7	32.14	3	3
17-00-01791	48.72	67.34	14.79	40.3	2	3
17-00-01792	56.2	58.69	15.76	31.66	4	3
17-00-01793	71.5	53.8	19.6	44.29	3	3
17-00-01794	53.9	44.8	12.8	21.52	7	3
17-00-01795	61.3	55.5	13	34.83	3	3

TABLE 1 (*Continued*)

Catalog	Max. Length (mm)	Max. Width (mm)	Max. Depth (mm)	Weight (g)	Microscope Images	Camera Images
17-00-01796	79.1	86.3	17.6	60.42	6	3
17-00-01797	74	112.8	24.7	135.22	4	3
17-00-01798	93.9	50	16.9	59.31	3	3
17-00-01799	79	58.8	13.4	33.69	5	3
17-00-01800	87.4	68.1	16.7	59.88	3	3
17-00-01801	86.03	68	17.03	59.88	8	3
17-00-01802	86.07	69.05	24.03	85.85	7	3
17-00-01803	68	61.06	14.09	41.38	6	3
17-00-01804	65.9	47.9	18.6	42.39	5	3
17-00-01805	71.2	44.1	16.1	37.35	6	3
17-00-01806	68.02	62.07	14.03	43.45	6	3
17-00-01807	70	61.8	12.9	41.75	7	3
17-00-01808	79.2	46.7	14	42.33	7	3
17-00-01809	65.3	53.4	13.1	29.47	4	3
17-00-01810	58.9	36.8	10.5	21.04	4	3
17-00-01811	79.06	77.06	22.05	99.2	8	3
17-00-01812	66.08	64.4	14.4	44.8	6	3
17-00-01813	60.3	56.4	12.4	33.52	5	3

Use-Wear Experiment

Obsidian from various Rapa Nui sources, donated by MAPSE, was flaked by K. Sullivan and utilized by TAO students to perform various experimental tasks, such as cutting and scraping of distinct materials. Students produced experimental baseline edge damage through two types of actions—longitudinal cutting, in a back and forth, sawing motion, and unidirectional transverse scraping. The experimenters performed the cutting and scraping actions in discrete areas on each obsidian flake for a total of 1000 repeated strokes, pausing at each 250-stroke interval to photograph edge condition at a low-power magnification (20-40×). Documenting the various intervals allows for the observation of the development of microscopic wear patterns through different actions performed on various materials. The experimental materials included: eucalyptus wood (hardwood), *mahute* (*Broussonetia papyrifera*, local soft wood), and soil (Fig. 9).

The experimental flakes will be used in future analytical research, serving as a comparative collection to make informed conclusions in microscopic analysis of use-wear patterns and possible utilization of prehistoric *matā*. The comparative collection is stored at MAPSE.

The data collection and laboratory analysis aided MAPSE in the curation of important prehistoric artifacts. Moreover, the experimental flakes contribute to the development of a comparative collection, which are available for the use of any interested party. Our hope is that TAO research may lay the foundation for future lithic research on the island into the use of *matā*.

Fig. 9. TAO students cutting Eucalyptus wood with obsidian flakes in order to understand how use-wear develops on tools.

Vertical Hydroponic Gardens

In 2018, TAO students embarked on an entirely new curriculum and project: the creation of vertical hydroponic gardens from repurposed materials collected in the island's landfill and recycling areas. While the end result of this project might not seem directly related to archaeology on the island, the hands-on curriculum surrounding the project was contextualized through an introduction to our growing knowledge of the clever ways in which islanders adapted agricultural practices to environmental conditions in prehistoric times.

TAO students began to study the domesticates (*e.g.*, sweet potato, taro, yam, sugar cane, ti) and traditional agricultural techniques (*e.g.*, rock mulching, rock veneer, stacked boulder concentrations, *pu* or planting holes in rocky areas, *manavai* or gardens enclosed by stacked circular stone walls) that have been reported both through oral tradition, and more recently, through archaeological research (Stevenson 1997; Wozniak 2001; Mieth et al. 2002; Stevenson et al. 2002, 2005, 2007; Mieth and Bork 2003; Ladefoged et al. 2005; Stevenson et al. 2006; Ladefoged et al. 2010; Mulrooney 2012).

TAO students realized that one of the benefits of our archaeological understanding of prehistoric agriculture on the island is that we have already identified a hearty and diverse group of domesticated species transported by Polynesians that can continue to serve as staple crops on the island, given the island's unique climate and environment. However, TAO students also concluded rather quickly that there were two considerable drawbacks to traditional agricultural technology on the island.

One of the shortcomings in prehistoric agricultural techniques was the availability and management of fresh water on the island. Some time ago, archaeologists identified the cultural and evolutionary importance of ancient hydrotechnology on the island (McCoy 1979). And more recently, archaeologists have acknowledged great potential in additional research regarding Rapa Nui's culture prehistoric hydrotechnology (Shepardson 2013:42):

> Comprehensive research (including survey, geophysical inquiry, and remote-sensing) of fresh and brackish water resource locations on the island is likely to provide more explanations for the locations and durations of settlements in prehistoric Rapa Nui than any other foreseeable research.

At last, archaeological research is beginning to shed more light on this topic (Martinsson-Wallin 1994; Hunt and Lipo 2001; Stevenson et al. 2002; Shepardson 2006b; Vogt and Moser 2010; Brosnan et al. 2018). While the island receives more than 1200 mm of rainfall on a yearly basis, the porous geological substrate results in the rapid loss of fresh water from rainfall as it permeates through the Earth's surface, and downhill to the sea.

The second shortcoming in traditional agriculture has to do with the island's small size and lack of nutrient-rich soils. As the modern population surges past 10,000 inhabitants, students reasoned that there simply is not enough space on the island to clear the acreage that would be necessary for fields of crops that could fully support island residents in the future.

Through iterative problem-solving brainstorming sessions based on scientific and cultural studies, TAO students concluded that future innovations in agricultural development on the island must incorporate methods to recycle fresh water whenever possible, and to expand vertically rather than horizontally across the island's terrain. They proceeded to assemble gardens that meet both of these visions: vertical hydroponic gardens that use a small electric pump to recirculate water continuously. TAO students assembled five different variations on vertical hydroponic gardens, using materials that were mostly available in the local landfill, the Orito recycling zone, and the island's abundant eucalyptus groves:

- Eucalyptus trunks and branches provided the vertical trellis framework for each garden.
- Discarded plastic bottles were cut in half to provide "pots" for plants in the garden.
- Lava rock, ceramic pebbles, and in some case even ocean microplastics were used in place of soil to provide a growing "matrix" that helps to stabilize plant roots.

Small amounts of biodegradable twine and vinyl tubing, along with a submersible pump (rated to move 600 liters of water per hour), were used to complete each functioning garden. The students naturally gravitated toward a vertical design so that water and nutrients not absorbed by a higher tier in the garden would simply trickle down to feed lower tiers, until the water emptied into a tank below the garden to begin the cycle through the pump once again. Within four days, the efficient watering and nourishing design of the gardens showed success in sprouting seeds (Figs. 10 and 11).

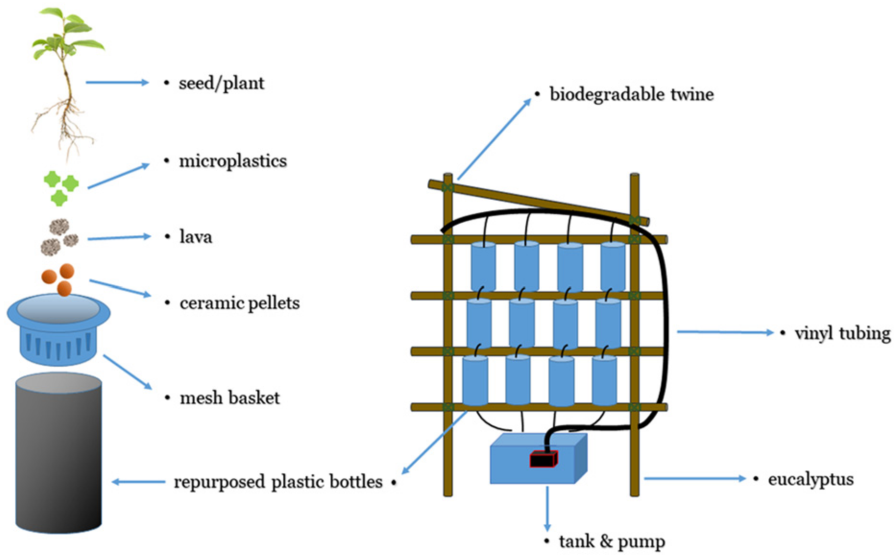

Fig. 10. Schematic diagram and magnification of the vertical hydroponic garden design created by TAO students.

Conclusions and Future Opportunities

Since the early 1900s, archaeologists and archaeological research have been ever-present elements in Rapa Nui's culture and tourist-driven economy. However, archaeological research has rarely been designed to address specific concerns within the modern residential community. TAO's unique experiential curriculum continues to provide examples of how community-oriented project design can provide a wealth of opportunities in the future for educational purposes, conservation efforts, and scientific research (Fig. 12).

The three-dimensional orthogonally-corrected photogrammetry project introduced TAO students to a wide variety of photography skills, software packages, and laboratory protocol that could provide a foundation for university studies and/or career paths in a number of different fields. At the same time, the finalized replicas resulting from this work are already used on a regular basis to provide access to cultural resources that are normally kept in boxes in the museum's storage area. Museum personnel have also begun to use the replica collection as a mobile educational package that allows them to offer on-site educational activities for the various schools and age groups on the island.

The *matā* project also introduced TAO students to laboratory research, data organization software, and technical conservation measures used within the island's museum for the curation of cultural resources. As work with the matā database continues, a new online interactive tool has been made available at www.terevaka.net/mata to provide public access and comparative analysis potential, meaning future studies of use-wear analysis on ancient obsidian remains could be conducted efficiently by members of the local island community through digital tools rather than by foreign archaeologists who gain access to extensive collections of artifacts.

Fig. 11. Functioning vertical hydroponic garden designed by TAO students.

Fig. 12. TAO 2018 students and staff visiting the Ahu Nau Nau site.

Finally, the vertical hydroponic garden project encouraged students to think about prehistoric lifeways and how traditional knowledge and resources can be integrated into modern solutions in the quest for sustainable economic development. TAO students also realized that the vertical orientation of the gardens, requiring very little land for production—as opposed to modern industrialized approaches to massive plowed fields for crop production, could also result in much better conservation of archaeological sites and artifacts that remain *in situ* in the island's countryside.

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