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Human dimensions in shellcraft: tool ownership differentiates taxa utilised and products produced

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Throughout the Pacific Islands, shellcraft has begun to feature prominently in development intervention which aims to generate positive livelihood outcomes for coastal communities. This activity often involves the post-harvest processing of natural assets, namely shells and skeletal remains of marine taxa, into jewellery by individuals or small-sized enterprises. To foster participation in shellcraft, development intervention commonly involves gifting or subsidising physical assets. Yet knowledge of the natural (i.e., taxa) and physical (i.e., tools) assets required for shellcraft remains scant. An understanding of human dimensions in shellcraft pertaining to patterns in asset use, such as how tool ownership differentiates taxa utilised and products produced, is important for determining if access to a specific tool is necessary, or an encumbrance, for achieving a desired outcome. In this study, we identified tools used and variation in tool ownership among artisans engaged in shellcraft to afford an accurate and realistic understanding of the tools required to participate in this activity. We then evaluate how ownership of a specific tool or type of tool differentiates both taxa utilisation and product production for shellcraft. Results indicate ownership of neither all nor any specific tool was required to participate in shellcraft, with artisans typically owning a unique combination of tools. Furthermore, results identified that some specific tools were critical for affecting the attractiveness of utilising certain taxa or producing certain products. Implications of the significant relationships between specific tools and certain taxa or products are discussed in the context of development intervention and commonly articulated theories of change where shellcraft is linked to subsistence fishing, aquaculture, or tourism.

KEYWORDS

fishery production system, development intervention, hybrid craft, wildlife, physical assets, natural assets

1 Introduction

Development intervention has become an integral instrument through which policies aim to generate positive livelihood outcomes for coastal communities globally (Roscher et al., 2022). Promotion of this strategy has been prolific, particularly in the Pacific Islands where small-scale fisheries are vital to local, national, and regional economies (Gillett and Fong, 2023). Approximately half the people in this region live in coastal areas (Andrew et al., 2019), of which many derive income and nutrition from small-scale fisheries that are, in some places, regarded as being in decline (Bell et al., 2009; SPC, 2015; Farmery et al., 2020). As part of regional (e.g., FFA and SPC, 2015; SPC, 2015) and national (e.g., MFMRD and SPC, 2019; NFA, 2021) recognition of the importance these fisheries have for coastal communities, there has been significant investment into development intervention which seeks to establish alternative activities within small-scale fishery production systems (Roscher et al., 2022).

One activity that has begun to feature prominently in development intervention for coastal communities involves utilising natural assets for shellcraft (Nimoho et al., 2016; Fröcklin et al., 2018; Purcell et al., 2019; Southgate et al., 2023). This activity, best contextualised as a 'hybrid' craft (*sensu* Grobar, 2019), often involves the post-harvest processing of natural assets, namely shells and skeletal remains of marine taxa, into jewellery by individuals or small-sized enterprises (Dias et al., 2011; Nijman and Lee, 2016; Fröcklin et al., 2018; Simard et al., 2019; Ruenes et al., 2023; Southgate et al., 2023). In its simplest form, shellcraft requires access to shells and tools as well as knowledge, skill, and confidence to process the available shells with the available tools (Simard et al., 2019; Mikhailovich et al., 2022; Porter et al., 2022).

While most coastal communities in the Pacific Islands have access to suitable shells (Simard et al., 2022, 2023), there exist considerable access and capacity constraints relating to tools (Simard et al., 2019; Porter et al., 2022). Shellcraft requires specialised tools (Tokerau, 2008; Simard, 2019) and access to these tools is commonly constrained by cost or availability (Teitelbaum and Fale, 2008; Fröcklin et al., 2018; Simard et al., 2019). Even when access constraints are overcome, mentorship or training may be required to build knowledge, skill, and confidence in proficient, and safe (see Chakraborty et al., 2020), use of a tool to yield market-acceptable products (Teitelbaum and Fale, 2008; Nimoho et al., 2016; Simard et al., 2019; Porter et al., 2022). Although there are examples where these constraints were overcome through endogenous (i.e., self-initiated) processes (Resture and Resture, 2005; Malm, 2009; Barclay et al., 2018; Simard et al., 2019), there are several recent examples where participation in shellcraft has been exogenously driven through planned intervention by external agencies (Nimoho et al., 2016; Fröcklin et al., 2018; Purcell et al., 2019; Southgate et al., 2023).

Intended or targeted pathways for exogenous development of shellcraft commonly involve gifting or subsidising tools in conjunction with training that intends to foster knowledge, skill, and confidence in processing locally available shells with those tools (Teitelbaum and Fale, 2008; Nimoho et al., 2016; Fröcklin et al., 2018; Purcell et al., 2019; Southgate et al., 2023). An often-implicit assumption in this approach is that an understanding of the tools required for shellcraft is sufficient to plan and guide intervention. Yet there exist examples within small-scale fisheries production systems where provision of physical assets led to unintended consequences, ultimately threatening livelihoods and degrading ecosystems (Gillett et al., 2008). Consider, for example, that access to a specific tool may influence the taxa utilised (Simard et al., 2022) or products produced (Teitelbaum and Fale, 2008; Simard, 2019). An understanding of human dimensions in shellcraft pertaining to patterns in asset use, such as how tool ownership differentiates taxa utilised and products produced, then becomes important for determining if access to a specific tool is necessary, or an encumbrance, for achieving a desired outcome.

Motivations underpinning exogenous development of shellcraft typically stem from theories of change where this activity, through links with other activities, such as subsistence fishing (Purcell et al., 2019; Porter et al., 2022; Simard et al., 2023), aquaculture (Teitelbaum and Fale, 2008; Fröcklin et al., 2018; Southgate et al., 2019), and tourism (Chand et al., 2014; Nimoho et al., 2016; Militz et al., 2021), facilitates environmental sustainability and poverty alleviation. Within this context, the need to avoid making untested assumptions that development intervention should focus on specific tools is salient. Inadvertently providing tools suited for taxa not readily accessible or sustainably sourced (Simard et al., 2024) risks undermining the intended livelihood outcomes. The same applies to inadvertently providing tools suited for taxa or products incompatible with tourism. While accepting that it is not possible, nor the intention, to fully control human dimensions in shellcraft, focusing development intervention on specific tools could, at least initially, affect the attractiveness of utilising certain taxa and producing certain products.

To provide guidance for development intervention that seeks to establish shellcraft as an alternative activity within small-scale fishery production systems, we identified tools used and variation in tool ownership among artisans engaged in shellcraft within the Pacific Island nation of Papua New Guinea (PNG). We then evaluated how ownership of a specific tool or type of tool differentiates both taxa utilised and products produced. This was achieved through univariate analyses modelling the taxa richness utilised or product richness produced and multivariate analyses modelling the likelihood of utilising each taxon or producing each product as functions of tool ownership. Implications of significant relationships between specific tools and certain taxa or products are discussed within the context of exogenous development intervention and commonly articulated theories of change where shellcraft is linked to subsistence fishing, aquaculture, or tourism.

2 Materials and methods

2.1 Study site

Marine taxa have long been used for personal ornamentation in PNG (Finsch, 1893; Lewis, 1939). More recently, post-harvest processing of marine taxa into jewellery has started to take a commercial focus, expanding rapidly in areas popular with tourists (Kinch and Burgess, 2009; Simard et al., 2019). At the Nusa Islands of

PNG (Figure 1), the chosen study site for our research, shellcraft is now a well-established and commercial activity. Over a span of two decades, participation in shellcraft at these islands has expanded to involve nearly 40 households (Simard et al., 2019). Prior research at the Nusa Islands showed artisans use multiple unique tools to process the shells and skeletal remains of 73 marine taxa into jewellery that is sold to domestic and international tourists (Simard et al., 2019, 2022). Knowledge that a substantial richness of natural and physical assets is leveraged to produce products in a competitive market environment is what makes the Nusa Islands an ideal study site to obtain an understanding of the tools required for shellcraft and investigate human dimensions in their use.

2.2 Data collection

A survey at the Nusa Islands was conducted in July 2019 to identify households engaged in shellcraft. Households having engaged in shellcraft during the previous year were asked to participate in a series of interviews. No household refused participation, and all households (n = 36) that met this criterion were interviewed. Interviews were conducted verbally in either English or Tok Pisin, depending on the preference of the artisans, and followed semi-structured formats guided by questionnaires.

The first interview concerned marine taxa utilised for shellcraft, and was the basis for an independent study (Simard et al., 2022). As part of the first interview, artisans were asked to identify all marine taxa they utilised for shellcraft and, for each of these, to indicate the quantity utilised during the previous year. These data, standardised as quantities of individuals utilised annually, were repurposed for use in this study.

The second interview concerned tools owned and products produced. Artisans were asked to identify all tools owned that were used for shellcraft during the previous year (Figure 2). Additionally, artisans were asked to identify all products produced from shellcraft during the previous year. To assist in standardising responses, products were identified using a photographic reference guide that *a priori* categorised products as bangles, bracelets, earrings, necklaces, or pendants (Figure 3).

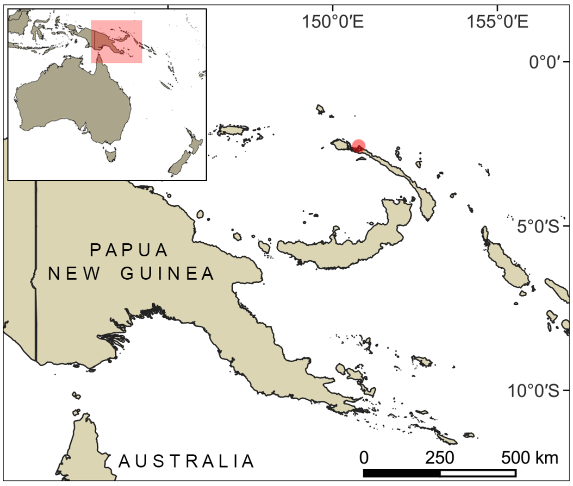

FIGURE 1
Map placing the Nusa Islands (red highlight) in geographical context within Papua New Guinea. Top left insert places the map in geographical context within the southwest Pacific region.

2.3 Data analyses

All statistical computing was performed using *R* software (version: 4.3.1), with the *stats* (R Core Team, 2023), *MASS* (Venables and Ripley, 2002), *mvabund* (Wang et al., 2012), and *vegan* (Oksanen et al., 2022) packages. For all analyses, statistical significance was accepted as $p < 0.05$ and summaries of data are presented in-text as means ± standard deviations.

Variation in tool ownership among artisans was expressed as a resemblance matrix based on Jaccard distances (*R* package: *vegan*; function: *vegdist*). The resemblance matrix was visualised using non-metric multidimensional scaling (*R* package: *vegan*; function: *metaMDS*). Influence of a specific tool on the variation in tool ownership was then evaluated based on the strength and significance of correlation between that specific tool and the plot configuration (*R* package: *vegan*; function: *envfit*).

To evaluate how ownership of a specific tool or type of tool differentiated marine taxa utilised for shellcraft, two analyses were performed. First, we modelled the taxa richness (i.e., count of unique taxa) utilised as a function of tool ownership using generalised linear models (GLMs) with a negative binomial error structure (*R* package: *MASS*; function: *glm.nb*); significance of a modelled fit, relative to a null model, was assessed with a likelihood-ratio test. Second, we modelled the likelihood of utilising each taxon as a function of tool ownership using GLMs with a binomial error structure and combined this with multivariate hypothesis testing, based on a summative likelihood-ratio statistic and p-values derived from 999 parametric bootstrap resamples (Warton et al., 2012), to make inferences for all taxa simultaneously (*R* package: *mvabund*; function: *manyglm*).

To evaluate how ownership of a specific tool or type of tool differentiated products produced from shellcraft, a similar approach was taken. First, we modelled the product richness (i.e., count of unique products) produced as a function of tool ownership using GLMs with a negative binomial error structure (*R* package: *MASS*; function: *glm.nb*). Second, we modelled the likelihood of producing each product as a function of tool ownership using GLMs with a binomial error structure and combined this with multivariate hypothesis testing, as previously detailed, to make inferences for all products simultaneously (*R* package: *mvabund*; function: *manyglm*).

In all models, ownership of a specific tool was treated as a binary predictor (i.e., owned or not owned). Ownership of a type of tool was also treated as a binary predictor to account for overlapping functionality among some of the tools identified (Simard, 2019). This applied to ownership of a drill, represented by mechanical and pump drills, or a saw, represented by coping and jewellery saws (Figure 2).

FIGURE 2
Tools that were used for shellcraft at the Nusa Islands of Papua New Guinea: **(A)** mechanical drill, **(B)** pump drill, **(C)** coping saw, **(D)** jewellery saw, **(E)** cutter pliers, **(F)** jewellery pliers, **(G)** needle file, **(H)** stone file, **(I)** grinder, and **(J)** electric rotary.

3 Results

3.1 Tool ownership

Artisans collectively identified 10 tools that were used for shellcraft (Figure 2), with 3.8 ± 1.6 (range: 1 – 8) tools owned per artisan. No artisan owned all tools, and only 4 artisans (11.1%) owned more than half. Variation in tool ownership among the 36 artisans resulted in 30 unique combinations of the 10 tools identified (Figure 4). The percentage of artisans owning a specific tool, and type of tool, is presented in Table 1.

Seven of the 10 tools identified significantly influenced the variation in tool ownership (Figure 4). This included jewellery pliers (r^2 = 0.64, p < 0.01), grinder (r^2 = 0.44, p < 0.01), cutter pliers (r^2 = 0.37, p < 0.01), jewellery saw (r^2 = 0.30, p < 0.01), stone file (r^2 = 0.30, p < 0.01), needle file (r^2 = 0.28, p < 0.01), and pump drill (r^2 = 0.24, p < 0.01). Neither mechanical drill (r^2 = 0.02, p = 0.67) nor the two least frequently owned tools, electric rotary (r^2 = 0.04, p = 0.52) and coping saw (r^2 = 0.01, p = 0.89), significantly influenced the variation in tool ownership.

3.2 Taxa utilisation as a function of tool ownership

Taxa richness utilised for shellcraft varied among artisans (20.3 ± 10.8 taxa; range 4 – 57) and collectively represented 73 taxa (Supplementary Material 1). No specific tool or type of tool was capable of explaining a significant amount of this variation (Table 2). The number of tools owned was also unable to explain

FIGURE 3
Products produced from shellcraft at the Nusa Islands of Papua New Guinea were categorised as **(A)** bangles, **(B)** bracelets, **(C)** earrings, **(D)** necklaces, or **(E)** pendants.

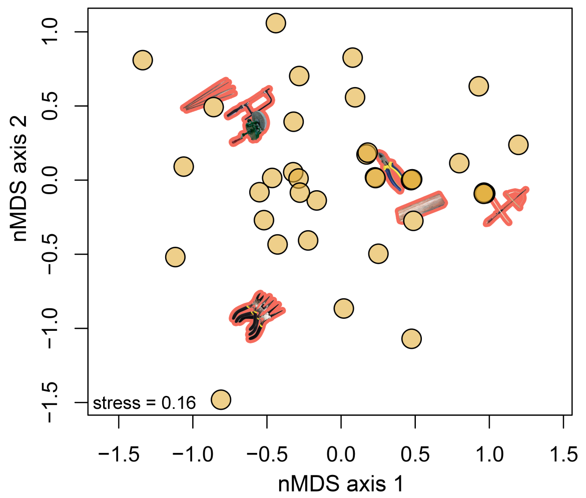

FIGURE 4
Variation in tool (n = 10) ownership among artisans (n = 36) visualised as a biplot of Jaccard distances using non-metric multidimensional scaling (nMDS). Positioning of a specific tool reflects its association with the plot configuration; only those tools that significantly (p < 0.05) influenced the variation in tool ownership are shown.

a significant amount of this variation (χ^2 = 1.26, p = 0.26), indicating that a greater richness of tools owned did not translate to a greater richness of taxa utilised.

The likelihood of an artisan utilising a certain taxon for shellcraft was significantly related to ownership of four specific tools (Table 2); ownership of an electric rotary, jewellery pliers, a jewellery saw, or a grinder was related to the likelihood of utilising a respective 31 (42.5%), 21 (28.8%), 20 (27.4%), or 16 (21.9%) taxa (Table 3). These relationships collectively concerned 47 (64.3%) of the 73 taxa utilised for shellcraft.

TABLE 1 Tools used for shellcraft, their primary functions, and the percentage of artisans owning a specific tool or type of tool.

Tool	Primary function	Artisans (%)
Drill	Drilling holes	72.2
Mechanical drill	Drilling large (> 0.5 mm ø) holes	52.8
Pump drill	Drilling small (< 1 mm ø) holes	19.4
Saw	Cutting materials	41.7
Coping saw	Cutting thick (> 4 mm) materials	5.6
Jewellery saw	Cutting thin (< 5 mm) materials	38.9
Cutter pliers	Fragmenting materials	77.8
Jewellery pliers	Attaching metal findings to pendants/beads	41.7
Needle file	Smoothing edges/shaping thin (< 10 mm thick) materials	22.2
Stone file	Shaping fragmented materials into beads	55.6
Grinder	Removing periostracum and prismatic calcite layers/shaping thick (≥ 4 mm) materials	50.0
Electric rotary	Carving/engraving materials	13.9

Ownership of an electric rotary often related to a decreased likelihood of utilising a given taxon (Table 3). This applied to 22 taxa, primarily represented by gastropods (n = 18) with a typical size of 3.4 ± 2.4 cm (range: 1.0 – 8.0 cm). The other four taxa that artisans owning an electric rotary were less likely to utilise included the crab (*Carpilus maculatus*), two bivalves (*Isognomon* spp.), and a larger (18 cm) gastropod (*Lambis lambis*). An increased likelihood of utilising nine taxa was also related to ownership of an electric rotary. Among these taxa, the strongest relationships were evident with four gastropods: *Conus ebraeus* (χ^2 = 12.71), *Euplica scripta* (χ^2 = 6.52), *Conus glans* (χ^2 = 5.09), and *Notocochlis gualteriana* (χ^2 = 5.09).

Ownership of a jewellery saw also often related to a decreased likelihood of utilising a given taxon (Table 3). This applied to 18 taxa, primarily represented by gastropods (n = 15) with a typical size of 3.7 ± 2.0 cm (range: 1.3 – 8.0 cm). The other three taxa that artisans owning a jewellery saw were less likely to utilise included the crab (*Carpilus maculatus*), a small (2.8 cm) bivalve (*Isognomon albisoror*), and a larger (14 cm) gastropod (*Mitra mitra*). Ownership of a jewellery saw related to an increased likelihood of utilising only two gastropods: *Ovula ovum* and *Turbo marmoratus*. When considering ownership of a saw more generally, as a type of tool, the same species were represented in addition to an increased likelihood of utilising sea turtle (Cheloniidae).

Ownership of jewellery pliers often related to an increased likelihood of utilising a given taxon (Table 3). This applied to 16 taxa, primarily represented by gastropods (n = 14) with a typical size of 5.0 ± 2.7 cm (range: 1.2 – 10.0 cm). The other two taxa that artisans owning jewellery pliers were more likely to utilise included a larger (14 cm) gastropod (*Mitra mitra*) and a bivalve (*Atrina pectinata*). A decreased likelihood of utilising five taxa was also related to ownership of jewellery pliers, but these relationships were relatively weak ($\chi^2 \leq 2.24$) despite their significance.

Ownership of a grinder also often related to an increased likelihood of utilising a given taxon (Table 3). This applied to 11 taxa, which included black corals (Antipathidae), nautilus (Nautilidae), a pearl oyster (*Pinctada margaritifera*), and several gastropods with nacreous shells (*Chrysostoma paradoxum*, *Rochia nilotica*, and *Turbo marmoratus*). A decreased likelihood of utilising five taxa was also related to ownership of a grinder, but these relationships were relatively weak ($\chi^2 \leq 2.89$) despite their significance.

3.3 Product production as a function of tool ownership

Product richness produced from shellcraft varied among artisans (3.5 ± 1.1 products; range: 1 – 5), with 19.4% of artisans (n = 7) producing all products identified (i.e., bangles, bracelets, earrings, necklaces, and pendants). Yet no specific tool or type of tool was capable of explaining a significant amount of this variation (Table 2). The number of unique tools owned was also unable to

TABLE 2 Statistical results for taxa utilisation (i.e., taxa richness and likelihood of utilising taxa) and product production (i.e., product richness and likelihood of producing products) as functions of tool ownership.

Tool	Taxa utilisation		Product production	
	Richness	Likelihood	Richness	Likelihood
Drill	$\chi^2 = 0.02$, $p = 0.89$	$\chi^2 = 67.9$, $p = 0.85$	$\chi^2 = 0.12$, $p = 0.73$	$\chi^2 = 1.9$, $p = 0.93$
Mechanical drill	$\chi^2 = 0.50$, $p = 0.48$	$\chi^2 = 58.8$, $p = 0.98$	$\chi^2 < 0.01$, $p = 0.99$	$\chi^2 = 3.0$, $p = 0.77$
Pump drill	$\chi^2 = 0.56$, $p = 0.45$	$\chi^2 = 90.5$, $p = 0.19$	$\chi^2 = 0.15$, $p = 0.70$	$\chi^2 = 9.5$, $p = 0.12$
Saw	$\chi^2 = 0.29$, $p = 0.59$	**$\chi^2 = 120.4$, $p < 0.01$**	$\chi^2 = 0.31$, $p = 0.58$	**$\chi^2 = 14.7$, $p = 0.02$**
Coping saw	$\chi^2 = 0.41$, $p = 0.52$	$\chi^2 = 50.2$, $p = 0.97$	$\chi^2 < 0.01$, $p = 0.98$	$\chi^2 = 7.5$, $p = 0.11$
Jewellery saw	$\chi^2 = 0.19$, $p = 0.66$	**$\chi^2 = 104.9$, $p = 0.04$**	$\chi^2 = 0.09$, $p = 0.77$	**$\chi^2 = 13.0$, $p = 0.03$**
Cutter pliers	$\chi^2 = 0.02$, $p = 0.89$	$\chi^2 = 64.1$, $p = 0.92$	$\chi^2 = 0.03$, $p = 0.87$	$\chi^2 = 3.6$, $p = 0.70$
Jewellery pliers	$\chi^2 = 3.36$, $p = 0.07$	**$\chi^2 = 127.2$, $p < 0.01$**	$\chi^2 = 0.54$, $p = 0.46$	$\chi^2 = 8.0$, $p = 0.25$
Needle file	$\chi^2 = 0.02$, $p = 0.89$	$\chi^2 = 69.0$, $p = 0.82$	$\chi^2 = 0.14$, $p = 0.71$	**$\chi^2 = 15.8$, $p = 0.02$**
Stone file	$\chi^2 = 0.01$, $p = 0.92$	$\chi^2 = 69.8$, $p = 0.80$	$\chi^2 = 0.40$, $p = 0.53$	$\chi^2 = 4.6$, $p = 0.56$
Grinder	$\chi^2 = 2.75$, $p = 0.10$	**$\chi^2 = 102.6$, $p < 0.01$**	$\chi^2 = 2.28$, $p = 0.13$	**$\chi^2 = 18.8$, $p < 0.01$**
Electric rotary	$\chi^2 = 0.97$, $p = 0.32$	**$\chi^2 = 108.6$, $p < 0.01$**	$\chi^2 = 0.35$, $p = 0.55$	$\chi^2 = 5.2$, $p = 0.46$

Statistically significant ($p < 0.05$) relationships appear in bold.

TABLE 3 Statistical results for the likelihood of utilising each taxon as a function of tool ownership.

Taxa utilised			Type of tool	Specific tool			
Taxon*	Class	Size** (cm)	Saws (coping + jewellery)	Jewellery saw	Jewellery pliers	Grinder	Electric rotary
Antipathidae spp.	hexacorallia	100.0				**LR = 5.61, p = 0.017 +**	
Architectonica perspectiva	gastropoda	5.0					
Atrina pectinata	bivalvia	26.0			**LR = 3.97, p = 0.044 +**		
Atrina vexillum	bivalvia	30.0					
Bulla vernicosa	gastropoda	3.5	**LR = 3.43, p = 0.001 -**	**LR = 3.13, p = 0.001 -**	**LR = 5.64, p = 0.001 +**		
Canarium urceus	gastropoda	5.0			**LR = 5.64, p = 0.001 +**		
Carcharhinus melanopterus	elasmobranchii	42.5					
Carpilus maculatus	malacostraca	18.0	**LR = 1.10, p = 0.001**	**LR = 1.00, p = 0.001 -**	**LR = 1.10, p = 0.001 -**	**LR = 1.42, p = 0.001 -**	**LR = 0.30, p = 0.001 -**
Cassidula nucleus	gastropoda	2.2					**LR = 1.27, p = 0.001 -**
Cheloniidae spp.	reptilia	80.0	**LR = 4.04, p = 0.048 +**				
Chrysostoma paradoxum	gastropoda	1.8				**LR = 6.05, p = 0.001 +**	**LR = 1.27, p = 0.001 +**
Conomurex luhuanus	gastropoda	5.0					**LR = 3.56, p = 0.001 -**

(Continued)

TABLE 3 Continued

Taxa utilised			Type of tool	Specific tool			
Taxon*	Class	Size** (cm)	Saws (coping + jewellery)	Jewellery saw	Jewellery pliers	Grinder	Electric rotary
Conus cf. *cuvieri*	gastropoda	11.5					
Conus ebraeus	gastropoda	4.4			LR = 4.65, *p* = 0.043 +	LR = 4.66, *p* = 0.047 +	LR = 12.71, *p* = 0.001 +
Conus glans	gastropoda	3.5					LR = 5.09, *p* = 0.027 +
Conus litteratus	gastropoda	13.0					
Conus marmoreus	gastropoda	10.0			LR = 6.56, *p* = 0.009 +		
Conus mustelinus	gastropoda	7.4			LR = 7.72, *p* = 0.001 +		
Conus stercusmuscarum	gastropoda	5.1					
Conus textile	gastropoda	10.0					
Conus tulipa	gastropoda	6.5	LR = 4.67, *p* = 0.001 -	LR = 4.25, *p* = 0.001 -			
Conus vexillum	gastropoda	9.2			LR = 5.64, *p* = 0.001 +		
Cypraea tigris	gastropoda	9.0					
Drupa ricinus	gastropoda	1.9	LR = 1.10, *p* = 0.001 -	LR = 1.00, *p* = 0.001 -	LR = 1.10, *p* = 0.001 -	LR = 1.42, *p* = 0.001 -	LR = 0.30, *p* = 0.001 -
Engina bonasia	gastropoda	1.0				LR = 2.89, *p* = 0.001 +	LR = 0.62, *p* = 0.001 -
Engina lineata	gastropoda	1.3	LR = 4.67, *p* = 0.001 -	LR = 4.25, *p* = 0.001 -			LR = 1.27, *p* = 0.001 -
Engina mendicaria	gastropoda	1.6	LR = 4.67, *p* = 0.001 -	LR = 4.25, *p* = 0.001 -			LR = 1.27, *p* = 0.001 -
Engina mundula	gastropoda	1.0					LR = 1.27, *p* = 0.001 -
Euplica scripta	gastropoda	1.2					LR = 6.52, *p* = 0.001 +
Euprotomus aurisdianae	gastropoda	7.0					LR = 1.62, *p* = 0.001 -
Gibberulus gibberulus	gastropoda	5.0	LR = 4.67, *p* = 0.001 -	LR = 4.25, *p* = 0.001 -			LR = 1.27, *p* = 0.001 -
Harpa amouretta	gastropoda	4.9	LR = 2.24, *p* = 0.001 -	LR = 2.04, *p* = 0.001 -	LR = 3.67, *p* = 0.001 +		LR = 0.62, *p* = 0.001 -
Imbricariopsis vanikorensis	gastropoda	1.4	LR = 4.67, *p* = 0.001 -	LR = 4.25, *p* = 0.001 -			
Isognomon albisoror	bivalvia	2.8	LR = 1.10, *p* = 0.001 -	LR = 1.00, *p* = 0.001 -	LR = 1.10, *p* = 0.001 -	LR = 1.42, *p* = 0.002 -	LR = 0.30, *p* = 0.001 -
Isognomon ephippium	bivalvia	10.0					LR = 4.45, *p* = 0.001 -
Lambis lambis	gastropoda	18.0					LR = 0.94, *p* = 0.001 -
Mauritia arabica	gastropoda	8.0					

(Continued)

TABLE 3 Continued

Taxa utilised			Type of tool	Specific tool			
Taxon*	Class	Size** (cm)	Saws (coping + jewellery)	Jewellery saw	Jewellery pliers	Grinder	Electric rotary
Melampus fasciatus	gastropoda	2.5	LR = 4.59, *p* = 0.044 -				
Mitra mitra	gastropoda	14.0	LR = 3.43, *p* = 0.001 -	LR = 3.13, *p* = 0.001 -	LR = 5.64, *p* = 0.001 +		
Mitra turgida	gastropoda	1.4					
Monetaria caputserpentis	gastropoda	3.4			LR = 6.75, *p* = 0.012 +		
Monetaria annulus/moneta	gastropoda	3.0					
Nassarius acuticostus	gastropoda	1.6					LR = 1.27, *p* = 0.001 -
Nassarius globosus	gastropoda	1.2					
Nautilidae spp.	cephalopoda	23.0				LR = 4.43, *p* = 0.001 +	LR = 0.94, *p* = 0.001 +
Neripteron siquijorense	gastropoda	2.1	LR = 1.10, *p* = 0.001 -	LR = 1.00, *p* = 0.001 -	LR = 1.79, *p* = 0.001 +	LR = 1.42, *p* = 0.001 +	LR = 0.30, *p* = 0.001 -
Nerita polita	gastropoda	3.0	LR = 5.96, *p* = 0.001 -	LR = 5.43, *p* = 0.001 -			
Notocochlis gualteriana	gastropoda	2.0					LR = 5.09, *p* = 0.027 +
Oliva amethystina	gastropoda	4.0					
Oliva caerulea	gastropoda	4.0					
Oliva carneola	gastropoda	2.0			LR = 2.24, *p* = 0.001 -	LR = 2.89, *p* = 0.001 -	LR = 0.62, *p* = 0.001 -
Oliva irisans	gastropoda	6.3				LR = 4.43, *p* = 0.001 +	
Oliva oliva f. flaveola	gastropoda	3.0					LR = 3.56, *p* = 0.001 -
Ovula ovum	gastropoda	8.0	LR = 1.79, *p* = 0.001 +	LR = 1.93, *p* = 0.001 +	LR = 1.10, *p* = 0.001 -	LR = 1.42, *p* = 0.001 -	LR = 0.30, *p* = 0.001 -
Palmadusta asellus	gastropoda	2.0					
Pictocolumbella ocellata	gastropoda	1.7					
Pinctada margaritifera	bivalvia	22.3				LR = 6.05, *p* = 0.001 +	LR = 1.27, *p* = 0.001 +
Pinctada maxima	bivalvia	20.0					
Polinices mammilla	gastropoda	5.0					
Pseudonebularia chrysalis	gastropoda	1.9	LR = 11.06, *p* = 0.002	LR = 9.57, *p* = 0.001 -			
Pteria penguin	bivalvia	20.0					
Rhinoclavis fasciata	gastropoda	8.0	LR = 2.24, *p* = 0.002 -	LR = 2.04, *p* = 0.001 -	LR = 3.67, *p* = 0.001 +		LR = 0.62, *p* = 0.001 -
Rochia nilotica	gastropoda	11.0				LR = 7.84, *p* = 0.007 +	
Strigatella litterata	gastropoda	1.8					

(Continued)

TABLE 3 Continued

Taxa utilised			Type of tool	Specific tool			
Taxon*	Class	Size** (cm)	Saws (coping + jewellery)	Jewellery saw	Jewellery pliers	Grinder	Electric rotary
Strigatella paupercula	gastropoda	2.0			LR = 5.23, p = 0.011 +		LR = 3.14, p = 0.001 +
Strigatella retusa	gastropoda	1.8					
Terebellum terebellum	gastropoda	5.0	LR = 4.67, p = 0.001 -	LR = 4.25, p = 0.001 -	LR = 7.72, p = 0.001 +		
Turbo maculatus	gastropoda	5.0					
Turbo marmoratus	gastropoda	18.0	LR = 6.75, p = 0.021 +	LR = 4.87, p = 0.034 +		LR = 5.78, p = 0.023 +	LR = 3.57, p = 0.049 +
Turbo petholatus	gastropoda	6.0					
Turbo setosus	gastropoda	5.0	LR = 2.24, p = 0.001 -	LR = 2.04, p = 0.001 -		LR = 2.89, p = 0.001 +	
Vexillum leucodesma	gastropoda	1.2			LR = 3.67, p = 0.001 +		LR = 0.62, p = 0.001 -
Vexillum plicarium	gastropoda	4.0	LR = 2.24, p = 0.001 -	LR = 2.04, p = 0.001 -	LR = 3.67, p = 0.001 +		LR = 0.62, p = 0.001 -

Statistically significant (p < 0.05) relationships are shown only for those specific tools or type of tool where the inference for all taxa was significant. Positive relationships appear in green; negative relationships appear in red.
*A voucher specimen of each taxon is illustrated in Supplementary Material 1; taxa in bold are also consumed locally based on Simard et al. (2023).
**Indication of typical size based on Simard et al. (2022).

explain a significant amount of this variation (χ^2 = 0.46, p = 0.50), indicating that a greater richness of tools owned did not translate to a greater richness of products produced.

The likelihood of an artisan producing a certain product from shellcraft was significantly related to ownership of three specific tools (Table 2); ownership of a grinder, needle file, or jewellery saw was related to the likelihood of producing pendants, earrings, bangles, and/or bracelets.

Ownership of a grinder was related to an increased likelihood of producing pendants, earrings, and bangles. The likelihood that artisans owning a grinder produced bangles (44.4%) was much higher (cf. 5.6%) than for artisans without this tool (χ^2 = 8.03, p < 0.01). The same applied to pendants (χ^2 = 5.78, p = 0.03) and earrings (χ^2 = 4.43, p < 0.01), with a respective 77.8% and 100% of artisans owning a grinder producing these products compared to a respective 38.9% and 83.3% of artisans without these tools. Ownership of a grinder was unrelated to the likelihood of producing either of the other two (bracelet or necklace) products.

Ownership of a needle file was similarly related to an increased likelihood of producing pendants and earrings. The likelihood that artisans owning a needle file produced pendants (87.5%) was much higher (cf. 50.0%) than for artisans without this tool (χ^2 = 4.06, p = 0.03). The same applied to earrings (χ^2 = 1.58, p < 0.01), with 100% of artisans owning a needle file producing this product compared to 89.3% of artisans without his tool. Ownership of a needle file was unrelated to the likelihood of producing the other three (bracelet, necklace, or bangle) products.

Ownership of a jewellery saw was the third tool related to an increased likelihood of producing pendants. The likelihood that artisans owning a jewellery saw produced pendants (85.7%) was much higher (cf. 40.9%) than for artisans without this tool (χ^2 = 7.65, p < 0.01). A jewellery saw was also the only tool related to a decreased likelihood of producing a product, with the likelihood that artisans owning a jewellery saw produced bracelets (71.4%) being less (cf. 95.5%) than those without this tool (χ^2 = 4.12, p = 0.02). Ownership of a jewellery saw was unrelated to the likelihood of producing any of the other three (earrings, bangles, or necklaces) products. When considering ownership of a saw more generally, as a type of tool, the increased likelihood of producing pendants remained significant (χ^2 = 9.21, p < 0.01), but not the decreased likelihood of producing bracelets (χ^2 = 3.57, p = 0.07).

4 Discussion

4.1 Shellcraft at the Nusa Islands

Shellcraft at the Nusa Islands was found to rely on a substantial richness of physical assets. Yet only a few physical assets appear necessary to participate in shellcraft because most artisans owned far fewer tools than were collectively identified. When considering variation in tool ownership resulted in 30 unique combinations of the 10 tools identified, it becomes apparent there is no specific tool or combination of tools that is necessary to participate in shellcraft. Variation in tool ownership was unrelated to income from shellcraft in the present study (Supplementary Material 2), with unique combinations of tools seemingly able to generate positive livelihood outcomes (Simard et al., 2019). Factors influencing an artisan's access to a specific tool, ability to use that tool, and desire to do so are presumably responsible for the variation in tool ownership.

While it is often assumed that owning more physical assets will translate to a greater range of options (DFID, 1999; UNDP, 2017), ownership of a greater tool richness did not translate to greater taxa or product richness within the shellcraft microcosm studied. Rather, ownership of a few specific tools related to a greater likelihood of utilising certain taxa or producing certain products. Artisans owning a grinder, jewellery saw, or needle file were more likely to produce pendants, for example. These three tools have complementary functions (Table 1), such that production of a pendant may entail using of a grinder to remove the back (i.e., non-nacreous layers) of a shell, before using a jewellery saw to cut a design that is then shaped using a needle file (e.g., Figure 3E). Depending on the taxon and intended design (e.g., solid vs. freeform shape) access to all three tools may not be necessary, and a grinder alone may be sufficient to produce solid shape pendants (e.g., Figure 3C). Combinations of other tools are likewise anticipated to have complementary functions unique to certain taxa or products. Since a broad range of products appeal to consumers, with personal aesthetic preferences in design and colour influencing purchase decisions (Militz et al., 2021), a unique combination of tools would theoretically enable an artisan to capture a particular market niche for certain taxa or products (Tokerau, 2008; Naidu et al., 2014; Simard et al., 2019, 2022).

Past information concerning shellcraft at the Nusa Islands confirms stability of tool ownership through time. Simard et al. (2019) identified nine tools used for shellcraft while the present study identified the same nine tools and one additional tool, the pump drill. Artisans have long been aware that a pump drill could be used for shellcraft, and use of this tool may relate to fewer mechanical drills being used (cf. Simard et al., 2019) given their similar function (Table 1). The present study also found artisans owned a similar tool richness (3.8 ± 1.6 tools) to what Simard et al. (2019) found artisans had owned (3.9 ± 1.6 tools) previously. This stability reaffirms that tool ownership in the present study was not coincidental but representative of shellcraft at the Nusa Islands.

Most of the tools identified were evidently imported and store-bought (Simard et al., 2019). Although artisans had indicated an array of traditional tools, such as those embedded within local culture (Finsch, 1893; Lewis, 1939), could be used in place of store-bought tools (Simard et al., 2019), use of traditional tools was quite limited in practice. No artisan had used traditional tools for fragmenting or shaping fragmented materials into beads during the previous year, despite awareness of such possibility (Simard et al., 2019). Further, the only traditional tool found to be used for shellcraft, the pump drill, was owned by far fewer artisans (19.4%) than a store-bought mechanical drill (52.8%). Noting costs of store-bought tools should incentivise use of traditional tools (Simard et al., 2019), an enduring bias towards store-bought tools suggests most artisans perceive use of traditional tools as unrealistic. Whilst cultural heritage is commonly embodied through taxa utilised and products produced (Barclay et al., 2018; Simard et al., 2019, 2022; Ruenes et al., 2023), a reliance on store-bought tools emphasises that shellcraft is truly a 'hybrid' craft blending traditional and modern elements (Grobar, 2019).

A distinction could also be made as to whether the store-bought tools used for shellcraft required electricity. At the Nusa Islands there was a reliance on hand-tools, with only a few (13.9%) artisans owning the sole electric-tool (i.e., electric rotary) identified. This likely reflects the lack of public infrastructure at the Nusa Islands for providing electricity. Whilst some artisans may have access to electricity through use of a private generator (Simard et al., 2019), the bias towards hand-tools suggests use of electric-tools for shellcraft was unrealistic. This implies improved access and capacity in use of electric-tools (e.g., Teitelbaum and Fale, 2008) is unlikely to provide long-term benefits to coastal communities lacking the necessary public infrastructure to support their use.

In summation, shellcraft at the Nusa Islands was reliant on a substantial richness of store-bought hand-tools. Ownership of neither all nor any specific tool was essential, whereas ownership of a unique combination of tools was typical. These results can be viewed as providing both an accurate and realistic understanding of the tools required for shellcraft. But, as alluded to previously, this information alone is insufficient to plan and guide exogenous development intervention that seeks to establish shellcraft as an alternative activity within small-scale fishery production systems. Additionally, an understanding of how tool ownership differentiates taxa utilised and products produced is critical for determining if access to a specific tool is necessary for achieving a desired outcome. In the next section, the relationships between specific tools and certain taxa or products are discussed within the context of exogenous development intervention.

4.2 Exogenous development intervention

One approach to thinking about the objectives, scope, and priorities for exogenous development intervention is to first gain an understanding of available assets upon which existing livelihoods are built and then identify patterns in asset use that generate positive livelihood outcomes (Allison and Ellis, 2001). By determining if access to a particular asset is necessary or sufficient for achieving desired outcomes, some guidance on where intervention should focus, at least initially, can be attained. Shellcraft, through links with subsistence fishing (Purcell et al., 2021), aquaculture (Mikhailovich et al., 2022), or tourism (Chand et al., 2014; Naidu et al., 2014; Fröcklin et al., 2018; Militz et al., 2021), has been shown to generate positive livelihood outcomes. Yet knowledge generation emphasising outcomes has detracted attention from the natural and physical assets required to generate those outcomes (Simard et al., 2022, 2024). Our study addressed this deficiency by seeking to understand how tool ownership differentiates taxa utilised and products produced. Below, we discuss how the knowledge generated can inform exogenous development intervention that seeks to establish shellcraft as an alternative activity linked to subsistence fishing, aquaculture, or tourism.

4.2.1 Subsistence fishing

Bivalves and gastropods are commonly fished for household consumption throughout the Pacific Islands (Dalzell et al., 1996; Szabó and Amesbury, 2011; Thaman et al., 2017). After consuming the soft tissue (meat) of these molluscs, shells of some taxa find cultural (e.g., Burgos, 2020), utilitarian (e.g., Thaman et al., 2017), or commercial (e.g., Simard et al., 2021) use. Most shells, however, are perceived as waste and discarded (Porter et al., 2022; Simard et al., 2023). By utilising this shell waste for shellcraft, there is potential for an existing activity (subsistence fishing) to support an additional value-adding activity (shellcraft) within coastal communities. There is a compelling argument for exogenous development intervention to expedite the integration of shell waste with shellcraft as a more efficient use of shell waste could generate positive livelihood outcomes (Sharp and Mariojouls, 2012; Purcell et al., 2019; Tilley et al., 2020; Porter et al., 2022; Simard et al., 2023). An understanding of tools used to process shells of the molluscs consumed is necessary to plan and guide such intervention.

Subsistence fishing tends to target a similar composition of molluscs throughout the Pacific Islands, such that the same genera, or even species, are consumed (Munro, 1994; Thomas, 2001; Kinch, 2003; Aswani and Vaccaro, 2008; Bao and Drew, 2017; Thaman et al., 2017; Simard et al., 2023). This includes many species utilised for shellcraft (Tilley et al., 2020; Purcell et al., 2021; Simard et al., 2022). At our study site, for instance, 15 taxa utilised for shellcraft are also consumed (Table 3). Considering tool ownership related to the likelihood of utilising 10 of these taxa, focusing development intervention on specific tools is likely necessary to affect the attractiveness of utilising shell waste for shellcraft. Specifically, a grinder most often associated with an increased likelihood of utilising certain taxa consumed (e.g., *Rochia nilotica*, *Turbo marmoratus*, and *Turbo setosus*). The importance of a grinder for linking subsistence fishing with shellcraft is also evident from practice. An intervention providing electric grinders in conjunction with training was recently trialled in Samoa (Purcell et al., 2019) where this tool is now used for processing shell waste from *Rochia nilotica* to generate new earnings (Purcell et al., 2021). Intervention aiming to expedite the integration of shell waste with shellcraft would benefit from ensuring artisans have access to a grinder as well as knowledge, skill, and confidence in the use of this tool.

4.2.2 Aquaculture

Molluscs are cultured to produce mother-of-pearl and pearls throughout the Pacific Islands (Shokita et al., 1991; Southgate et al., 2008). Much of what is produced, however, is still exported in unprocessed form (Johnston et al., 2019; Purcell et al., 2019; Simard et al., 2021). As both mother-of-pearl and pearls can be utilised for shellcraft, there exists potential for an existing activity (aquaculture) to support an additional value-adding activity (shellcraft) within coastal communities (Teitelbaum and Fale, 2008; Fröcklin et al., 2018; Johnston et al., 2019; Simard et al., 2022). Culture of pearl oysters (*Pinctada* spp. and *Pteria penguin*), for example, could provide artisans a renewable source of shells and opportunity to diversify products using pearls (Teitelbaum and Fale, 2008; Southgate et al., 2019; Tanu et al., 2022). Positive livelihood outcomes from exogenous development intervention linking aquaculture with shellcraft in Fiji and Tonga (Mikhailovich et al., 2022) make a compelling argument for this kind of intervention throughout the Pacific Islands (Southgate et al., 2023) and in other regions (Fröcklin et al., 2018; Saucedo et al., 2022). An understanding of the tools used to process shells of cultured molluscs, however, is necessary to plan and guide such intervention.

Molluscs cultured in the Pacific Islands have included pearl oysters (*Pinctada* spp. and *Pteria penguin*), trochus (*Rochia nilotica*), and turbo snails (*Turbo* spp.), all of which can be utilised for shellcraft. At our study site, for instance, three species of pearl oysters (*Pinctada margaritifera*, *Pinctada maxima*, and *Pteria penguin*), trochus, and three species of turbo snails (*Turbo marmoratus*, *Turbo petholatus*, and *Turbo setosus*) were utilised for shellcraft (Table 3). Considering tool ownership was related to the likelihood of utilising four of these taxa (i.e., *P. margaritifera*, *R. nilotica*, *T. marmoratus*, and *T. petholatus*), focusing development intervention on specific tools is likely necessary to affect the attractiveness of utilising cultured molluscs for shellcraft. The importance of an electric rotary for carving pearl oysters and turbo snails has been evident from practice (Manieva and Telii, 2008; Teitelbaum and Fale, 2008), and this was reaffirmed in the present study where ownership of this tool was associated with an increased likelihood of utilising *P. margaritifera* and *T. marmoratus*. Likewise, the same can be said for a grinder (Manieva and Telii, 2008; Tokerau, 2008), which was associated with an increased likelihood of utilising a pearl oyster (*P. margaritifera*), trochus, and certain turbo snails (*T. marmoratus* and *T. setosus*). Intervention aiming to link molluscan aquaculture with shellcraft would benefit from ensuring artisans have access to grinders and electric rotary tools as well as knowledge, skill, and confidence in the use of these tools.

4.2.3 Tourism

Tourism is perceived as the most probable avenue by which to generate positive livelihood outcomes for coastal communities in the Pacific Islands (Connell and Rugendyke, 2008; Connell, 2018). Among the opportunities associated with tourism, souvenir production has the greatest potential to maximise the accrual and distribution of economic benefit (IFC, 2016; Militz et al., 2021). Popular souvenirs in the Pacific Islands include locally made products that are artistic and traditional in nature (Naidu et al., 2014; Militz et al., 2021), attributes which typify products produced from shellcraft (Resture and Resture, 2005; Barclay et al., 2018; Simard et al., 2019; Ruenes et al., 2023). Demand for such products is evident but remains largely unmet (Chand et al., 2014; IFC, 2016; Militz et al., 2021). To address this demand, exogenous development of shellcraft is considered necessary to ensure products produced meet expectations (Nimoho et al., 2013; Chand et al., 2014; IFC, 2016; Militz et al., 2021). To plan and guide such intervention, an understanding of how tool ownership differentiates taxa utilisation and product production is required.

Expectations of what constitutes an appropriate souvenir requires consideration be given to the taxa utilised. Tourism demands souvenirs that have been produced in an environmentally 'friendly' (Chand et al., 2014) or 'sustainable' (Militz et al., 2021) manner. Yet shellcraft has been shown to utilise taxa threatened with overexploitation (Kinch and Burgess, 2009; Nijman, 2019; Simard et al., 2022; Ruenes et al., 2023). At our study site, for instance, shellcraft utilised taxa (i.e., Antipathiidae, Cheloniidae, and Nautilidae) subject to laws implementing the Convention on International Trade in Endangered Species (CITES) in PNG (Kinch and Burgess, 2009; Simard et al., 2022). As a fear of sanctions may instil an aversion to shellcraft (Gössling et al., 2004; Militz et al., 2021), there is need for exogenous development intervention to carefully consider provision of tools associated with these taxa. This concerns the saw, grinder, and electric rotary (Table 3). Whilst a grinder or electric rotary related to an increased likelihood of utilising black corals (Antipathidae) or nautilids (Nautilidae), these relationships were relatively weak, compared to those for other taxa. The increased likelihood that artisans owning a saw utilised sea turtle (Cheloniidae), however, was one of only three positive relationships for this tool. Both coping and jewellery saws have interchangeable blades, allowing artisans to modify these tools for use with sea turtles even if initially outfitted with blades better suited for molluscs (Simard, 2019). Interventions aiming to link tourism with shellcraft should consider the appropriateness of gifting saws and complement any provision of saws, grinders, or electric rotaries with training that communicates the inappropriateness of utilising certain taxa for producing souvenirs.

Expectations of what constitutes an appropriate souvenir also require consideration of the products produced. Bracelets, earrings, and necklaces produced from shellcraft are particularly popular with tourists in the Pacific Islands (Chand et al., 2014; Militz et al., 2021). Yet the available product richness at tourism destinations often fails to meet expectations (IFC, 2016; Militz et al., 2021). While exogenous development intervention may seek to enhance product richness through gifting tools (Manieva and Telii, 2008; Tokerau, 2008; Amos et al., 2014), our study showed that neither a greater tool richness nor any specific tool led to production of a greater product richness. Rather, specific tools related to an increased likelihood of producing certain products. Should there be desire to stimulate production of bangles, earrings, or pendants, such intervention would benefit from ensuring artisans have access to grinders, needle files, and jewellery saws as well as knowledge, skill, and confidence in use of these tools.

5 Conclusion

When considering an intended or targeted pathway for exogenous development of shellcraft, there is a need to shift thinking from whether this activity will generate desired outcomes to what physical assets are required to generate those outcomes. In the present study, shellcraft was found to rely on a substantial richness of store-bought hand-tools. Ownership of neither all nor any specific tool was essential, whereas ownership of a unique combination of tools was typical. These results provided an accurate and realistic understanding of the tools required for shellcraft and presented a basis for further examination of human dimensions in shellcraft.

Through an understanding of how tool ownership differentiated taxa utilised and products produced it was possible to determine if access to a specific tool was necessary, or an encumbrance, for achieving a desired outcome. In the present study, grinders were critical for enhancing the attractiveness of utilising shell waste from subsistence fishing or shells of commercially cultured taxa whereas saws were seen to encourage use of taxa, such as sea turtles, incompatible with tourism. Given the emphasis on establishing shellcraft as an alternative activity within small-scale fishery production systems for coastal communities both in the Pacific Islands (Nimoho et al., 2016; Purcell et al., 2019; Southgate et al., 2023) and globally (Fröcklin et al., 2018; Porter et al., 2022) the present study has significant practical application to help plan and guide appropriate exogenous development intervention.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Research activities associated with this study were reviewed and approved by University of the Sunshine Coast's Human Research Ethics Committee (S191337). Authorisation to conduct research activities in Papua New Guinea (PNG) was obtained through a Memorandum of Subsidiary Agreement (FIS/2014/060) between the Australian Centre for International Agricultural Research and the PNG National Fisheries Authority. Permissions to engage with residents of the Nusa Islands were obtained from elected and traditional community leaders. Written informed consent to participate in this study was provided by the participants.

Author contributions

TM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft. NS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – review & editing. JK: Conceptualization, Data curation, Funding acquisition, Project administration, Writing – review & editing. PS: Conceptualization, Funding acquisition, Project administration, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2024.1354163/full#supplementary-material

SUPPLEMENTARY MATERIAL 1
Voucher specimens of the taxa utilised for shellcraft.

SUPPLEMENTARY MATERIAL 2
Variation in tool ownership and income from shellcraft.

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