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prepared by

Paul Southgate – University of the Sunshine Coast

*co-authors/
contributors/
collaborators*

Thane Militz – University of the Sunshine Coast
Pranesh Kishore – University of the Sunshine Coast
Max Wingfield – University of the Sunshine Coast

approved by

Dr Chris Cvitanovic, Research Program Manager, Fisheries

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Fiji's next generation of mabé pearl farmers

2 Executive summary

Pearl culture in the Pacific offers livelihood opportunities for coastal communities that may include oyster collection and supply to cultured pearl producers, collection and culture of oysters for mabé pearl production and value-adding of raw materials (cultured mabé pearl and oyster shell of mother-of-pearl) to produce jewellery and handicraft products for domestic and export sales. This project built on the outputs of prior ACIAR projects to demonstrate the feasibility of these activities at community level in Fiji, Tonga and Papua New Guinea, and their compatibility.

Expansion of community-based spat collection in Fiji provides a means of improved supply of oysters (*Pinctada margaritifera*) to Fiji's cultured pearl sector, potentially mitigates the impacts of natural disasters such as tropical cyclones (on supply to the sector) and broadens the socio-economic benefits of this activity. In partnership with the Ministry of Fisheries Fiji (MFF) the number of Fijian coastal communities benefiting from pearl oyster spat collection increased to twenty-eight. In spat collecting communities where both *P. margaritifera* and *Pteria penguin* are collected as spat, the latter can be retained for mabé pearl culture. In partnership with MFF, this project established Fiji's first community pearl farms through successful transitioning of spat collection communities to mabé pearl culture. Eight community pearl farms now generate income from mabé pearl production. This project also demonstrated production of high-quality retail-ready pearl and pearl shell handicraft items by previously unskilled women's groups following appropriate training. Production workshops equipped with power tools were established in Ba (Viti Levu) and Somosomo (Taveuni) and supported training in handicraft and business skills for production of handicrafts that find ready domestic markets and sales at major tourist souvenir outlets in Fiji. Similar handicraft skills and production training, using hand tools, and based on training schedules and knowledge products developed by this project in PNG (see below), was carried out at communities in Vanua Levu, where access to electricity is unreliable. Economic assessment of the pearl sector in Fiji identified minimum viable farm size for cultured pearl production and demonstrated the profitability of both community-based pearl oyster spat collection and mabé pearl production.

The Kingdom of Tonga is unique among the pearl-producing countries of the South Pacific in focusing on mabé pearl culture using the winged pearl oyster *Pteria penguin*. Project activities in Tonga supported development of simplified and standardised hatchery production methods for *Pteria penguin*, based on the use of microalgae concentrates as a larval food source. This supported routine and regular production of pearl oyster spat and improved oyster supply to farmers. Economic modelling of hatchery production in Tonga could inform consideration of cost recovery for spat supply as the sector strengthens. The main pearl producing area in Tonga is Vava'u but, aligning with government priorities, this project supported expansion of mabé pearl farming in the Ha'apai island group and Tongatapu, through establishment of new farms and related training and extension activities. Unfortunately, both sites were badly impacted by the Hunga Tonga-Hunga Ha'apai volcanic eruption in January, 2022. Expansion of the Tongan mabé pearl sector has generated a 73% increase in annual pearl production to nearly 5,000 pearls, with an increase in annual production value to around \$732,000. The sector continues to attract new entrants with a five-fold increase in the number of people engaged in pearling activities, since 2013; 43% of which are women. One of the reasons for this was demonstrated by economic analysis conducted during the project, which showed that annual mabé pearl production from just 100 oysters generated estimated annual profits of more than double the average annual income in Tonga. This level of mabé pearl production requires less than 10 hours labour input per week, ensuring compatibility with other subsistence activities. The Vava'u Pearl Centre (VPC) was developed and further consolidated as the major focal point for the pearl sector in Vava'u. The VPC operates as a training and production centre for artisans, as the main retail outlet for pearl products and as a museum/heritage display for visitors. Vava'u-based pearl farmers and artisans recently established a small export market for value-added mabé pearls to Hawaii.

In the PNG, potential for further developing pearl-based livelihoods was explored. This involved documenting existing mabé pearl and mother-of-pearl (MoP) handicraft value-chains and examining opportunities for market-push interventions, with most retailers expressing interest in selling PNG-produced mabé pearl and MoP handicrafts. Opportunities for market-pull interventions were

examined in coastal destinations popular with cruise tourism. Cruise passengers in PNG expressed interest and willingness to purchase mabé pearl and MoP handicrafts, demonstrating preference for specific products and product attributes. Despite apparent demand, most cruise passengers indicated current opportunities to purchase mabé pearl and MoP handicrafts in PNG were limited. To overcome the deficiency of mabé pearl and MoP handicrafts in PNG, a handicraft skills training program was implemented in New Ireland and Milne Bay. With input and support from Australian Volunteers International (AVI) and DFAT-DAP, 82 classes, consisting of 20 unique workshops, were attended by 268 participants (116 individuals). The written material supporting these workshops was developed into a comprehensive manual (ACIAR Monograph 208) detailing use of hand tools and macramé for producing MoP handicraft. The manual has helped support further development of skills outside the classroom and beyond the life of the Project. A portion of the Mabé pearl and MoP handicrafts produced during the skills training program supported controlled market experiments to more accurately gauge demand for these products in coastal destinations popular with cruise tourism. These experiments confirmed sales of mabé pearl and MoP handicrafts in PNG are limited by supply, not demand, indicating need to increase local production of mabé pearls and MoP shell if the full-benefit of pearl and shell-based livelihoods is to be realised in PNG.

Major markets for mabé pearl and pearl shell handicrafts in Fiji, Tonga and PNG are domestic and rely on international tourists. The global shut-down associated with the COVID pandemic had a significant impact on international tourism with, for example, cruise ship tourism ceasing completely and Tonga closing its international border from March 2020 to September 2022. This understandably affected sales and income for those in the pearl livelihoods sector. For example, six monthly sales (to December 2019) at the VPC in Tonga, prior to the international closure totalled ~AUD 35,865 compared to sales of ~AUD 10,500 between May and December 2022.

This project was reviewed in 2020. The review recommended further investment in the sector by ACIAR and a new project¹ was developed with the aim of improving and expanding production and sales, developing improved business structures and opportunities, and strengthening governance frameworks and markets for the artisanal mabé pearl and pearl shell handicraft sectors in the Pacific.

¹ FIS/2019/122 “Towards more profitable and sustainable mabé pearl and shell-based livelihoods in the western Pacific”

3 Background

Pearl farming is the Pacific region's most valuable and highest priority aquaculture activity (SPC, 2007; Ponia, 2010) and pearl culture supports significant export industries in French Polynesia and the Cook Islands, collectively worth around \$180 million per annum (Ponia, 2010). As well as export income, pearl culture provides opportunities for income generation at community level and individuals may be directly involved in pearl farming, in supply of pearl oysters to pearl farms, or with associated handicraft production that offer opportunity for income generation, particularly for women and younger people. In recognising these opportunities, pearl culture has been introduced to atolls throughout French Polynesia, as a government initiative, to address sociological problems such as depopulation and unemployment (Arnaud-Haond et al., 2003; Southgate et al., 2008; Andréfouët et al., 2012).

The economic and community benefits generated by pearl culture in Polynesia have not yet been realised in the western Pacific. However, ACIAR has led research towards similar development in western Pacific countries. Technical advances in Fiji and Tonga, for example, have resulted in improved supply of oysters to pearl farmers and provide greater opportunity for community involvement. As a result, pearl farming in these countries is segmenting with engagement of communities and small-scale farmers in addition to larger farming operations. Community-based juvenile oyster (spat) collection and mother-of-pearl (MoP) handicraft production were established in Fiji during the ACIAR-PARDI project. As a result, spat collection now generates significant incomes for almost 30 Fijian communities. Furthermore, PARDI value-chain analysis identified that around \$8.5 million worth of pearl handicraft items are imported to Fiji each year targeting international tourists. This represents considerable potential for import replacement through local production that can now be supported by improved local oyster supply. Pearl handicraft training of a local women's group showed that unskilled women can be trained to produce high quality pearl shell jewellery and handicraft items. However, despite these initial successes, pearl culture and associated activities are still at an early stage of development. Further research is required to consolidate community engagement with pearl farming, to maximise livelihood opportunities and community benefits from the sector, and to facilitate sector growth.

This project built on the research outputs, successes and experiences of all prior ACIAR projects in this field. It focused on further developing the pearl livelihoods sector within western Pacific countries by broadening opportunities for community engagement with the sector to maximise livelihood benefits. Research activities focused primarily on three potential income-generating activities: (1) collection of juvenile black-lip pearl oysters (*Pinctada margaritifera*) that are sold to round pearl farms for pearl production; (2) production of mabé pearls (also called half-pearls) using the winged pearl oyster, *Pteria penguin*; and (3) production of pearl shell, mabé pearl and shell handicrafts for domestic sale.

4 Objectives

Objective 1: To consolidate and expand community-based spat collection program (Fiji)

- Undertake research to optimise spat collection methodology.
- Undertake research to optimise husbandry methods for juvenile pearl oysters.
- Undertake research supporting production of juvenile oysters for sale or local culture (sector segmentation).
- Undertake routine extension and training activities to consolidate the outcomes of the above research activities.
- Develop micro-enterprise structures supporting long term oyster production and trading capacity.

Objective 2: To consolidate and expand community-based half-pearl (mabé) production (Fiji/Tonga)

- Undertake research to optimise mabé production methods.
- Undertake routine extension and training activities to consolidate the outcomes of the above research activities and to develop commercial production and product quality capacity in communities involved in spat collection.
- Conduct market surveys of pearl and MoP trade in PNG tourist markets.
- Conduct consumer surveys and value-chain analyses to identify the scope of pearl/MoP markets and to direct product development.
- Handicraft skills training and development.
- Product development for identified domestic market channels.

Objective 3: To expand pearl and mother-of-pearl (MOP) handicraft production by community and women's groups (Fiji/Tonga)

- Develop a robust model for community based commercial enterprise based on production and sale of mother-of-pearl and half pearl handicrafts in Ba, Fiji.
- Extend the community-based handicraft production model to three other sites in Fiji (possibly Taveuni, Lau and Viti Levu).
- Skills training and identification of artisans with appropriate skills.
- Identify and evaluate domestic and international markets for MoP handicraft products and development of a production strategy.
- Product development for identified market channels.
- Develop overseas markets for products with emphasis on 'ethical' markets.

Objective 4: To expand pearl and mother-of-pearl (MOP) handicraft production by community and women's groups in PNG

- Conduct market surveys of pearl and MoP trade in PNG tourist markets.
- Conduct consumer surveys and value-chain analyses to identify the scope of pearl/MoP markets and to direct product development.
- Handicraft skills training and development.
- Product development for identified domestic market channels.

Objective 5: To evaluate the economic and socio-economic impacts of pearl-based livelihood development in partner communities

- Conduct surveys in partner communities/within partner community groups (Fiji, Tonga, PNG).
- Determine livelihood impacts of a range of community activities (e.g., spat collection, pearl production, handicraft production) within community and broader contexts.
- Conducted economic pearl industry 'snap-shots' in Fiji and Tonga at the start and towards the end of this project and 'cost-benefit' analyses to determine the impacts of project interventions.
- Economic production models will be further developed for pearl and pearl handicraft production.

5 Methodology

5.1 Methodology

This project drew heavily on prior ACIAR research which developed generic methods for pearl oyster collection and culture in non-atoll environments of the western Pacific. Specific activities varied among collaborating countries reflecting their different stages of sector development, the two oyster species involved, and their different products.

5.1.1 Spat Collection

Methods for spat collection are well established and have been utilised in a number of recent ACIAR projects including FIS/2006/138 and FIS/2006/172. In collaboration with Fiji Fisheries, these methods were used to establish a national spat collection program in Fiji during the ACIAR PARDI Pearl project which engaged 15 communities throughout Fiji in this activity (Kishore et al., 2018). A long-line is deployed on the surface (or sub-surface) and is supported by floats. It provides a substrate from which spat collectors, composed of mesh bags containing settlement substrate (e.g., shade cloth, monofilament net) or mesh 'rope', are attached. They are deployed for 8-10 months when they are retrieved and inspected for recruits, which are removed. Timing of spat collector deployment is a key determinant of success. It must coincide with natural oyster recruitment but minimise 'over-catch' of unwanted species that will restrict the available surface area for pearl oyster recruitment and compete with them for food. This basic methodology was optimised during this project through investigation of temporal recruitment of target species, seasonal growth rates of spat on collectors and economic assessment of variations in spat collector deployment strategies – i.e., what is the economic effect of deploying collectors twice a year (for six months) versus a single deployment of 8-10 months? Spat collection activities were maintained at the 15 community sites established within the Fiji national spat collection program during the ACIAR-PARDI Pearl project and extended to other appropriate community sites. Spat collection research at each site was established and maintained by project staff and Fisheries officers according to a scheduled research and extension program.

5.1.2 Nursery culture

Much of our knowledge of nursery culture requirements of pearl oysters results from prior ACIAR projects (e.g., Friedman and Southgate 1999; Southgate and Beer, 1997) and 'standard' methods have been developed (Southgate, 2008; Southgate, 2021). However, best practice varies between sites because of variations in environmental and water quality factors. A key issue is to determine the frequency with which pearl oysters should be inspected and cleaned because this will form the basis for community-based oyster husbandry efforts and training. Other key issues relate to husbandry and survival of oysters following their removal from spat collectors, specific husbandry practices for different sizes of pearl oysters, best culture unit and culture density for different sizes of pearl oysters and presentation of pearl oysters to maximise their perceived value (by pearl farmers).

There was considerable liaison with, and direct involvement of, industry collaborators in this project. This was possible because of existing linkages established through prior (e.g., FIS/2006/172, FIS/2006/138 and PARDI/2010/001) ACIAR Projects. Pearl farms in Vava'u (Tonga) and Savusavu, Taveuni and Rakiraki (Fiji) were actively involved in nursery culture experiments and made significant in-kind contributions to the Project (labour, long-line space, boat use/fuel etc.). Nursery culture research was also conducted at each partner community involved in spat collection and was established and maintained by project staff and Fisheries officers according to a scheduled research and extension program.

5.1.3 Half-Pearl production

The methods for half-pearl production are now well established and have been further developed for *Pteria penguin* in prior ACIAR Projects (e.g., Kishore et al., 2013). Oysters are selected for half-pearl production on the basis of good nacre colour and quality. They are then anaesthetised or forced

open before commercially available hemi-spherical nuclei are glued to the inside surface of the shells. Multiple nuclei can be applied to each shell. Oysters are then placed in clean water to recover and then placed into culture nets and removed to the pearl farm. A nacre thickness of around 1 mm is considered commercially acceptable and, while the rate of nacre secretion over the nucleus varies according to culture conditions and water temperature, a 6-10 months culture period is normally required. Half-pearls are then cut from the shell and prepared for sale (value-added). Pearl quality is determined using qualitative assessment of colour, lustre and surface blemish, according to standard pearl quality assessment (Matlins, 1996).

Research issues addressed in this project included the relationship between pearl quality/value and nucleus and oyster size, and the influence of culture period on nacre secretion rates and pearl quality/value. In Fiji, this research was done with the two commercial pearl oyster species that recruit to spat collectors there (*P. margaritifera* and *Pt. penguin*). In Tonga it was done with *Pt. penguin* only. Half-pearl culture research was conducted at each partner community involved in successful spat collection. It was established and maintained by project staff and Fisheries officers according to a scheduled research program that will also include extension activities. Extension workshops to train pearl farmers in half-pearl production methods and pearl quality improvement were conducted successfully during the ACIAR-PARDI Pearl project and FIS/2009/057 and a similar approach was used in this project. Extension materials (basic culture manuals) developed to support half-pearl training workshops in the ACIAR-PARDI project were further developed and revised (based on research results) during this project.

A full-time Fiji-based Project Scientist (Dr. Pranesh Kishore) was employed to manage and oversee the spat-collection, pearl culture and half-pearl production components of this project in Fiji and Tonga in consultation with the Project Leader. Dr. Kishore is a Fiji national who conducted his MSc and PhD research on aspects of the pearl industry in Fiji and is well acquainted with the Fiji and Tongan pearl industries and with all technical components of pearl oyster farming and pearl production. He has an established working relationship with Fiji Fisheries and worked with them in implementing the national spat collection program.

5.1.4 Handicraft production

The three partner countries had differing research and development requirements relating to handicraft production. Two strategies were developed to address these requirements: (1) centralised production based on shared access to powered machinery and equipment and (2) home-based production based on privately-owned hand tools.

A half-time handicraft coordinator was employed to manage and oversee implementation of the first strategy in Fiji and Tonga, in consultation with the Project Leader; Ilse-Marie Erl, an Auckland-based professional jewellery designer and producer who tutors in this field at the Unitech Institute of Technology in New Zealand. Centralised production and training were coordinated through the Marama Shellcraft Fiji workshop in Ba (Viti Levu), Fiji, the Nasomo Ra Marama handicraft workshop in Somosomo (Taveuni), Fiji and the Vava'u Pearl Centre in Tonga. For each centre, an appropriate training curriculum for use of electric equipment was developed and implemented, with training activities composing of a series of short training courses to build skills gradually within trainee groups. Each training module was 2-4 weeks in length.

The second strategy was supported by training activities organised jointly with community partners. In PNG, an AVI volunteer (Sue McCuaig) cooperatively explored feasibility of home-based production handicraft production based on privately-owned hand tools in New Ireland and Milne Bay during the first two-years of the project. The enthusiasm and success of these introductory training activities formed the basis for developing more formalised training activities with hand tools. Ms. Nitya Simard, as a PNG-based consultant, produced a dedicated training manual to support MoP handicraft production with hand tools (ACIAR Monograph 208). This training manual guided extension of the home-based production strategy in New Ireland and Milne Bay as well as in remote communities in Fiji.

5.1.5 Enterprise Development and Marketing

Research to identify potential channels to domestic markets was conducted primarily through interviews and face-to-face discussions. It assessed the market potential from major retail outlets (e.g., Tappoos, Jacks, Prouds in Fiji), specialist tourist handicraft outlets, resorts and hotels, airlines, tourist operators and government agencies. Options for potential markets include made-to-order products such as MoP name badges and other bespoke items. Research also assessed potential overseas markets including Oxfam, Trade Aid and other 'ethical market' retailers attracted to Pacific artisans/handicrafts etc. A number of smallholder products from Pacific-island countries have achieved certification through Fair Trade (World Fair Trade Organisation, WFTO) and are now reaching 'ethical markets'. These include sugar from Fiji, cocoa from PNG and vanilla from Tonga. Development of Australian markets for appropriate smallholder products from the Pacific region is a priority for DFAT and is facilitated by a recent \$5 million DFAT-funded project run by the FairTrade Association of Australia and New Zealand.

Enterprise development and marketing aspects of this project were overseen by a consultant (Mr. Theo Simos) who was subcontracted through the University of the Sunshine Coast for this work. Mr. Simos operated as a part-time (30%) business development coordinator managing and overseeing the business, enterprise and marketing components of this project in all partner countries in consultation with the Project Leader. Mr. Simos has extensive commercial experience and worked as a value-chain specialist in the ACIAR-PARDI and other ACIAR projects. He managed the ACIAR-PARDI pearl handicraft training project which provides an excellent background for the proposed work and awareness of the key issues relating to community enterprise development and marketing. Mr Simos sits on the Marketing & Strategy Committee and Producer Support & Relations Committee of the FairTrade Association of Australia and New Zealand, providing the project with excellent international insight relating to marketing of pearl and pearl handicraft products into ethical markets. Mr. Simos is familiar with the pearl industries in Fiji and Tonga through his work with the ACIAR-PARDI project and is already involved with enterprise development and marketing of pearl products in Fiji through his involvement with the ACIAR-PARDI handicraft project.

Research activities in Fiji:

Successful community-based trial MoP handicraft production, in a community group with no former shell handicraft experience, was demonstrated during the ACIAR-PARDI project. The activities undertaken in this project include routine production and sector stratification, quality control, enterprise development and marketing. At a finer scale the enterprise development component of this research included establishment of commercial entities and facilities, building cost centre competency, development of management expertise, building of profit centre management and business account capacity, production design and development, and development of governance models for sustainable business practice.

While an objective of this project was to develop commercial MoP handicraft production at a number of sites in Fiji, our approach was to first develop a robust model for community-based commercial handicraft enterprise built through existing collaboration with the Ba Women's Forum with which trial MoP handicraft production was undertaken within the ACIAR-PARDI project but further research and capacity development was required to develop a robust model for commercial community pearl and pearl shell handicraft production. This model, if successful, provides a basis for extension to other suitable Fijian communities.

Research activities in Tonga:

The Tongan pearl sector is expanding because of improved availability of hatchery produced juvenile oysters. A key factor in managing this expansion is maintenance of product quality. Further research into factors influencing half-pearl quality in Tonga and extension of results to existing and new pearl farmers will assist in consolidating and improving product quality. Further development of mabé pearl and MoP handicraft skills through training was undertaken to support improved product quality and to support diversification within the sector. Handicraft training was provided to Tongan artisans through a series of short training courses based on the approach used with the Ba Women's Forum in Fiji during the ACIAR-PARDI project. Each training module, of 2-4 weeks each, followed a

curriculum of training activities, developed and overseen by the project handicraft coordinator in consultation with the Project Leader.

Training in basic business skills and enterprise development to support sustainable sector development in Tonga, was addressed through a series of short training courses. Specialist guidance relating to quality assessment and valuation of half pearls produced in Tonga was also provided to pearl farmers and artisans by project personnel in workshop fashion, with appropriate extension materials. Quality control and accurate grading and valuation of Tongan pearls are important steps for the industry as it looks to develop export markets. Research linkage with the Ministry of Labour, Commerce and Industries were further developed during this project to facilitate marketing, branding and export potential for Tongan pearl products.

The Tongan pearl and pearl shell handicraft sector is well developed but primarily services a domestic market. Expansion of sector production provides an opportunity to develop export markets for its products which are unique in Pacific-island countries. This project examined potential domestic and international markets for pearl and MoP handicraft products and provided feedback and training related to product development and production strategy for identified market channels.

Research activities in PNG:

Our approach in PNG was first develop a better understanding of the current and potential demand for pearl and MoP handicraft products in PNG using interviews and surveys in major centres and tourist destination. Market surveys were conducted in tourism 'hubs', and similar centres such as Alotau (Milne Bay Province), Kokopo (East New Britain), Port Moresby (National Capital District), and Kavieng (New Ireland Province). Consumer surveys were conducted to explore consumer types and spending patterns, market demand and need. Surveys were conducted in Alotau targeting cruise ship arrivals to PNG. Value chain analyses was conducted to identify challenges, bottlenecks and opportunities for handicraft producers and will dovetail with market survey findings.

A full-time project scientist (De'arne Kershler) was employed for the first two years of this project to manage and oversee the market and consumer surveys and value-chain analyses required in PNG. The data generated was used to inform product development, research and training and extension activities. Handicraft training and extension programs were developed and handicraft and basic business skills training was conducted with partner communities in Kavieng (Nusalik Island) with which there is existing handicraft support activity, and in Alotau in Milne Bay which is the major tourist hub for PNG. Enterprise development training was coordinated with the training activities of ASEM/2014/095² which began working with pearl-handicraft producers in Kavieng in March 2017. Socio-economic assessment of research interventions in PNG were also conducted during this project.

² ASEM/2014/095: "Improving opportunities for economic development for women smallholders in rural Papua New Guinea"

6 Achievements against activities and outputs/milestones

Objective 1: To consolidate and expand community-based spat collection program (Fiji)

no.	Activity	outputs/ milestones	completion date	comments
1.1	Research to optimise spat collection methodology	A manual describing an optimised spat collection methodology Y2, M6		<p>Initial research assessed spat collection potential at 26 sites throughout Fiji to establish good sites and to assess efficacy of methodology at broad scale. Results were published by Kishore et al. (2018):</p> <p style="text-align: center;">Kishore, P., Bingnald Vuibeqa, G., Southgate, P.C. 2018. Developing a national spat collection program for pearl oysters in the Fiji Islands supporting pearl industry development and livelihoods. <i>Aquaculture Reports</i> 9, 46-52.</p> <p>Further research involved investigation of factors including:</p> <ul style="list-style-type: none"> • Inshore/offshore spat collector deployment • Influence of spat collector immersion times • Influence of deployment depth on recruitment • Seasonal influence on spat collection • When to harvest to maximise oyster yield • Potential of short spat cropping cycles <p>An experiment to determine the recruitment pattern of pearl oyster spat on collectors made from locally available material was established. Material used were bamboo, ropes made from coconut husks, normal ropes, dead oysters shells, and the usual imported spat collector for comparison. Initial results were encouraging as all the material used recruited spat. Bamboo and ropes made from coconut husks had higher number of spat recruited compared to all other material used including imported spat collectors.</p> <p>Research involved two USP students, Kristina Sankar (EU scholarship) and Charlene Erasito (ACIAR-USP scholarship). Both successfully completed their MSc degrees. Kristina's research informed site selection for spat collection to maximise recruitment, while Charlene's research assessed the potential for early harvest of oyster juveniles from spat collectors followed by intermediate culture, as a mechanism to improve oyster yield and farmer income. Research showed the spat collector deployment during summer (Nov.-April) generated more pearl oysters, deployment of spat collectors for 8-months generated similar oyster yields to 14-month deployment (but smaller oysters), and the most profitable production scenario was to harvest spat collectors after 14-months deployment followed by a 6-month intermediate culture period. Results were published as:</p> <p style="text-align: center;">Erasito, C., Prasad, R., Southgate, P.C., Kishore, P. 2022. Optimizing community-based pearl oyster (<i>Pinctada margaritifera</i>) spat collection strategies in the Fiji Islands. <i>Aquaculture Reports</i> 26, 101288</p> <p>Combined results supported development and fine-tuning of the "Pearl Oyster Spat Collector Deployment Manual" now used as a basis for community training and extension activities by Fisheries personnel.</p>

1.2	Research to optimise husbandry of juvenile oysters	A manual detailing an optimised methodology for juvenile husbandry Y2, M12		<p>A number of factors were investigated for their impacts of oyster growth and survival including oyster size, culture depth and water quality parameters. This research was often accommodated within community training activities at the seven communities engaged in mabé pearl culture. Communities received regular hands-on training relating to removal of oysters from spat collectors, oyster husbandry and chaplet³ preparation and periodicity of cultured oyster cleaning.</p> <p>Research involved USP student John Carreon, an ACIAR/USP scholarship student who successfully completed his MSc. Research addressing this topic was also conducted by ACIAR/USP scholarship student Charlene Erasito (see 1.1) whose research investigated the influence of juvenile age/size on oyster performance in intermediate culture in panel nets (see 1.1). Research supported further development and fine-tuning of a manual used to support extension training (see 1.1). Log-books "<i>Pearl oyster spat collector deployment and monitoring record</i>" and "<i>Juvenile pearl oyster cleaning, mortality and survival record</i>" were developed for scheduling and recording community culture activities and to support extension activities and monitoring and evaluation.</p>
1.3	Production of juvenile oysters	<p>Site-specific strategies for husbandry of juvenile oysters to larger sizes</p> <p>A manual outlining best practice for juvenile production Y3, M12</p>		<p>Experiments were established at all partner spat collection communities (up to 26 in the final year of the project) to monitor oyster performance and determine husbandry needs. Results showed little difference between sites and indicated that a single production approach and a universal manual would be appropriate for all sites (see 1.2).</p> <p>Research tested, in particular, the use of chaplets (generally used in Fiji to hold oyster juveniles) vs. cord technical nakasai (CTN), with the latter generally performing better, and adopted as standard practice. In assessing potential to reduce the spat collector deployment period from 12-14 months period (current) to 8 months, the smaller spat that resulted were cultured on CTN's with or without protective mesh cages. Results showed minimal predation among exposed oysters on CTNs and good oyster growth rates. Results outlined in 1.1 indicated that the most profitable production scenario for spat/juveniles was to harvest spat collectors after 14-months deployment followed by a 6-month intermediate culture period using panel nets. However, panel nets are imported and expensive and demonstration of the successful use of CTN's for spat/juvenile culture, reduces costs of culture equipment and utilises locally available materials in place of imported goods (i.e., panel nets)</p>

³ Chaplet = a rope to which pearl oysters (~10-12) are tied for holding in suspended culture.

1.4	Extension and training	15-20 spat collecting communities and 10-15 fledgling pearl farmers with knowledge of best-practice collection and culture methods. Y6, M8		<p>Over the duration of this project, training and extension, supported by project manuals (see 1.1, 1.2, 2.1), was extended to:</p> <ul style="list-style-type: none"> • 30 spat collecting communities • 7 mabé pearl farming communities • 1 private-sector mabé pearl farmer <p>Training assisted communities to increase spat collector infrastructure (i.e., oyster collection capacity) by seven-fold. Training in all aspects of pearl oyster collection, culture and husbandry, mabé pearl production, harvest and grading undertaken by project personnel was also attended by Ministry of Fisheries personnel that now have improved capacity for training and extension activities required for future sector expansion.</p> <p>One of the very first communities (women's group) to be introduced to mabé pearl farming has now started to engage its male members to carry out farming activities deemed difficult and inappropriate for female members. These include long line and spat collector deployments where heavy anchors are required. These activities were otherwise carried out by Ministry of Fisheries under project supervision. Training over the years have enabled the members of the community to gain ample experience to carry out such important activities independent of the usual support.</p>
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1.5	Develop microenterprise structures	<p>Improved commercial capacity in partner communities.</p> <p>Appropriate governance models in partner communities supporting sustainable business practice Y3, M12</p>		<p>Examples of the enterprise linkages established during this project include:</p> <ul style="list-style-type: none"> • Between pearl oyster collecting communities and mabé pearl producing communities (sales of oysters) • Between oyster/mabé pearl producing communities and handicraft producers (sales of shells and mabé pearls) • Between pearl oysters collecting communities and private-sector round pearl farms (sales of oysters) • Between handicraft producers and major retailers (sales of handicrafts and value-added items) • Between handicraft producers and overseas clients (export sales and internet-based sales) <p>Goodwill between groups was also demonstrated by Ravita Women's Group, which donated some of their adult oysters to the Raviravi Women's Group, following Cyclone Yasa, which destroyed all adult oysters awaiting pearl implanting at Raviravi. This situation would otherwise have resulted in no annual oyster implanting and no mabé pearl sales at Raviravi, which would have significantly affected their cash flow. The relationship built from the donation of oysters is an indication that local communities are ready to assist each other during challenging times.</p> <p>Commercial capacity in partner communities improved through financial literacy training. In Ba via regular training within Activity 3.1. and placement of two short-term (~6-months, 2017-18) Scope Global volunteers who provided marketing and management skills to the group, improvements to processes and procedures, allowed direct marketing of products to retail outlets and resorts, shows, expos and markets, and supported establishment of basic website and social media pages and direct involvement in retail sales:</p> <p>https://www.instagram.com/maramashells/ https://www.facebook.com/maramashellcraftfiji/ https://maramashellsfiji.wixsite.com/website</p> <p>In Ravita and Raviravi, improved commercial capacity resulted via training activities outlined in Activity 3.3, supported by information provided in ACIAR Monograph 208 "Training Manual for Making and Selling Shell Jewellery and Macramé" (Simard, 2019), produced by this project</p> <p>Enterprise training at spat/mabé/handicraft communities was also supported by the log books developed during this project: "Half pearl implanting, culture, harvest and sales record" and "Handicraft product sales record" (see 1.1 and 1.2)</p>
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PC = partner country, A = Australia

Objective 2: To consolidate and expand community-based half-pearl production (Fiji and Tonga)

no.	Activity	outputs/ milestones	completion date	comments
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<p>2.1</p>	<p>Research to optimise mabé production methods</p>	<p>A manual describing best practice mabé production methods Y2, M12</p>	<p>Fiji: Research involved investigation of a number of factors on mabé pearl yield and quality including:</p> <ul style="list-style-type: none"> • Influence of oyster cleaning intervals post implanting • Influence of anaesthetic type and dosage pre implanting • Influence of oyster size and nucleus position • Methods for adhering nucleus to shell valve • Causes and mitigation of shell splitting during and after mabé pearl formation <p>Results informed similarly focused and more detailed research in Tonga conducted within FIS/2016/126. Collective outputs were used as a basis for manuals describing mabé pearl seeding and pearl harvesting and grading. Results also informed an economic assessment examining potential profitability of community-based mabé pearl production in Fiji reported by Johnston et al. (2020):</p> <p style="text-align: center;">Johnston, W.L., Kishore, P., Vuideqa, G.B., Hine, D. and Southgate, P.C. 2020. Economic assessment of community-based pearl oyster spat collection and mabé pearl production in the western Pacific. <i>Aquaculture</i> 514, 734505</p> <p>Stress and mortality of pearl oysters during nucleus implanting for mabé pearl production can be reduced using appropriate anaesthetics that allow improved access to nucleus implanting sites. Two anaesthetic agents - benzocaine (0.25, 0.50 and 1.20 g L⁻¹) and 1-propylene phenoxetol (2.50, 3.00 and 3.50 mL L⁻¹) were assessed for their efficacy in inducing relaxation in 'small' (dorso-ventral height [DVH], 78.7 ± 1.6 mm), 'medium' (DVH, 118.2 ± 2.0 mm) and 'large' (DVH, 149.3 ± 1.1 mm) cohorts of the winged pearl oyster, <i>Pteria penguin</i>. More large than small oysters relaxed at all anaesthetic concentrations with large oysters requiring shorter exposure time to become relaxed than small oysters. Benzocaine (1.20 g L⁻¹) and 1-propylene phenoxetol (3.50 mL L⁻¹) were the most effective treatments. Results were reported as:</p> <p style="text-align: center;">Kishore, P., Wingfield, M., Miltz, T.A., Southgate, P.C. 2022. Anaesthetic induced relaxation of the winged pearl oyster, <i>Pteria penguin</i>, varies with oyster size and anaesthetic concentration. <i>Aquaculture Reports</i> 22, 100987.</p> <p>Tonga: Research involved investigation of a number of factors on mabé pearl yield and quality including:</p> <ul style="list-style-type: none"> • Nacre secretion rate • Influence of environmental factors on nacre secretion and mabé pearl quality • Influence of nucleus position on nacre secretion and mabé pearl quality • Influence of oyster size on nacre secretion mabé pearl quality • Seasonal influence on pearl quality <p>Some outputs required, and justified, more detailed investigation and provided a basis for research within a concurrent ACIAR project (FIS/2016/126) which had greater focus on factors influencing mabé pearl production and quality. This aspect of research within FIS/2016/126 was undertaken by USC PhD student Sophie Gordon, who was an AVI volunteer on this project.</p> <p>Outputs from the above research provided the basis for a series of manuals dealing with various aspects of pearl oyster culture and mabé pearl production:</p> <ul style="list-style-type: none"> • "Hatchery and nursery production of <i>Pteria penguin</i>" • "Introduction to mabé pearl farming using <i>Pteria penguin</i> in the Kingdom of Tonga: what you need to know before starting a pearl farm" • "Farming procedures for mabé pearls from <i>Pteria penguin</i> in the Kingdom of Tonga: what you need to know to manage and maintain a pearl farm" • "Maintaining your mabé pearl oyster farm" • "Growing mabé pearl oysters and making cylinders for <i>Pteria penguin</i> culture" • "Seeding mabé pearl oysters (<i>Pteria penguin</i>)"
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			<ul style="list-style-type: none"> • "Harvesting and grading mabé pearls from <i>Pteria penguin</i>" <p>While some of these manuals are specific to Tonga, others have been developed with collective inputs from research in Fiji and Tonga and have been used for extension in both countries. We intend to combine these manuals into a single volume for publication in the FAO Fisheries Technical Paper series.</p> <p>Results and standardisation of culture methods informed an economic assessment of the potential profitability of community-based mabé pearl production in Tonga. The results of this assessment were recently published by Johnston et al. (2020):</p> <p style="padding-left: 40px;">Johnston, W.L., Gordon, S.E., Wingfield, M., Halafih, T., Hine, D., Southgate, P.C. 2020. Economic feasibility of small-scale mabé pearl production in Tonga using the winged pearl oyster, <i>Pteria penguin</i>. Aquaculture Reports 17, 100347.</p>
2.2	Extension and training activities	<p>Production of mabé in 10-15 communities in Fiji.</p> <p>Production of mabé in 3-5 new farms in Tonga and a 20-30% increase in pearl production by the industry.</p> <p>Y3, M12</p>	<p>Fiji: Training and extension activities were extended to:</p> <ul style="list-style-type: none"> • 7 mabé pearl farming communities • 1 private-sector mabé pearl farm <p>Production of mabé pearls was successfully achieved by five communities.</p> <ul style="list-style-type: none"> • e.g., in 2020, Raviravi community produced more than 1,800 pearls valued at F\$20,450. The Prime Minister delivered the cheque accompanied by seven Ministers. <p>Training of additional communities was delayed due to impacts of Tropical Cyclone Winston, then COVID. It should be noted that the expansion of mabé pearl production needs to occur in a considered manner, particularly given that knowledge of market capacity is lacking. Unfettered expansion of the sector could lead to saturation of the market and may compromise pearl quality.</p> <p>The Ministry of Fisheries with the support from the project have continued to address numerous requests by newer communities to have spat collection trialled in their fishing areas. Spat recruitment in some of these sites is good indicating potential for mabé pearl farming in these communities. The onset of the COVID-19 pandemic impacted these opportunities with these communities, instead, given the option of selling their spat to established mabé pearl farms.</p> <p>Tonga: Training activities were extended to:</p> <ul style="list-style-type: none"> • 9 existing mabé pearl farms • 15 new mabé pearl farming communities <p>Between 2015 and 2018, mabé pearl production increased by:</p> <ul style="list-style-type: none"> • 73% by quantity (from 2,700 to 4,680 pieces) • 182% by value (from T\$260,000 to T\$732,000)

PC = partner country, A = Australia

Objective 3: To expand pearl and mother-of-pearl handicraft production by community and women’s groups (Fiji and Tonga)

no.	Activity	outputs/ milestones	completion date	comments
3.1	Develop a commercial community-based MoP handicraft enterprise in Ba, Fiji.	A model for community-based MoP handicraft enterprise that includes all requirements for successful commercial handicraft production Y2, M4		<p>A selected group from the Ba Women’s Forum (BWF) was developed as a commercial community-based MoP handicraft enterprise in Ba, Fiji.</p> <p>Enterprise model encompassed:</p> <ul style="list-style-type: none"> • Formation of semi-autonomous body (Marama Shellcraft Fiji; MSF) of member artisans within BWF • MSF dedicated communal workshop with electric equipment for shellcraft production • Registered incorporated company under corporation’s laws • Established roles/responsibilities • MSF access to own bank account for commercial use • MSF accountable for revenue, sales planning, expense management • Enterprise linkages between MSF and communities engaged in oyster and mabé pearl farming (see 1.5) • Shellcraft products marketed to retailers (e.g., Jacks and Tappoo) and direct to consumers at markets <p>This enterprise model was successful in achieving commercial handicraft production and sales and the required operational and support mechanisms. Considerable opportunity and demand for handicraft products was generated when mabé pearls (not just MoP) became available to the MSF group during the project. Regular sales of MSF mabé pearl handicrafts to major retailers in Fiji were established prior to the onset of the COVID pandemic.</p>
3.2	Extend the pearl handicraft enterprise model to other sites in Fiji.	Establish successful commercial pearl handicraft enterprises in three new communities in Fiji. Y3, M12		<p>Successful commercial pearl handicraft enterprises were established in three new communities:</p> <ul style="list-style-type: none"> • Somosomo (Na Somo Ra Handicraft Centre) • Raviravi • Ravita <p>The pearl handicraft enterprise model developed in Activity 3.1 was adapted to suit community needs and governance set-up. For example, electric equipment vs. hand-tools, community group vs. women’s NGO.</p> <p>Establishment of a machine-based workshop within the Fisheries facility at Savusavu, was approved by Fisheries but postponed because of COVID impacts. This facility will be of particular benefit to community members reliant on hand-tool based handicraft production. It will provide a means for rapid preparation of oyster shells (i.e., smoothing, grinding, polishing) that can be later fashioned using hand tools back in the community.</p>

<p>3.3</p>	<p>Skills training and identification of skilled artisans</p>	<p>Improved skills and handicraft making skills in partner communities</p> <p>Identification of the most skilful artisans in each partner community</p> <p>Y1, M12 Y2, M12 Y3, M12 Y4, M12 Y5, M12 Y6, M10</p>	<p>Fiji: Regular handicraft skills workshops were conducted with:</p> <ul style="list-style-type: none"> • Marama Shellcraft Fiji; MSF, Ba, Viti Levu • Na Somo Ra Handicraft Centre, Somosomo, Taveuni • Raviravi community, Vanua levu • Ravita community, Vanua Levu <p>Power tool-based workshop training included machine use and maintenance, design, handicraft skills and hand-tool use and was provided by New Zealand based handicraft trainers Marie Erl and Neke Moa (Ba and Somosomo) and by Nitty Simard at Raviravi and Ravita. Basic business and enterprise development skill training of the MSF group was provided via regular training visits from project business consultant Theo Simos and Marie Erl. Similar business skills training of the Somosomo group was provided by Marie Erl.</p> <p>Tonga: Regular handicraft skills workshops were conducted with:</p> <ul style="list-style-type: none"> • Vava'u Pearl Centre (VPC), Vava'u • Pangai, Hihifo, Felemia, Uiha communities (Ha'apai) <p>Neke Moa and De'arne Kershler provided training of artisans in Tonga, with smaller, more focused, training workshops provided by two AVI volunteers (Sue McCuaig and Emma Krusic).</p> <p>Training at all centres was supported by information provided in ACIAR Monograph 208 "Training Manual for Making and Selling Shell Jewellery and Macramé" (Simard, 2019), produced by this project</p> <p>At all training centres, key artisans within trainee groups were identified for development as future local handicraft trainers. In Tonga in particular locals trained by the project at the VPC were later used to provide handicraft skills training at communities in Ha'apai. This approach became particularly advantageous during COVID travel restrictions when overseas trainers could not travel to Tonga.</p>
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3.4	Identify and evaluate domestic and international markets	Information on potential markets for pearl and pearl handicraft products and their potential capacities. Y1, M12 Y2, M12 Y3, M12	<p>Fiji: Information on potential markets, their capacities and market access were obtained from discussions with:</p> <ul style="list-style-type: none"> • Oxfam Trading • Australian Museum • TradeAid NZ • Tappoos • Jack's Handicrafts <p>Discussions led to enterprise linkages with Tappoos and Jack's Handicrafts, production of specific lines for them and sales displays at their retail outlets including Nadi airport. In 2019, sales to Jack's Handicrafts exceeded F\$ 8,500.</p> <p>Tonga: Market survey research conducted in Tonga between 2018 and 2020 included:</p> <ul style="list-style-type: none"> • Cruise ship passenger survey • Tourist (non-cruise ship passengers) survey • Pearl handicraft sales data from the Vava'u Pearl Centre (VPC) <p>Results informed product development and skills training such as optimal mabé seeding protocols e.g., nucleus shape/size, and preferred mabé jewellery designs.</p> <p>The VPC is a major retail outlet for farmers/artisans with total sales from July to October 2019 of T\$ 40,000. In 2019, promotional activities were undertaken to create greater awareness of the VPC and to promote domestic market opportunities. They included networking with local tour operators, better signage, posters, radio announcements etc. The project/VPC was successful with a DFAT-DAP application and received \$7,285 towards billboards, improved lighting for the showroom, jewellery display stands, packaging items, brochures, uniforms etc.</p> <p>A 2-day brand awareness and marketing workshop was held at the VPC in March 2020 and included 17 pearl farmers/artisans as well as Fisheries staff. It was co-sponsored/funded and presented by the project, Ministry of Fisheries and WorldBank. Resulting from this workshop, Tonga's mabé pearl farmers and artisans secured a valuable contract for regular export of value-added mabé pearl pieces to Jewels of Polynesia (https://jewelsofpolynesia.com/) in Hawaii.</p>
3.5	Product development for identified market channels	A range of products that have identified markets. Y1, M12 Y2, M12 Y3, M12 Y4, M12 Y5, M12 Y6, M10	<p>Fiji: Eight (8) product ranges were developed with identified markets in jewellery, souvenir, home décor, and export sectors. Some products are made to specific requirements of local souvenir retailers.</p> <p>Tonga: Product development driven strongly by markets and market preferences identified by consumer surveys (see 3.4)</p>

3.6	Develop overseas markets for products	Overseas markets identified for specific pearl and pearl handicraft products. Y3, M12 Y5, M12 Y6, M10		<p>Fiji: Overseas markets have shown little interest in purchasing current product ranges.</p> <p>Activity 3.4 identified overseas markets require low prices, high grade workmanship, and new designs incorporating precious metals. These export challenges cannot be addressed with current resources/skill levels/business expertise.</p> <p>Effort focused on developing highly differentiated products to compete with imports in the domestic market.</p> <p>Tonga: Effort focused on developing domestic market opportunities linked to tourism.</p> <p>There seems to be opportunity to develop expatriate markets (Auckland, Sydney etc) where premium prices may be realised. Tonga's mabé pearl farmers and artisans have secured a contract for regular export of value-added mabé pearl pieces to Jewels of Polynesia (https://jewelsofpolynesia.com/) in Hawaii (see 3.4)</p>
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PC = partner country, A = Australia

Objective 4: To expand pearl and mother-of-pearl handicraft production by community and women's groups in PNG

no.	Activity	outputs/ milestones	completion date	comments
4.1	Conduct market surveys in PNG tourist markets	Detailed report containing information on potential markets for pearl and pearl handicraft products and their potential capacities. Y1, M12		<p>Key tourist markets were identified to exist in:</p> <ul style="list-style-type: none"> • Milne Bay Province • East New Britain Province • New Ireland Province • National Capital District <p>A survey of commercial retailers and artisans at these locations provided baseline information on existing market.</p> <p>Potential markets identified:</p> <ul style="list-style-type: none"> • import replacement in existing market • informal vending at cruise destinations • product diversification using mabé pearls <p>Potential capacity of informal vending at cruise destinations was evaluated with market surveys – results published by Militz et al. 2021:</p> <p style="text-align: center;">Militz, T.A., Kershler, D., Southgate, P.C. 2021. Informing artisanal pearl and pearl shell handicraft production for the cruise tourism market through analysis of intended purchase behaviour. <i>Tourism in Marine Environments</i> 16, 45–58.</p>

4.2	Conduct consumer surveys and value-chain analysis	<p>Identify popular pearl and pearl shell handcraft items purchased by consumers and their relative values.</p> <p>Description of the value-chain for pearl and pearl shell handcraft items in PNG. Y2, M12</p>	<p>Consumer surveys conducted in Milne Bay identified:</p> <ul style="list-style-type: none"> • popular mabé and shellcraft products • relative values • product attributes influencing purchase decisions • demographic preferences for products and product attributes <p>Value-chain analysis for pearl and shellcraft products was conducted for two locations:</p> <ul style="list-style-type: none"> • Milne Bay Province – by AVI volunteer, Mollie Bain • New Ireland Province – results published by Simard et al. (2019): <p>Simard, N., Militz, T.A., Kinch, J., Southgate, P.C. 2019. Artisanal, shell-based handcraft in Papua New Guinea: challenges and opportunities for livelihoods development. <i>Ambio</i> 48, 374–384.</p>
4.3	Handicraft skills training and development	<p>Improved skills and handcraft making skills in partner communities</p> <p>Identification of the most skilful artisans in each community Y2, M12 Y3, M12 Y4, M12 Y5, M12 Y6, M10</p>	<p>Handicraft skills training delivered in:</p> <ul style="list-style-type: none"> • Milne Bay Province (3 communities) • New Ireland Province (7 communities) <p>AVI volunteer, Sue McCuaig, assisted in delivery of handcraft skills workshops.</p> <p>Handicraft skills training manual developed and published by ACIAR:</p> <p>Simard, N. 2019. Training Manual for Making and Selling Shell Jewellery and Macramé. ACIAR Monograph No. 208. pp. 79.</p> <p>A “Vendor’s Guide” was produced to facilitate multilingual communication between artisans and tourists at informal markets.</p>
4.4	Product development for identified domestic market channels	<p>A range of products that have identified markets (<i>see 4.1 and 4.2</i>). Y1, M12 Y2, M12 Y3, M12 Y4, M12 Y5, M12 Y6, M10</p>	<p>A “Project Catalogue” was produced to illustrate the range of products developed with artisans.</p> <p>A product range of 100% PNG origin products was developed which requires no imported tools or materials to produce.</p> <p>Products are now supplied to 11 private-sector retailers and sold at informal markets.</p>

PC = partner country, A = Australia

Objective 5: To evaluate the economic and socio-economic impacts of pearl-based livelihood development in partner communities

no.	Activity	outputs/ milestones	completion date	comments
5.1	Conduct surveys in partner communities and partner community groups in PCs	Socio-economic data for testing project impacts. Y1, M12 Y3, M12 Y6, M10		<p>Fiji/Tonga: A dedicated ACIAR SRA project FIS/2018/129⁴ was established to monitor and evaluate socio-economic impacts of pearl-based livelihood development in Fiji and Tonga. The project, led by Sustineo P/L from Canberra and was completed in 2020. Very positive socio-economic impacts were reported in:</p> <p style="text-align: center;">Mikhailovich, K., Mackenzie, E., Smith, D. 2023. Enhancing coastal livelihoods through half-pearl aquaculture and handicrafts in Tonga and Fiji. <i>Development in Practice</i> 33:1, 110-121, DOI: 10.1080/09614524.2022.2128721</p> <p>Papua New Guinea: Baseline socio-economic data collected from three regions of PNG (1) Tigak Islands (New Ireland) (2) Lavongai (New Ireland) (3) Kwato/Logea Islands (Milne Bay)</p> <p>Baseline socio-economic data collected from the Tigak Islands was published by Simard et al. (2019) (see above):</p> <p>Multi-Country: Baseline measures of women’s empowerment were collected from participants involved in the Kwato/Logea (PNG), Ravita, and Raviravi (Fiji) community skill development workshops.</p>
5.2	Determine livelihood impacts within community and broader contexts	Reports and publications describing both short- and longer-term livelihood benefits resulting from this project. Y2, M12 Y6, M10		<p>Fiji/Tonga: A dedicated ACIAR SRA project FIS/2018/129 was established to monitor and evaluate socio-economic impacts of pearl-based livelihood development in Fiji and Tonga, led by Sustineo P/L from Canberra. Results are reported by Mikhailovich et al. (2023).</p> <p>Papua New Guinea: Annual socio-economic surveys were undertaken for three regions of PNG: (1) Tigak islands (New Ireland) (2) Lavongai region (New Ireland) (3) Kwato/Logea Islands (Milne Bay)</p> <p>Livelihood impacts have already been realised in the Tigak islands region (2019 data):</p> <ul style="list-style-type: none"> • 52 artisan households (= 225 dependents) → 28.8% increase from 2017 • Weekly household income from shell handicrafts is PGK 145.96 → 5.1% increase from 2017 • Annual income generated from shell handicraft sector is PGK 379,500 → 27.9% increase from 2017

⁴ FIS/2018/129: “Monitoring and Evaluation of Socio-Economic Impacts of Pearl-based Livelihood Development”

5.3	Industry 'snap-shots' and 'cost-benefit' analysis	<p>Data on industry structure and economics at different stages of the project.</p> <p>Y1, M12 Y3, M12 Y5, Y6, M10</p> <p>Detailed cost-benefit analysis for the project.</p> <p>Y6, M10</p>	<p>Fiji/Tonga: Industry 'snap-shots' for Fiji and Tonga described in publication:</p> <p>Johnston, W.L., Hine, D., Southgate, P.C. 2019. Overview of the development and modern landscape of marine pearl culture in the south Pacific. <i>Journal of Shellfish Research</i> 38(3), 499-518</p> <p>Sector development data is gathered annually via annual census and updated.</p> <p>Papua New Guinea: Captured for PNG as part of the surveys identified in Activities 4.1, 4.2, 5.1, and 5.2.</p> <p>Cost-benefit analysis and broader project economic impacts were unable to be addressed as planned because of COVID-19 related travel restrictions.</p>
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5.4	Develop economic models for pearls and handicrafts	Models describing set-up and operational costs, potential production levels and income, and risk analysis for production of oysters, pearls and handicrafts. Y3, M12	<p>Fiji/Tonga: Economic models for pearl culture in Fiji and Tonga have been developed. The general Fiji model was reported by Johnston et al. (2018) and economic assessment of community-based pearl oyster spat collection and mabé pearl production in Fiji by Johnston et al. (2020).</p> <p>Johnston, W., Hine, D. Southgate, P.C. 2018. Economic Modelling of Round Pearl Culture in Fiji and Assessment of Viable Farm Size. <i>Journal of Shellfish Research</i> 37, 79–91.</p> <p>Johnston, W., Kishore, P., Vuibeqa, G.B., Hine, D. and Southgate, P.C. 2020. Economic assessment of community-based pearl oyster spat collection and mabé pearl production in the western Pacific. <i>Aquaculture</i> 514, 734505.</p> <p>Economic feasibility of small-scale community-based mabé pearl production in Tonga was investigated within related project FIS/2016/126⁵ because it addressed culture system development (technical) and was reported by Johnston et al. (2020).</p> <p>Johnston, W., Gordon, S.E., Wingfield, M., Halafihi, T., Hine, D., Southgate, P.C. 2020. Economic feasibility of small-scale mabé pearl production in Tonga using the winged pearl oyster, <i>Pteria penguin</i>. <i>Aquaculture Reports</i> 17, 100347.</p> <p>Cost-benefit analysis of differing pearl production methods in Tonga has been completed and reported as:</p> <p>Johnston, W., Gordon, S.E., Wingfield, M., Halafihi, T., Southgate, P.C. 2022. Influence of production method on the profitability of mabé pearl farming using traditional and research-informed nucleus implanting practices with the winged pearl oyster, <i>Pteria penguin</i>. <i>Aquaculture</i> 546, 737280.</p> <p>Assessment of the cost of juvenile oyster supply (hatchery production) in Tonga has been completed and published as:</p> <p>Johnston, W., Wingfield, M., Gordon, S., Halafihi, T. Southgate, P.C. 2020. Production cost of farm-ready pearl oysters (<i>Pteria penguin</i>) used for mabé pearl production in Tonga. <i>Journal of Shellfish Research</i> 39, 671–677.</p> <p>See section 7.5</p> <p>Village-based production in PNG: Economic data relating to the cost of start-up, operational costs, income, and risks have been collected as part of the annual socio-economic surveys in New Ireland Province.</p> <p>A baseline model has been communicated by Simard et al. (2019) (see 5.1).</p>
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PC = partner country, A = Australia

⁵ FIS/2016/126: “Half-pearl industry development in Tonga and Vietnam”

7 Key results and discussion

7.1 Fiji

Key result 1: Community-based spat collection now established in 28 communities

Spat collection was expanded to new communities in Fiji during this project, with 28 communities now benefitting from this activity. While the Ministry of Fisheries (MoF) is closely involved in the deployment of spat collectors, training of community members, extension and brokering of spat sales to pearl farmers, all these activities (except the latter), and their planning, and selection of most appropriate sites supporting sector expansion, involved close collaboration with the project and direct involvement of the Fiji-based project scientist Dr. Pranesh Kishore. This close collaboration, including joint field-based training and technical activities, built technical capacity within the MoF's dedicated 'pearl team', and within partner communities. Between 2016 and 2021, totals of 16,376 *P. margaritifera* and 11,514 *Pteria penguin* spat were harvested by partner spat collecting communities, generating a total income of F\$74,000 over this period.



Economic assessment of spat collection in Fiji, showed it to be a profitable activity with a 4 x 100 m longline spat farm, supporting 1,240 spat collectors, generating around 2,332 *P. margaritifera* with a Net Present Value (NPV) of US\$10,439 and a Modified Rate of Return of 12.2%. Additional value from capture of *Pteria penguin* spat, used subsequently for mabé pearl and handicraft production was not included in the analysis, published as:

- Johnston, B., Kishore, P., Bingnald-Vuibeqae, G., Hine, D., Southgate, P.C. 2020. Economic assessment of community-based pearl oyster spat collection and mabé pearl production in the western Pacific. *Aquaculture* 514, 73450

Project research to fine-tune spat collection practice, based on Kishore et al. (2018), involved a number of ACIAR-USP Master's scholarship students (John Adams Carreon, Charlene Erasito and Kristina Sankar). Research from all studies contributed to refinement of spat collection methods (e.g., siting, depth and timing of spat collector deployment and oyster harvesting strategy) that were incorporated into broader MoF/project practice as well as community training and extension activities. For example, oyster yield was shown to improve when spat collectors were deployed during warmer months and after shorter durations of spat collector deployment. The most profitable scenario for pearl oyster spat collection in Fiji is to harvest spat collectors after 14-months then grow oysters in panel nets for a further 6-months, prior to their sale, providing broader options for spat farmers. Some of these findings were published as:

- Erasito, C., Prasad, R., Southgate, P.C., Kishore, P. 2022. Optimizing community-based pearl oyster (*Pinctada margaritifera*) spat collection strategies in the Fiji Islands. *Aquaculture Reports* 26, 101288.

Key result 2: Modelling forecasts positive economic returns from spat collection activities

Fijian spat collecting communities which recruit *Pteria penguin* are able to retain them for on-growing and mabé pearl production. Emphasis in Fiji has been on developing mabé pearl production capacity within these communities and seven communities have successfully engaged in mabé pearl production during the project. Mabé pearl sales during the project totalled F\$43,975 and production is ongoing. Economic modelling and cost-benefit analysis of community mabé pearl production in Fiji showed that 2 x 100 m longlines supporting 2,000 implanted *Pt. penguin*, with an estimated capital cost of \$7,319, could generate annual production of 5,400 mabé pearls generated an NPV of \$491,864. The MIRR and benefit-cost ratio of the modelled mabé pearl farm were 22.64% and 7.24, respectively, indicating the profitability of community mabé pearl production. These findings were published as:

- Johnston, B., Kishore, P., Bingnald-Vuibeqae, G., Hine, D., Southgate, P.C. 2020. Economic assessment of community-based pearl oyster spat collection and mabé pearl production in the western Pacific. *Aquaculture* 514, 73450



Key result 3: Locally made spat collectors demonstrate potential to replace imported spat collectors

Pearl oyster spat collection from the wild is the primary source of oysters for mabé production in Fiji. Spat collectors currently used in Fiji are commercially made and imported at a cost. They are made from perforated plastic ribbon which can degrade, cause pollution and adverse environmental impacts (Crusot et al., 2022). Alternative spat collections made from locally available materials were established to determine their suitability for spat collection and pearl oyster recruitment. Four locally

available materials (bamboo, strings made from coconut husks, dead oyster shells and ropes) were assessed against currently used commercial spat collectors for comparison. After two-month deployment at a depth of 4 m, pearl oyster spat had recruited to all substrates. Highest recruitment was recorded on strings made from coconut husks. Unfortunately, the trial could not run for its intended six-month period because of the impacts of Tropical Cyclone Yasa. Despite this, initial results indicate that there is potential for replacement of commercially-available spat collectors with local materials which would reduce farm set-up costs, support easier entry to the spat collection sector, facilitate greater availability of pearl oyster spat to a growing sector and, potentially improve environmental outcomes.



Spat collection trial set-up using different locally available materials and initial results; (a) dead oyster shells were tied to each other using cable ties; (b) material trialed for spat attachment substrates were bamboo, rope, string made from cococnut husks, presently used spat collector and dead oyster shells; (c) black-lip spat attached to bamboo; and (d) winged oyster spat attached to bamboo.

Key result 4: Best practice for deployment and harvesting of spat collectors identified

Spat collectors are normally deployed for a period of 12 – 14 months in Fiji before recruited spat are harvested. This period prevents communities from using the same spat collectors in the subsequent deploying season. Instead, requests are made for new spat collectors for deployment while the used ones are in the process of drying and clean-up. To address this issue, earlier removal of recruited spat from spat collectors after 10 months deployment was investigated. Removed spat were tied to cord technical nakasai (CTN) ropes and, because of their smaller size and their greater risk of

predation, some CTNs with spat attached were placed within cylindrical cages made from chicken mesh, to assess whether this improved survival. This method follows similar methods for culture of small *Pteria penguin* spat in Tonga developed as part of ACIAR project FIS/2026/126⁶ (Gordon et al., 2020). After three months, mortality of oysters within protective cages and those without protection was minimal and oyster growth was not significantly improved when cultured in protective cages. Results demonstrate that earlier removal of recruited oyster spat from spat collectors is possible with minimal impact on growth and survival. This production scenario allows same-season reuse of spat collectors, improving oyster yield and crop value. It also supports development of oyster culture capacity among spat farmers assisting their transition towards mabé pearl farming. Finally, this procedure adds to the culture options for spat farmers and their communities in providing potential for segmentation and specialisation of culture activities. While the use of protective mesh cages did not improve survival and oyster growth, their use did not negatively affect oyster performance, therefore, providing options for mitigating predation at sites with greater predation pressure.

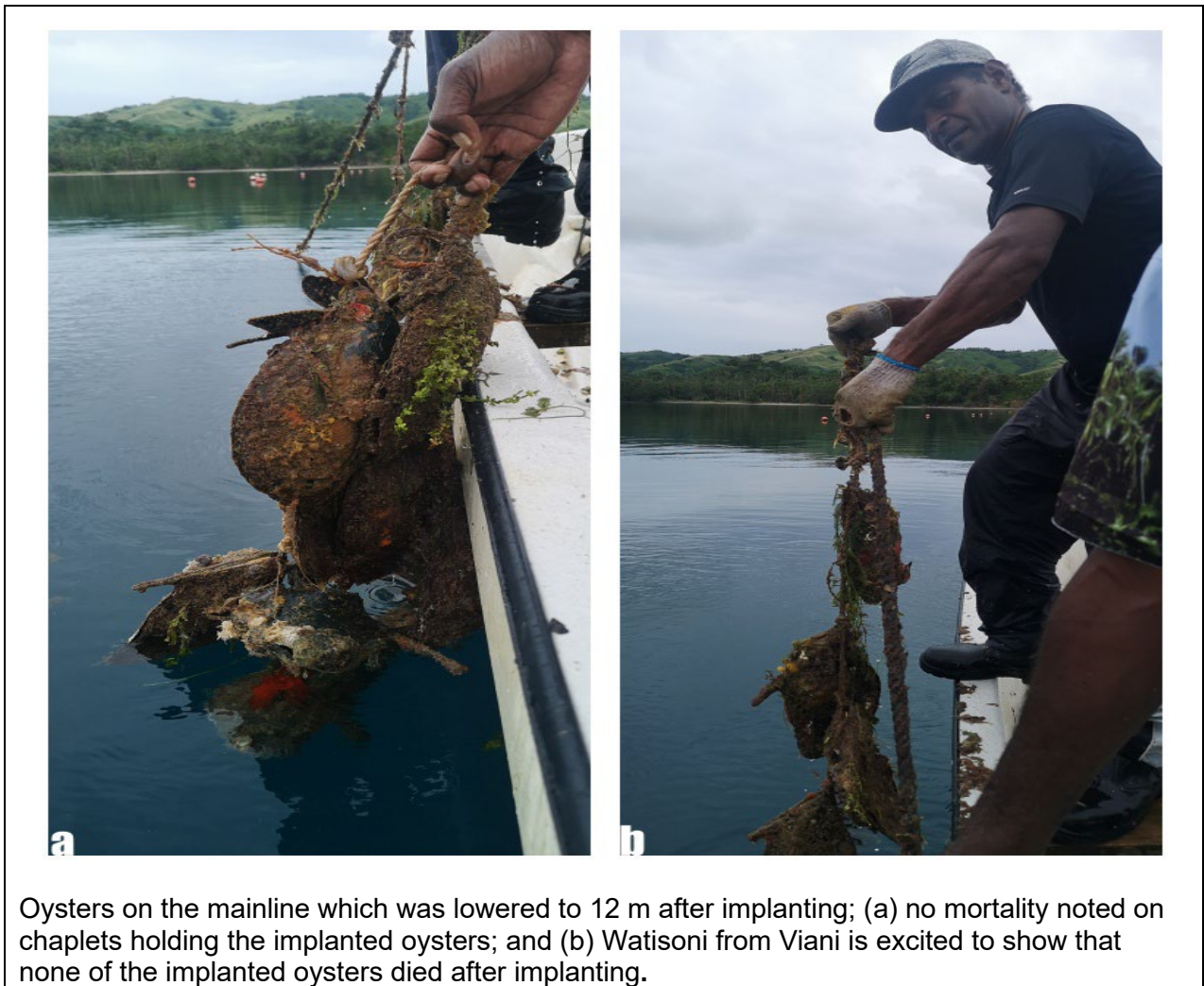


Spat tied to cord technical nakasai (CTN) rope and placed in cylindrical mesh cages for protection from predation; (a) members from Raviravi Women’s Group making cylindrical mesh cages from chicken mesh wires; (b) Kalesi from Raviravi tying spat to CTN; (c) Ramo from Raviravi showing a CTN with 20 spat tied as part as part of the optimum stocking density experiment; (d) Mili with spat on a CTN placed inside the cylindrical mesh cage; and (e) initial observations showed no form of predation among spat on CTN without protective cylindrical mesh cage.

⁶ FIS/2016/126: “Half-pearl industry development in Tonga and Vietnam”

Key result 5: Optimal depth for culturing oysters implanted with mabé pearls identified.

Mortality among pearl oysters after mabé pearl implantation is common and is related to several factors including nucleus implanting skills, oyster health, handling after implanting and environmental conditions. In attempts to minimize mortality of implanted oysters, changes were applied to existing culture methods. Of particular interest was the depth at which oysters were kept after implanting. Current culture depth of implanted oysters is 6 m. At this depth, mortality among implanted oysters of up to 30% is often reported after about one month which gradually decreases over time. To address this newly implanted oysters were experimentally held at a depth of 12 m and survival and resulting mabé pearl quality was assessed. The assumption was that cooler water at greater depth would slow the metabolic rate of oysters and aid their recuperation following implantation. Oysters held at 6 m and 12 m depths were monitored after 1 month, 6 months and when mabé pearls were harvested. Both oyster survival and mabé pearl quality were improved when oysters were cultured at a depth of 12 m (compared to 6 m). It is assumed that improved mabé pearl quality resulted from the deposition of finer, thinner nacre, generating improved lustre (Southgate, 2021). Immediate transfer of newly implanted oysters to a depth of 12-15 m, where they are held for the entire mabé pearl culture period, is now standard practice within the Fiji mabé pearl sector.





Key result 6: Commercial enterprises successfully expanded operations to produce pearl and pearl shell handicraft items

Initial value chain analysis identified that around FJD 8.5 million (≈ USD 4 million) worth of pearl and pearl shell handicraft items are imported into Fiji each year, targeting international tourists. This represents considerable potential for import replacement through local production, supported by improved local oyster (shell) supply from expansion of community spat collecting initiatives (see above). Pearl handicraft skills training in Fiji was initiated in partnership with the Ba Women’s Forum (BWF) and Ba Town Council (BTC). Modern machinery to assist sanding, polishing and cutting of pearl shells, and smaller tools for shaping, drilling and engraving were supplied in a dedicated workshop established within the women’s bure at Ba. The workshop supported regular training of the women’s shellcraft group by international handicraft skills trainers, leading eventually to production of high-quality, retail-ready pearl shell jewellery and handicraft items. Eventually operating as an autonomous unit with the BWF, Marama Shellcraft Fiji (MSF), the group attained ‘Fiji Made’ accreditation and sold their products at major retail outlets in Fiji and to international customers. In parallel with handicraft skill training, the MSF group received training to assist business operation and development, as well as marketing and market access. Based on the success of handicraft training at Ba, a second pearl handicraft training centre was established in partnership with the village of Somosomo at Taveuni. The Nasomo Ra Marama Handicraft group from Somosomo developed a well-equipped workshop supporting shell processing and handicraft

production. Based on the model developed at Ba, the Somosomo group also received regular handicraft and business skills training, and now produce high quality items sold at local markets, to major retail outlets and local resorts and on consignment to handicraft and jewellery retailers.



Members of Marama Shellcraft Fiji (MSF) in their workshop in Ba practicing pearl shell polishing, design and engraving with trainer Neke Moa from New Zealand (top left); (b) members of the Nasomo Ra Marama Handicraft group from Somosomo Village, Taveuni, polishing pearl oyster shells in their workshop (top right); (c) Nazmin Ali, Workshop Supervisor of MSF instructing in preparing invoices and delivery documents for the first MSF order to the Jacks Group of Companies (bottom).

Key result 7: Communities successfully expanded operations to produce pearl and pearl shell handicraft items

The two handicraft training workshops established at Ba and Somosomo (see above) require a source of power for the machinery used in shell processing. But because power is not readily or cheaply available in many coastal communities in Fiji, a new program of pearl shell handicraft training using hand tools was established to training women from three communities hosted by the Navatuda Women’s Club in Raviravi (Vanua Levu). Training included nine workshops delivered over eight days, and focused on basic handicraft skills (cutting, grinding, filing, sanding, macramé, design and jewellery components) as well as basic business skills and marketing. Sets of hand tools were provided to the Navatuda Women’s Club to allow participants to continue to apply their newly

acquired skills. The Ministry of Fisheries supported this initiative by funding a small facility for the display and sales of pearl handicrafts within Raviravi Village. Hand tool-based pearl shell

Women of the Na Somo Ra Handicraft Centre, at Somosomo, Taveuni (top) and Marama Shellcraft Fiji (MSF), Ba (below) celebrate graduation after successful training to produce high quality mother-of pearl and mabé pearl jewellery products.



handicraft production is well suited to remote communities that have access to pearl shells (through the spat collection program), or who produce their own mabé pearls (see above). A training manual for making and selling shell jewellery (ACIAR Monograph 208), developed for the PNG component of this project (see below) was used to guide community hand tool-based training in Fiji too.

Key result 8: 'Taveuni pearl hub' found beneficial to all parties

The Taveuni pearl hub model involved three separate but nearby community women's groups and a commercial cultured pearl farm (Civa Pearls Fiji) working together with broad oversight and guidance from the pearl farm owner. Links between the community groups included: (1) community-based (Draketi) spat collection (see above) and sales of resulting spat to the commercial pearl farm; (2) provision of older (no longer productive) pearl oysters to a women's group in a second community (Qamea) for mabé pearl production; (3) sale of resulting mabé pearls and pearl shell to the Nasomo Ra Marama Handicraft group from Somosomo (see above) for handicraft and jewellery production.

This approach proved very successful and potentially provides a model that could be applied in other parts of Fiji and for further potential development of 'co-operative' models for community engagement on the pearl livelihoods sectors in Fiji and other countries. The mabé pearl farm at Qamea was established through a partnership between the project, Civa Fiji Pearls and the Vanua Trust of Laucala.

Key result 9: Strengthening of ACIAR's partnership with the Ministry of Fisheries

Perhaps the most important achievement of this project in Fiji is the continued strengthening of the collaborative partnership between the project and the 'pearl team' within the Ministry of Fisheries, which is responsible for oversight of the Fijian pearl and pearl livelihoods sector. This strong relationship has provided a basis for sustainable expansion of the sector as well as delivery of extension activities and training of existing and new community ventures. This has supported development of the sector to include 28 communities involved in pearl oyster spat collection; seven community-based mabé pearl farms, two communities specialising in jewellery and handicraft production, and the transition of successful spat collection communities to mabé pearl production and value adding through handicraft production.

7.2 Tonga

Key result 1: Fifteen new pearl farms established with support from Vava'u Pearl Centre

Participation in mabé pearl farming has increased by approximately 300% with 15 new pearl farms being developed during this project. Pearl farming has expanded from the islands of Vava'u to include the island groups of Ha'apai and Tongatapu. Residents of all three of Tonga's major island groups are now able to participate in pearl farming and to benefit from the ensuing opportunities. Between 2015 to 2018 mabé production in Tonga increased by 72% to 4,680 pearls and the total annual value of the Tongan pearls has increased by 182% to T\$732,000 over the same period. Improved mabé production procedures and efficiencies, developed from research by Dr. Sophie Gordon as part of the closely allied ACIAR project FIS/2016/126 that identified "optimised" production practices capable of increasing annual returns by up to 94% and supporting sector expansion.

Further development of the Vava'u Pearl Centre (VPC) as a central point for farmer/artisan training activities has supported capacity building exercises relating to oyster farming, mabé pearl production and processing and assessment of pearl quality and value. These activities were supported by dedicated training manuals and other support/demonstration tools.

Key result 2: Modelling forecasts positive economic returns from mabé pearl farming activities

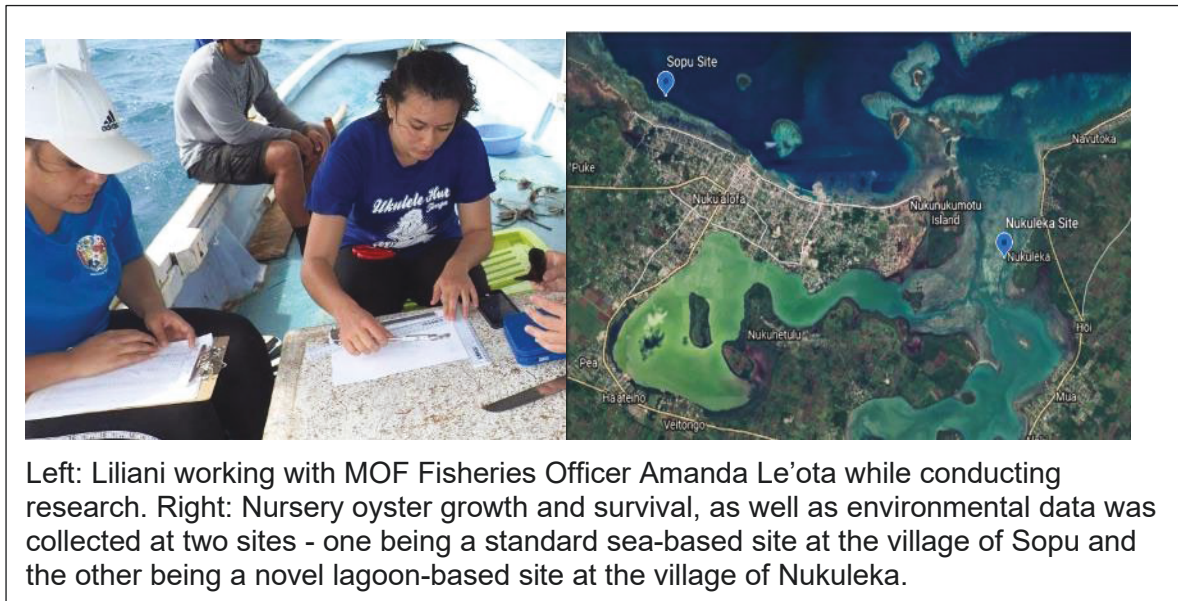
Economic assessment of mabé pearl production in Tonga showed it to be a very profitable activity. Capital (establishment) costs of around US\$2,027 were estimated for a small farm targeting annual mabé pearl production from 100 oysters, generating 231 mabé pearls annually. Annual profitability of US\$9,338 generated a benefit-cost ratio of 4.86 and an income of more than twice the average national income in Tonga. Of particular importance was that the modelled farm required less than 10 hours labour input per week ensuring that mabé pearl production is not only highly profitable, but compatible with other subsistence activities and local lifestyles. These findings were published as:

- Johnston, W.L., Gordon, S.E., Wingfield, M., Halafihi, T., Hine, D., Southgate, P.C. 2020. Economic feasibility of small-scale mabé pearl production in Tonga using the winged pearl oyster, *Pteria penguin*. *Aquaculture Reports* 17, 100347.

Key result 3: Improved understanding of environmental factors that influence growth and survival of *Pteria penguin* spat and juveniles

Ready access to off-shore nursery sites and predation are major bottlenecks to nursery production of *Pteria penguin* in Tonga. Studies addressing the influence of culture site and environmental factors on growth and survival of *Pteria penguin* spat and juveniles in Tonga were undertaken by ACIAR/USP Masters Scholarship holder and Tongan citizen Liliani Hughes. Her research assessed nursery culture potential and the differences between juvenile oyster growth and survival at two contrasting sites with very different physical, environmental and water quality conditions. Spat performance was compared at a protected, inshore lagoonal site (Nukuleka) with that of spat held at the regular MoF oceanic nursery site at Sopu. Growth and survival were assessed after 3 and 11 months. Oyster survival at Nukuleka was twice that of oysters at Sopu and growth (despite being grown at a higher density due to the higher survival) was approximately 60% better at Nukuleka. A follow-up experiment confirmed that the Nukuleka site supports excellent growth and survival of pearl oyster juveniles. Based on these results Nukuleka was further developed as a nursery site to improve Tonga's nursery production outcomes, and provide non-weather dependant access. Liliani's studies were completed in July 2021 and will contribute significantly towards building regional research capacity in this field.

- Finaulahi, Liliani Elizabeth Hughes. 2021. Optimising the nursery culture of the winged oyster, *Pteria penguin*, for mabe pearl production in Tonga. The University of South Pacific, Master's thesis, pp. 70.



Key result 4: Communities and women's groups successfully expanded operations to produce pearl and pearl shell handicraft items

Twenty handicraft skills training workshops were conducted in Tonga during this project, to train 58 artists of which 36% were female. This training was linked with other MoF, DFAT and World Bank initiatives to maximise outcomes and artisanal access to equipment, tools and training resources. There has been a specific focus on identifying skilled Tongan artisans and providing them with advanced skills so that they become pearl handicraft trainers for other local artisans in a "Train



Two of Tonga's leading pearl artisans Andrew Motulinka (left) and Estimoa Kuilber (right) who now train and mentor other artists.

the Trainer" program. In 2020, local trainers led by Andrew Motuliki, conducted 5-day handicraft training workshops in Vava'u and Ha'apai. The development of such local capacity proved to be particularly important when COVID-19 international travel restrictions were applied.

Key result 5: Vava'u Pearl Centre becomes central hub for artisan training and sales of pearl and pearl shell handicraft item

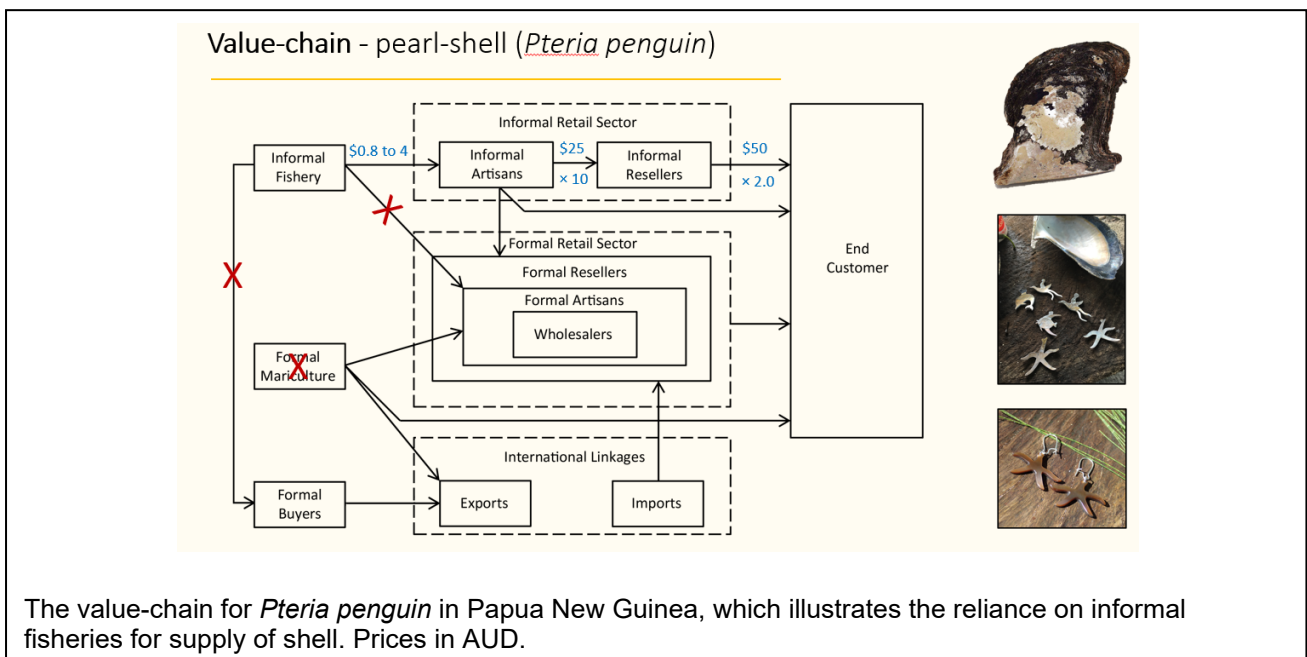
The Vava'u Pearl Centre (VPC), in Vava'u, Tonga, was upgraded in July 2019 to become the central hub for artisan training and a focal retail outlet for pearl products, with commission being paid to VPC. Regular pearl tours assist sales at the VPC which, from July to October 2019 totalled ~\$40,000TOP. The VPC workshop is well equipped and provides a safe, modern and efficient workspace for local artisans. The workshop is open Monday to Friday and is used by local artisans at a small cost (to cover consumables). The VPC team have been trained as quality control regulators to ensure that defined product quality standards are maintained. Ms Naua Lakai was trained as a pearl farmer and artisan during this project. She now manages the VPC and was invited to attend the successful ACIAR Pearl Expo in Canberra (December 2019), where she promoted Tongan pearl products and described local impacts of this Project.

The number of people trained to produce pearl handicrafts in Vava'u more than doubled initial training expectations and additional training workshops were provided by linking with the DFAT "Tonga Skills" program. Female participation as both pearl farmers and artisans increased steadily during the project to around 44% of total pearl related employment, facilitated by project training efforts at VPC.

7.3 Papua New Guinea

Key result 1: Pearl and pearl shell value chains mapped

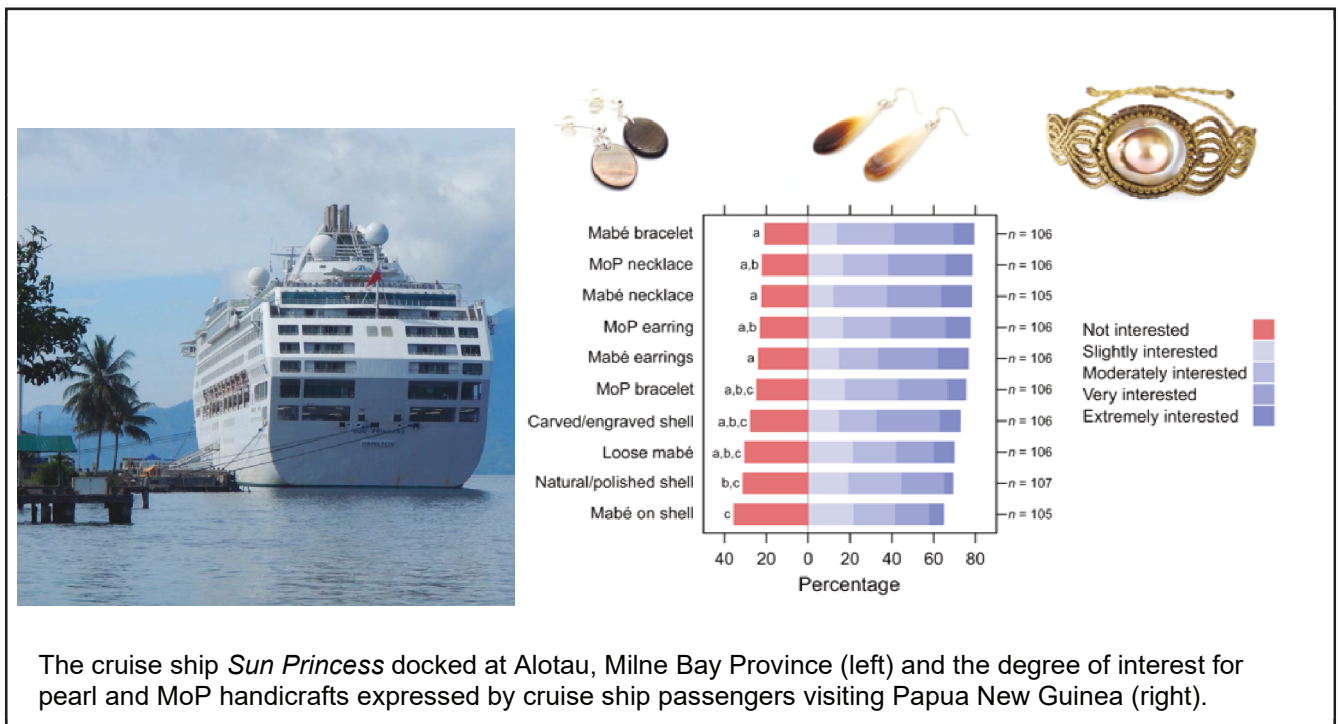
Interviews with commercial retailers ($n = 31$) and artisans ($n = 80$) of pearl and MoP products in NCD, Milne Bay, East New Britain, and New Ireland provided baseline information on existing mabé pearl and MoP handicraft value-chains. Two sources of pearl-shell were identified: artisanal fisheries and mariculture. Mabé pearls were obtained either from a single domestic mariculture operation (Coral Sea Mari-Culture PNG Ltd) or imported. Artisanal fisheries harvest of pearl-shell supplied both informal and formal artisans, and is the sole source of pearl-shell utilised by informal artisans. Fishing activities are informal, harvesting pearl-shell by hand while free-diving, and target three species: *Pinctada margaritifera*, *Pinctada maxima*, and *Pteria penguin*. Fishers sell *P. margaritifera* at USD \$0.30 to \$5.93 per shell (two valves), *P. maxima* at \$2.96 to \$14.82 per shell, and *P. penguin* at \$0.59 to \$2.96 per shell, with price variation largely dependent on valve size. All the *P. maxima* (100.0 %) shells, but only a portion of the *P. margaritifera* (39.9 %) and *P. penguin* (52.7 %) shells, utilised by artisans are purchased from fishers; the remainder are supplied through the artisans' own fishing activities. Mabé pearl products were only sold by formal sector retailers, whereas pearl-shell products were sold by both informal and formal sector retailers. In the informal sector of the pearl industry market-chain, pearl-shell products were sold at informal craft markets by retailers of shell-handicraft. Pearl-shell products often comprised only a small portion of the available MoP handicraft products. The majority (55.9 %) of informal retailers selling pearl-shell products were artisans, while the remainder were resellers who purchased pearl-shell products from artisans. Informal artisans sold pearl-shell products at a price range of \$2.96 to \$88.91 while informal resellers sold pearl-shell products at a price range of \$2.96 to 177.82. A quarter (24.2 %) of informal artisans ($n = 33$), but none of the informal resellers, also sold pearl-shell products to formal resellers. Retailers in the formal sector of the market-chain sold pearl-shell (93.5 % of retailers), round pearl (41.9 %), and mabé pearl (29.0 %) products. All retailers engaged in the resale of pearl and/or pearl-shell products. In addition to reselling pearl and pearl-shell products, 32.3 % of retailers also produced their own pearl and pearl-shell products (i.e., formal artisans) and four (12.9 % of retailers) of these formal artisans also engaged in wholesale of pearl and pearl-shell products (i.e., wholesalers) to other resellers. No participants in the pearl industry market-chain exclusively engaged in formal artistry or wholesale of pearl and pearl-shell products.



Key result 2: Cruise passengers found interested in purchasing pearl and pearl shell handicrafts whilst in PNG

International visitor data obtained from the PNG Tourism Promotion Authority was reviewed and revealed a rapid expansion of PNG’s cruise ship industry. Many of the destinations visited do not have access to the existing pearl and MoP handicraft value-chains, identifying unexplored market opportunity. Using structured interviews, the Project evaluated cruise passenger preferences and intended purchase behaviour towards a range of mabé pearl and MoP handicrafts. Most cruise passengers expressed both an interest and willingness to purchase mabé pearl and MoP handicrafts, though preferences were found to exist for specific products and product attributes. Latent factor analysis revealed cruise passenger preferences could be summarised by the importance an individual assigned to a handmade product, a product with accompanying information, or the aesthetic appeal of a product. The importance assigned to these factors was found independent of cruise ship and passenger demographics, but partly explained by purchase intent (i.e., purchase for self or others). Factoring these results into handicraft development strategies will help maximize local economic benefits from pearl industries and cruise tourism in Papua New Guinea, but also throughout the Pacific region. Results were published as:

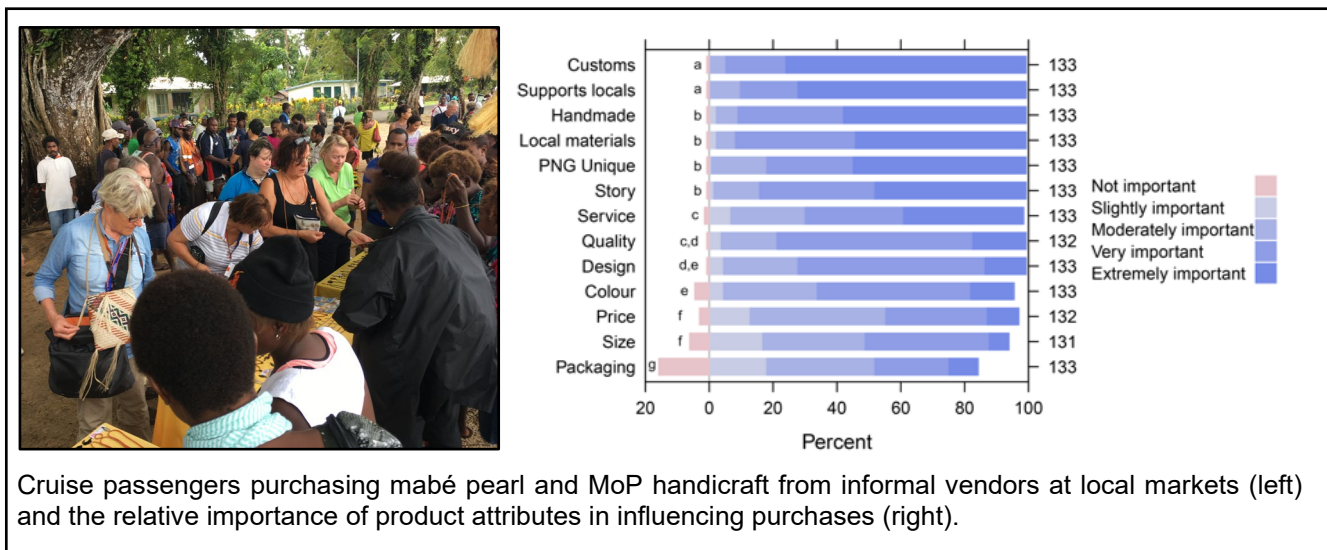
- Militz, T.A., Kershler, D., Southgate, P.C. 2021. Informing artisanal pearl and pearl-shell handicraft production for the cruise tourism market through analysis of intended purchase behaviour. *Tourism in Marine Environments* 16, 45–58.



Key result 3: Cruise passenger preference for pearl and pearl shell handicraft identified

The self-declared willingness of cruise passengers to support indigenous peoples through purchase of mabé pearl and MoP handicraft was validated through an experimentally controlled market scenario. Using the theoretical measures of interest and willingness-to-pay for various mabé pearl and MoP handicrafts, a range of appropriate products were developed and offered at an informal market to cruise passengers during shore visits to Alotau, Milne Bay Province. Cruise passenger purchases of mabé pearl and MoP handicrafts were non-random, with MoP earrings accounting for 66% of purchases and mabé pearl jewellery (earrings and necklaces) collectively accounting for only 16% of purchases. Cruise passengers purchased all products at all available price points, although a preference for MoP earrings and mabé necklaces at lower price points was evident. When looking at income share, MoP earrings accounted for only 37% of sales value which was comparable to the

sales value (37%) of the less popular mabé products, due to differences in product price. The most important product attributes influencing purchase were provision of customs related information and knowing the purchase supports local livelihoods. In contrast, packaging was the least important attribute, with 16% of cruise passengers indicating packaging was not important at all. Importance of product attributes was related to the cruise passengers' demographic. Older (> 65 years of age) passengers ascribed lesser importance on product authenticity and males ascribed greater importance on aesthetics (design/colour), price, packaging, and customer service than females. The results will allow for better targeted product design and marketing of mabé pearl and MoP handicrafts to cruise passengers in Papua New Guinea.



Cruise passengers purchasing mabé pearl and MoP handicraft from informal vendors at local markets (left) and the relative importance of product attributes in influencing purchases (right).

Key result 4: Handicraft and business skills training delivered to artisans in New Ireland Province and in Milne Bay Province

Handicraft skills training was concentrated in New Ireland and Milne Bay, owing to the presence of existing domestic market channels. In New Ireland, Sue McCuaig (ABV) conducted creative design workshops for artisans on Nusalik Island, in April 2016. Artisans had the opportunity to work with mabé pearls and were successful in producing high quality, unique designs. Sue subsequently worked with Nittyta Simard from the Nago Island Mariculture and Research Facility (NIMRF) to facilitate on-going engagement with artisans via more regular workshops. This approach was strongly supported by NFA through construction of a dedicated shellcraft centre at the NIMRF. The shellcraft centre allowed for delivery of weekly skill-development classes to interested artisans. Over the course of the Project, 82 classes of 20 unique workshops were attended by 268 participants (116 individuals). The booklets developed for the workshops were compiled into a single comprehensive manual detailing use of hand tools and macramé in shell handicraft production. This helped enable delivery of the workshop series to remote communities unable to travel to the NIMRF shellcraft centre. Participants in Project training activities are given a copy of the manual to support further development of skills outside of the classroom and beyond the life of the Project.

In Milne Bay, Sue conducted a series of workshops on pearl and pearl-shell handicraft production with hand tools, supported by a HOMDAP grant of \$25,000 for resources and equipment. Further funding of \$15,000 was obtained from the DFAT-DAP program and allowed extension of the NIMRF workshops series to artisans at the Kwato and Logea Islands.

Over the course of the Project, several opportunities arose to engage with partner agencies to deliver additional business skills training to artisans. In 2019, the New Ireland Provincial Government engaged the International Training Institute to deliver a 3-day business management and computer skills workshop in Kavieng to six artisans engaged in the Project. The Women's Entrepreneur Network in collaboration with Project staff and the New Ireland Arts and Crafts Association (NIACA) have delivered MSME registration, tax return, and networking workshops to thirteen artisans in Kavieng. Thirty-seven artisans trained by the Project also received broader business and financial

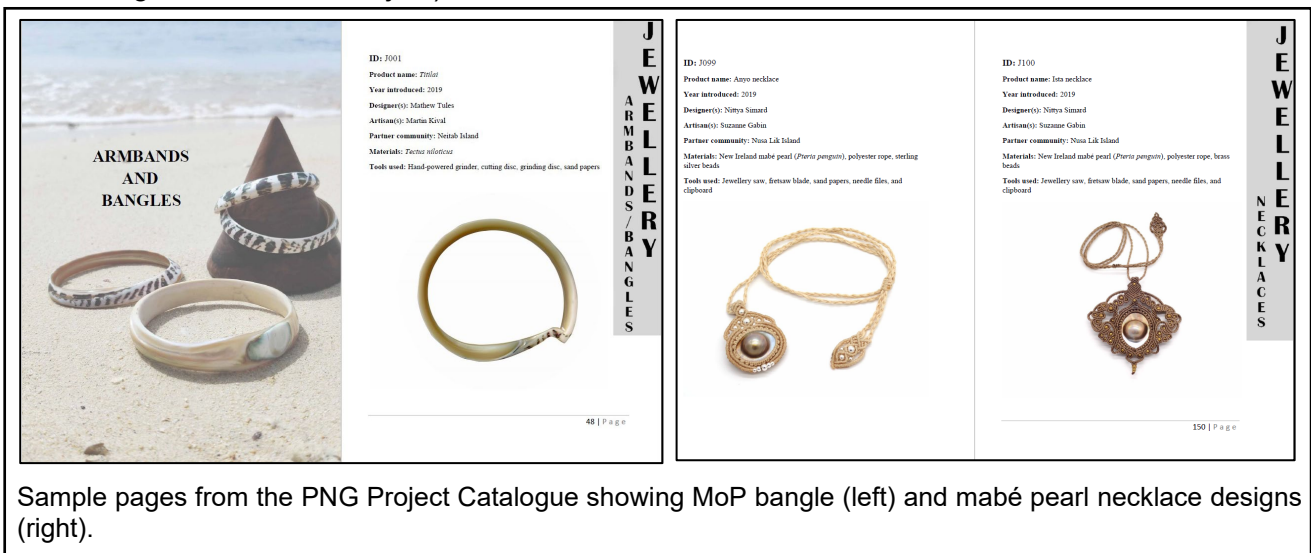
management skills training from Prof. Barbara Pamphilon as part of family livelihood wellness modules conducted within ASEM/2014/095.



Cover page of the manual (ACIAR Monograph 208) developed in support of handicraft skills training (left) and a Tunnung artisan participating in Project training guided by the manual (right). During the Project, the manual supported shell handicraft training within the Logea/Kwato, Neitab, Tunnung (PNG), Ravita and Raviravi (Fiji) communities.

Key result 5: New products developed for domestic market channels

Panel discussions with community elders, key informant interviews, and consultation of the literature on New Ireland ethnography has facilitated the use of traditional techniques and artistic design in product development. This, in combination with a reliance on local and renewable materials, has resulted in a regionally unique style of jewellery of 100% PNG-origin that does not compete directly with the MoP handicrafts being developed elsewhere in the Project (Fiji, Tonga). A “PNG Project Catalogue” was produced to showcase the range of products developed for the PNG market over the course of the Project. The catalogue has been instrumental in establishing partnerships between artisans and the formal retail sector as it allows artisans to provide prospective clients a range of design options which can be replicated on commission. This has attracted inter-provincial and international resellers to begin placing larger orders with individual artisans and cooperatives. By the end of the Project, 11 formal sector retailers in PNG were reselling New Ireland shellcraft (only one was doing this at start of Project).



Sample pages from the PNG Project Catalogue showing MoP bangle (left) and mabé pearl necklace designs (right).

To help artisans better engage with international tourists at informal market venues, a Shell Handicraft Vendor Guide was produced. The guide provides information regarding shells used and international trade restrictions concerning those shells in both *English* and *Tokpisin* – with shells additionally identified by their *Tokples* (*Tigak* and *Tungag*) names. Through use of the guide, artisans can become better informed and communicate quarantine restrictions, which is the most important product attribute to cruise passengers (see above).



Key result 6: Pearl-based livelihoods are providing socio-economic benefits to communities in PNG

A thorough understanding of livelihoods is necessary to ensure development policies are compatible with both resource conservation and the social and economic goals of development. Few studies, however, focus on value-adding activities occurring post-harvest in artisanal fisheries. The transformation of mollusc shells and skeletal remains of other marine taxa into artistic jewellery and decorative items is becoming an increasingly important livelihood activity for rural, coastal communities across the Pacific. The Project found shellcraft production makes valued contributions to rural livelihoods in PNG. The shellcraft sector of the Tigak Islands was a primary or supplementary income source for approximately 6% of the region’s population, and the weekly income of artisan households exceeded the regional average (USD \$43.60) by an additional 78%. Shellcraft offers an opportunity for income generation that does not appear to engender the negative social repercussions attributed to income generation from logging, mining, or other fishing activities in PNG. In contrast to fishery sectors where participation is limited by physical fitness or cultural taboos, shell-based handicraft production engaged men, women, the elderly, and disabled persons. The major challenges facing this livelihood sector are perceptions of marine resource declines and a lack of livelihood flexibility, attributed to the specialisation of material assets and skills. Improving market heterogeneity and developing coastal aquaculture may facilitate sustainable development of this livelihood sector. For further information please see:

- Simard, N.S., Militz, T.A., Kinch, J., Southgate, P.C. 2019. Artisanal, shell-based handicraft in Papua New Guinea: Challenges and opportunities for livelihoods development. *Ambio* 48, 374–384.



Nittyta Simard conducting an interview with Catherine Passingan from the Nusa Islands community (left). Income for housing improvements were identified as a benefit of engaging in shellcraft-based livelihood by nearly a third of all artisans, here Teresia Boas proudly stands in front of her new house which was funded through income generated by shellcraft sales.

7.4 Baseline measures of women’s empowerment

Key results: Capacity for women to engage in pearl-based livelihoods is limited without intervention

To rigorously assess, demonstrate and learn about the impact of development interventions that are working towards women’s empowerment, baseline measures of women’s empowerment were collected from participants involved in the Kwato/Logea (PNG), Ravita, and Raviravi (Fiji) community skill development workshops. Empowerment was measured using the quasi-quantitative measurement tool developed by Oxfam GB (Lombardini et al., 2017). The measurement tool provides a framework categorised into three levels of change, each containing a range of indicators representing the characteristics of an ‘empowered women’ in the socio-economic context under analysis. These indicators can also be taken to represent latent variables (termed attributes) indicative of different aspects of their lives. Most respondents were found to be empowered in their work/life balance, ability make decisions, and in teamwork and leadership. Respondents were lacking in their capacity to engage in shellcraft prior to Project intervention. It can be anticipated that Project activities will have the greatest impact in empowering artisans’ capacity to engage in pearl-based livelihoods, although preliminary assessment during FIS/2018/129 suggests broader empowerment across most/all attributes has occurred. These results serve as a baseline metric against which long-term empowerment impacts of Project activities and development interventions will be assessed.

The percentage of respondents indicating they were in an ‘empowered’ state across each of the assessed attributes of empowerment (each comprising n indicators) prior to Project intervention.

Attributes (n = indicators)	Fiji (Ravita) Score (%)	Fiji (Raviravi) Score (%)	PNG (Logea/Kwato) Score (%)
Self-perception (n = 3)	54.5	51.3	47.4
Capacity to engage in PBL (n = 3)	0.0	2.6	22.8
Personal freedom (n = 2)	68.2	57.7	71.1
Access to resources (n = 4)	59.1	52.0	59.2
Teamwork and leadership (n = 3)	87.9	64.1	64.9
Ability to make decisions (n = 1)	90.9	76.9	89.5
Work life balance (n = 1)	100.0	100.0	100.0
Break stereotypes (n = 2)	48.5	57.7	76.3

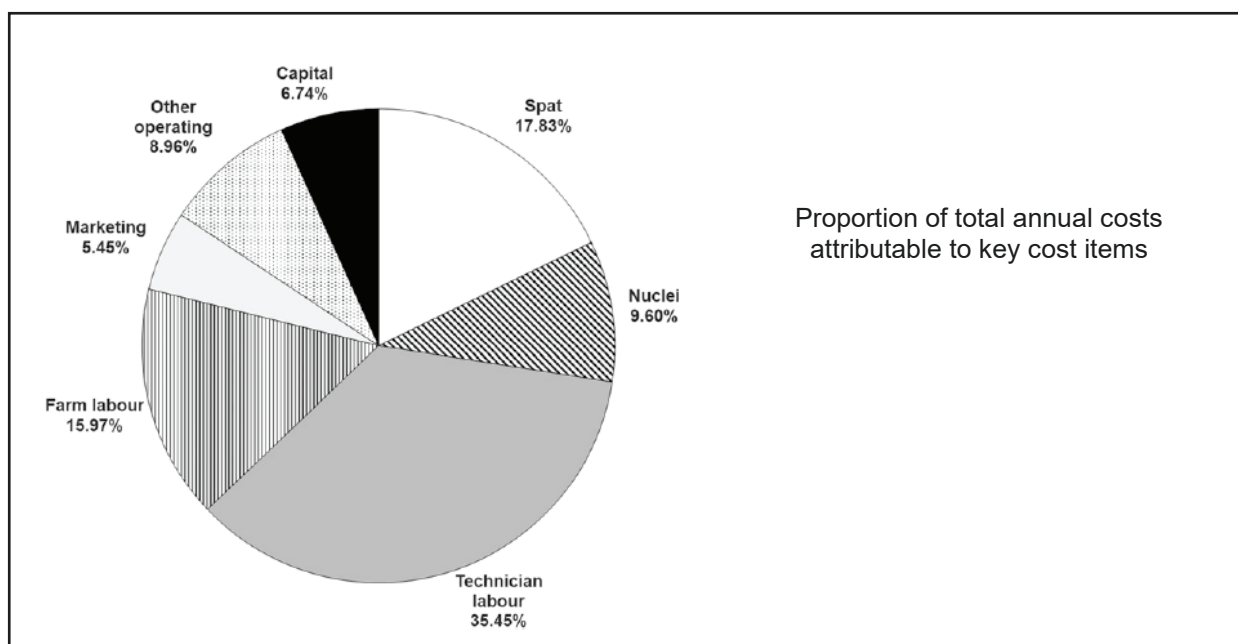
7.5 Developing economic models for pearl-based livelihood activities

Key results: Modelling forecasts positive economic returns for several pearl-based livelihoods activities in Fiji and Tonga

Lack of understanding of economic and commercial realities are considered key factors in the poor rate of uptake and success of many aquaculture enterprises in Pacific-island countries (Hambrey Consulting, 2011). This project developed whole-farm economic models for round and mabé pearl production systems; established minimum viable farm size for both round and mabé pearl culture; confirmed profitability of spat collection operations generating downstream economic opportunity; demonstrated significant profitability from small-scale community-based mabé pearl culture operations, and proof of economic viability of new or modified pearl production. These outputs as well as improved knowledge of establishment, input and operational costs associated with various component of the pearl livelihoods value chain, assist decision making and provide a platform for informed and sustainable sector development, and are detailed below.

Economic model for round pearl culture in Fiji: Round pearl culture is an increasingly important industry in Fiji. Significant barriers to entry include high capital outlay and technical requirements, and a high turnover of small to medium size farms has limited industry growth. The Project developed a viable-scale farm model for round pearl culture in Fiji to assist new or potential entrants understand costs, risks, and production levels required for success. Major production costs were labour (51%), oyster stock (18%), and pearl nuclei (10%). At steady state, median annual profitability was determined to be \$156,362, but inclusion of price and production risk factors reduced annual profitability to \$29,463. The model farm achieved an internal rate of return of 36% with a benefit–cost ratio of 1.8 and payback period of 5 y. Farms holding 100,000 oysters and producing more than 8,000 pearls are deemed of viable scale. At this scale, farms can attract overseas pearl seeding technicians, apply economies of scale, and invest profits into future development. Given the average rural household income in Fiji is \$5,800, round pearl culture offers significant economic opportunity and delivers socioeconomic benefits for rural communities in upstream (oyster stock supply) and downstream (handicrafts, jewellery, and tourism) activities.

- Johnston, W.L., Hine, D., Southgate, P.C. 2018. Economic modelling of round pearl culture in Fiji and assessment of viable farm size. *Journal of Shellfish Research* 37, 79–91.



Economic model for pearl oyster production in Tonga: The Kingdom of Tonga is unique among the pearl-producing countries of the South Pacific in focusing on mabé pearl culture using the winged pearl oyster *Pteria penguin*. The Tongan mabé pearl sector is developing rapidly and stimulated by routine supply of spat to mabé pearl farmers, from the government hatchery at no cost. It is likely that some level of cost recovery for spat supply will be considered as the sector strengthens, but information on hatchery production costs is limited. The Project determined the costs of operating the government pearl oyster hatchery in Tonga and developed an economic model to assess the production cost of juvenile oysters. Modelling was based on a single annual hatchery run generating 6,600 oysters from the ocean-based nursery for delivery to commercial pearl farms. Estimated capital cost was USD 19,079 (excluding government buildings and chattels), and the major production costs were hatchery labour (37%), capital purchase and replacement (20%), and nursery labour (10%). Total annual costs for the pearl oyster hatchery were USD 13,263, equating to a cost of USD 2.01 per oyster supplied to farmers in Tonga. Given significant annual profits of around USD 9,338 that can be generated from 100 harvested oysters, there is justification for cost recovery. This detailed assessment of the real costs of hatchery operations has resulted in a full and comprehensive understanding of production cost of farm-ready pearl oyster *Pteria penguin* used for mabé pearl production in the kingdom of Tonga.

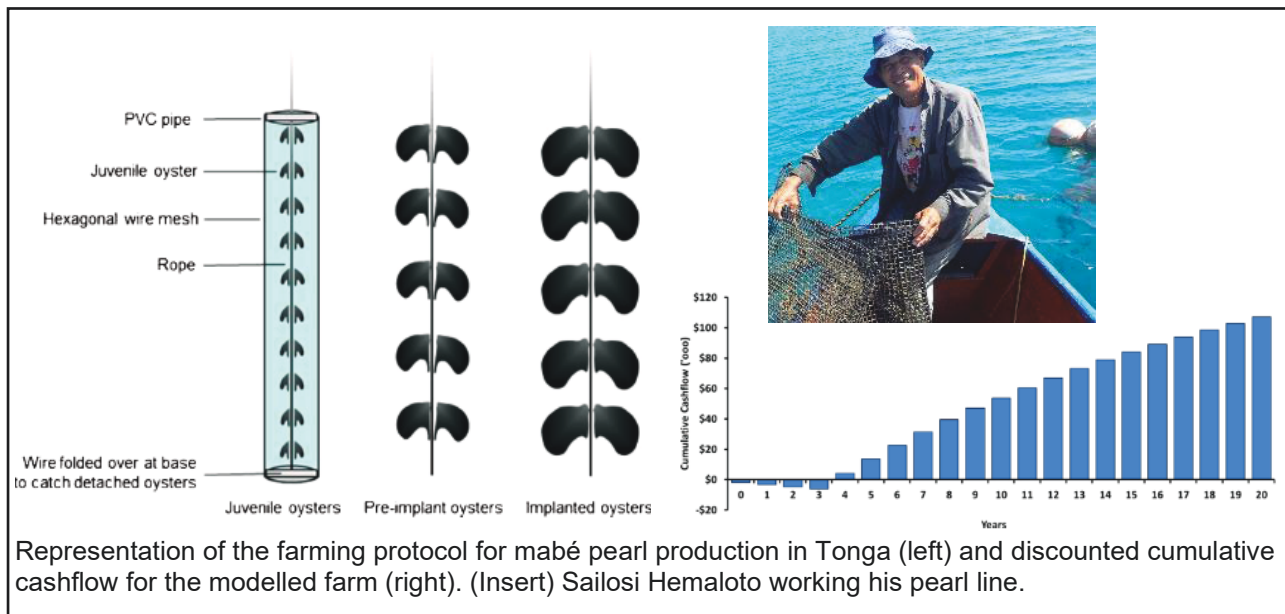
- Johnston, W.L., Wingfield, M., Gordon, S., Halafihi, T., Southgate, P.C. 2020. Production cost of farm-ready pearl oysters (*Pteria penguin*) used for mabé pearl production in Tonga. *Journal of Shellfish Research* 39, 671-677.

Economic model for mabé pearl production in Tonga: Mabé pearl culture is an increasingly important rural livelihood in south Pacific countries as it offers a low-cost, low-tech alternative to round pearl culture. Mabé pearl production can be achieved by local people with appropriate training, and the products offer further livelihood opportunities through value-adding and local production of jewellery and handicraft items. The Kingdom of Tonga is unique among south Pacific pearl producing countries in focusing primarily on mabé pearl, not round pearl, culture using the winged pearl oyster, *Pteria penguin*. The Tongan mabé pearl sector has developed rapidly over recent years and is sustained by routine hatchery production of spat and recently improved pearl culture methods. The Project determined establishment and operational costs of a subsistence-level mabé pearl farm in Tonga and developed an economic model to assess potential profitability of such operations. The representative mabé pearl farm modelled in this study targeted annual mabé pearl production from 100 oysters. Estimated capital cost (US dollars; USD) was USD2,027 and major production costs were labour (29%), marketing (24%), and capital purchase and replacement (16%). Annual production of 231 saleable mabé pearls generated a net present value (NPV) of USD 107,101. The

modified internal rate of return (MIRR) and benefit-cost ratio of the modelled mabé pearl farm were 20.46% and 4.86, respectively, with a payback period of 4 years. Given the average annual income in Tonga is USD 4,020, the modelled mabé pearl farm offers significant economic opportunity (USD 9,338 annual profit after all costs, including owner/operator wages) and supports additional socio-economic benefits for rural communities involved in downstream activities relating to handicraft and jewellery production, and tourism. The findings of this study assist stakeholder understanding of costs, risks and production levels required for profitable mabé pearl production.

- Johnston, W., Gordon, S.E., Wingfield, M., Halafiji, T., Hine, D., Southgate, P.C. 2020. Economic feasibility of small scale mabé pearl production in Tonga using the winged pearl oyster, *Pteria penguin*. *Aquaculture Reports* 17, 100347.





Economic model for community-based pearl oyster spat collection and mabé pearl production in the western Pacific: Cultured pearl production, and associated activities, are of crucial social and economic importance to remote coastal communities in Polynesia and the western Pacific. The project determined the potential profitability of (1) community-based pearl oyster spat collection operations targeting *Pinctada margaritifera*, and the subsequent sale of pearl oysters to round pearl farms; and (2) the use of *Pteria penguin*, collected incidentally from *P. margaritifera* spat collection operations, for mabé pearl production. The spat collection farm modelled was comprised of four 100m longlines supporting 1,240 commercial spat collectors, with an estimated capital cost of \$1,245 (all figures in USD). The spat collection operation produced 2,332 saleable *P. margaritifera* pearl oysters (sold to round pearl culture operations) with estimated NPV of \$10,439. The MIRR generated was 12.24%, with a benefit-cost ratio was 1.52, and a payback period of 4 years. The downstream mabé pearl farm modelled was comprised of two 100 m longlines supporting 2,000 implanted *Pt. penguin* oysters with an estimated capital cost of \$7319. Annual production of 5,400 mabé pearls generated an NPV of \$491,864. The MIRR and benefit-cost ratio of the modelled mabé pearl farm were 22.64% and 7.24, respectively, with a payback period of 3 years. Incorporating production and price risk into the model reduced the expected NPV of the mabé pearl farm to \$297,507. The models developed provide valuable new information for prospective pearl oyster spat and mabé pearl farming community groups, donors, funding bodies and other stakeholders, and provide a valuable extension tool supporting further development of the pearl sector in Fiji and the broader Indo-Pacific region.

- Johnston, W., Kishore, P., Vuibega, G.B., Hine, D., Southgate, P.C. 2020. Economic assessment of community-based pearl oyster spat collection and mabé pearl production in the western Pacific. *Aquaculture* 514, 734505.



Category	Quantity
Longline number/length	2/100 m
Total number of chaplets	306
Chaplets with implanted oysters/oysters per chaplet	200/10
Chaplets with pre-implant oysters/oysters per chaplet	106/20
Production length after implant (months)	12
Nuclei per oyster	3
Annual oyster harvest	2000
Number of saleable pearls produced annually	5400

Commercial spat collectors used for community-based spat collection in Fiji (left) and farm husbandry and production parameters for mabé pearl production using *Pteria penguin* (right).

8 Impacts

8.1 Scientific impacts – now and in 5 years

Project research had the following major impacts on scientific knowledge and practice:

- Improved knowledge of all aspects of pearl oyster and mabé pearl culture methodology resulted in improved yields (e.g., spat collected, oysters reared to pearl production size, oyster survival and improved mabé pearl yield) and production value.
- Government agencies in partner countries are now familiar with effective and improved culture methodology underpinned by economic assessment, as a basis for their management of sustainable sector development and extension. Extension and training activities are supported by project produced manuals and other knowledge products.
- Numerous peer-reviewed publications (section 9.2) on many aspects relating to the development and sustainability of the pearl livelihoods sector (e.g., technical, economics) as well as training materials, have added significantly to relevant scientific knowledge of this field. This information will be the foundation for future studies by researchers and students in partner countries and within the region.

8.1.1 Students

Regional scientific impacts included students from the University of the South Pacific who completed research projects

Sankar, Kristina. 2018. Abundance, best immersion time and influence of depth on *Pinctada margaritifera* (Linnaeus, 1758) and *Pteria Penguin* (Roding, 1798) spat in North-Eastern Viti Levu, Fiji. University of the South Pacific. pp 32.

Carreon, John Adams Gasaga. 2019. Growth comparison study of black-lip pearl oysters, *Pinctada margaritifera* (Linnaeus, 1758) at different depths in Savusavu Bay, Fiji Islands. University of the South Pacific. pp 39.

Erasito, Charlene Patrina. 2021. Optimizing spat collection strategies and culture methods of naturally produced black-lip pearl oysters, *Pinctada margaritifera* (Linnaeus, 1758), for local communities in Fiji. University of the South Pacific. pp. 40.

Finaulahi, Liliani Elizabeth Hughes. 2021. Optimising the nursery culture of the winged oyster, *Pteria penguin*, for mabe pearl production in Tonga. University of South Pacific. pp. 70.

Five years from now, the scientific impacts and novel research outcomes from this project will continue to underpin expansion and innovation in the pearl livelihoods sector. Development and standardisation of culture methods provides a sound basis for further sustainable expansion of the sector, which is strengthened by detailed economic assessment of key components of the value chain, showing not only economic viability, but compatibility of these activities with other livelihood activities. Given this, the next 5 years will likely see further expansion of the sector in partner countries, with a high likelihood of the uptake such activities in other countries within the region, not involved with this project.

8.2 Capacity impacts – now and in 5 years

The broad capacity impacts of this project include:

- Significant institutional capacity has been built within major partner agencies relating to pearl oyster propagation and husbandry, mabé pearl production, training and extension, research and field-work planning and execution, and community/stakeholder engagement.

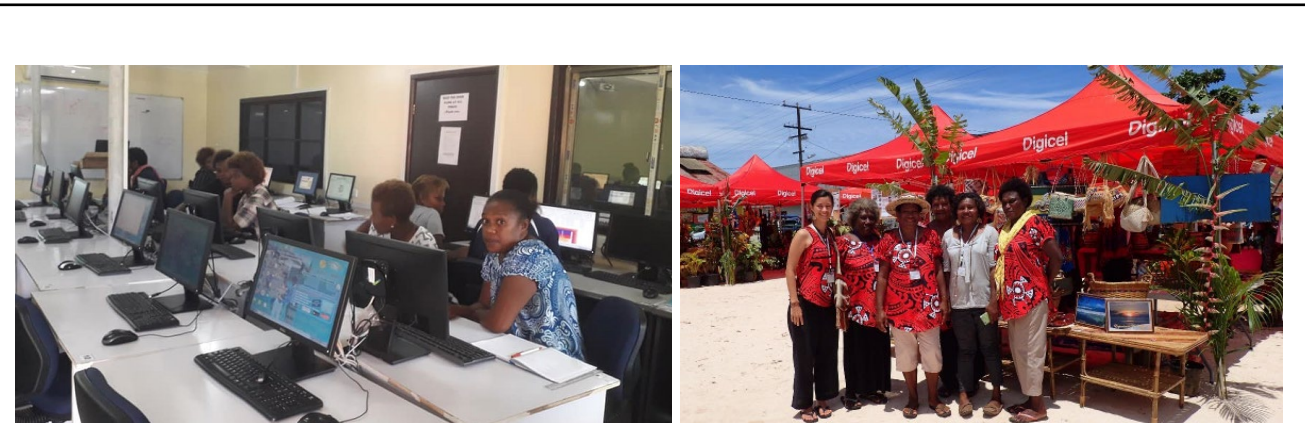
- Government agencies in partner countries are now familiar with effective and improved culture methodology underpinned by economic assessment, as a basis for their management of sustainable sector development, extension and training.
- The capacity of partner communities to engage with one or more components of the pearl livelihoods sector, and generate income from it, has been developed during the project. Community and individual farmer/artisan training in technical, commercial and governance aspects during the project have substantially improved current and future capacity within the sector in all partner countries.
- Involvement of students from the region in project research improve regional capacity within the sector and provides a foundation for future studies by researchers and students in partner countries and within the region.
- The project generated new insights to consumer preference, products of interest, product attributes of importance, and appropriate pricing for mabé pearl and pearl shell handicrafts targeting domestic tourist markets. This information supports better informed product development and handicraft skills training, and improves artisan ability to maximise import replacement and local economic benefits.
- Extensive training and mentoring of artisans in all partner countries improved technical, artistic, business and marketing skills and competencies of both new and established pearl and shell artisans.
- The project supported establishment and/or further development of organisations associated with the pearl livelihoods sector in all partner countries. In Fiji, an inception workshop was initiated, in partnership with Fiji Fisheries, for all community spat and mabé pearl farms as a networking event, as a basis for regular future meetings. In Tonga, project staff and partner organisations have worked closely the Tonga National Pearl Farmers Association (TNPFA) to advance commercial and business skills, and to improve the TNPFA's constitution, administrative structure and governance. In PNG, the Project supported the formation of the New Ireland Arts & Crafts Association (NIACA) as the first body in New Ireland Province to formally represent artisans, which has resulted in improved communication between private-sector, government, and artisans, in addition to better enabling the Project to disseminate research outputs to key stakeholders. Partner agency linkages resulting from formation of the NIACA have included extension of Provincial and donor-organisation training programs to artisans via NIACA. For example, six artisans nominated by the Project participated in a 3-day business management and computer skills workshop delivered by the Provincial Government through the International Training Institute. Additionally, the Women's Entrepreneur Network (local NGO) has collaborated with NIACA and Project staff to deliver SME registration, taxation, and networking workshops to interested artisans.
- The project has also constructed or contributed to infrastructure that is vital for training, production and/or sales of pearl shell or mabé pearl handicrafts or shellcraft, now and into the future. In Tonga for example, in partnership with Tonga Fisheries, the project established the Vava'u Pearl Centre (VPC), which is a hub for training, and handicraft production, the main retail outlet for pearl products and a museum/heritage display for visitors. In Fiji, modern, fully equipped production workshops were established in Ba (Viti Levu) and Somosomo (Taveuni) to support training activities and handicraft production. In PNG, NIACA secured 30,000 PGK in funding from the provincial government for construction of a dedicated craft market in Kavieng, while the Town Council supported this initiative by erecting a temporary craft market until construction is completed. These developments will provide new market opportunities for artisans and increase the local profile of shell-handicraft. Additionally, Construction of a dedicated shellcraft centre at the NIMRF greatly improved NFA's capacity to support shellcraft livelihoods in New Ireland by providing opportunity to deliver regular training workshops. During the life of this project, 116 artisans received training at the centre, including members of the Panakondo Artisan Co-Operative Ltd., Ward 2 Women Association, Ward 2 Disabled Community, the Ornamental Horticulture Women's Group and staff from OLSH International School.
- Where formal workshop facilities were unavailable, handicraft skills training using hand tools, along with basic business literacy training, were extended to selected

communities. In PNG, 59 artisans from Neitab, Tunnung, Kung, Meterankasing, and Tabut communities, as well as artisans at Raviravi and Ravita in Vanua Levu, Fiji, received such training.

Five years from now, new capacity generated by this project within partner agencies, pearl farmers and artisans and their associations and related support groups and agencies will continue to underpin expansion of this livelihood sector in all partner countries.



The temporary craft market erected along the waterfront in Kavieng provided a dedicated location for artisans to sell products, better connecting artisans with potential customers. Insert shows NIACA committee member Hon. Sikal Kelep (Kavieng Town Mayor) speaking with Project-trained artisans at one of the NIACA craft exhibitions.



Artisans participating in business management and computer skills training delivered by the Provincial Government through the International Training Institute (left). NIACA committee members responsible for organising the first Kavieng craft exhibition (right).



Nitty Simard conducting community-based shellcraft skills training at Tunnung Island (left) and at the NIMRF shellcraft centre (right).

8.3 Community impacts – now and in 5 years

Fiji: Seven of the eight mabé pearl farms established during this project are operated by women's groups. The revenue generated benefits community infrastructure and community functions, may be used for church contributions, with some often reinvested into the pearl farming operation through purchase of equipment and consumables. The women's group at Raviravi (Vanua Levu) is the most advanced of the mabé communities in Fiji. When Fiji's Prime Minister visited them to hand over a cheque for sales of their mabé pearls, he noticed the dire need of the village to have a good road access and a seawall to protect the village from rising seawater level. Within a month of the Prime Minister's visit, the more than 5 km access road to the village was upgraded and a seawall of approximately 150 m in length was constructed. Seeing the success of the project and progress made by the Raviravi Women's Group, the Ministry of Fisheries has also constructed a handicraft centre for them where local artisans can conveniently carry out handicraft production and display their products for sales. Members of the Ravita community on the other hand have saved a portion of the money generated from the sales of spat and mabé pearls for construction of a village hall. For other community groups, revenue from spat and mabé pearl sales is mainly saved in registered group bank accounts, to be used as needs arise.

Tonga: Project outputs have broadened community impacts through increased community participation (now including communities from all 3 major island groups) and inclusion of priority groups (i.e., women, youth and remote communities) along the pearl industry value chain (e.g., increase in the number of women pearl farmers and artisans). Improved collaboration between community stakeholders within and across island groups (e.g., pearl farmers from Ha'apai connecting with skilled youth artisans in Vava'u to produce high quality pearl jewellery for sale) has also provided positive community impacts. These are important outcomes that provide a basis for future development and expansion of the Tongan pearl sector. Sales of pearls and handicraft products have benefited farmers and artisans in many ways and examples include:

- A single mother of five children can support her family and opened her first bank account.
- A young man in his 20's made enough money to pay for his two sister's school education.
- A 72 year-old farmer is able to support his extended family and contribute to his community.

- A pearl farmer with a disability can support his whole family and will pass the farm down to his children.
- A women farmer/artisan was able to buy a boat for her pearl farm operations.

Papua New Guinea: More than two-thirds (68.4%) of artisans engaged in pearl and mother-of-pearl handicraft production perceived a community benefit resulting from their and other's participation in this livelihood activity. Community benefits were primarily related to the economic aspects of this activity (70.6%), including job creation and income for community infrastructure, contributions to church, supporting other members of the community, and contributions to customary activities (e.g., mortuary feasts). Non-monetary benefits to the community (29.4% of listed benefits) were seen as a greater social engagement of the community. While no artisan identified detriments of this livelihood activity on their community at the time of interview (2017), the increased cash flows accompanying later sector expansion resulted in NIACA raising concern regarding financial mismanagement which could undermine provincial health initiatives (such as increased expenditure on tobacco, alcohol, and betelnut). The Project addressed these concerns through linkages with ASEM/2014/095⁷ to deliver the family livelihood wellness modules to artisans.

Family benefits were perceived by 89.5% of artisans, which were also primarily related to income generation (94.9% of listed benefits). This included income for living necessities, extra money for non-essentials, and paying for medical expenses. Non-monetary benefits were associated with participation in a culturally important, skilled occupation. No artisan identified detriments of this livelihood to their family and all artisans were optimistic about future income from shellcraft with 89.5% of artisans willing to encourage other artisans to participate in this livelihood activity.

How artisans in Papua New Guinea perceive pearl and mother-of-pearl handicrafts benefiting their community and families (Simard et al., 2019).

Community benefits	Percentage of artisans	Family benefits	Percentage of artisans
Improvement of community infrastructure	21.0	Purchase of food and clothing	81.6
Increased social engagement of community	18.4	Paying for children's school fees	31.6
Financial contribution to church	15.8	Paying for housing improvement	28.9
Job creation	10.5	Having a skilled occupation	10.5
Financial support for others	10.5	Extra money for non-essentials	7.9
Financial contribution to community activities	5.3	Paying for medical expenses	2.6
Uncertain	31.6	Uncertain	10.5

The influx of new entrants to the pearl and mother-of-pearl handicraft sector during the Project (175 artisans who received training) foreshadows challenges in maintaining resource availability over the next 5 years. In many cases, an influx of new entrants into resource-dependent occupations reduces individual income as available resources are further divided. In-country aquaculture production of pearl-oyster as a source of raw-material for shellcraft would greatly improve livelihood security, as artisans are currently reliant on artisanal fisheries for supply of shell. The development of community-based aquaculture for pearl oysters based on spat collection as developed in Fiji during this project, should be a goal for future development of this sector in PNG (Simard et al., 2019).

8.3.1 Economic impacts

Tonga: Pearl production in Tonga has benefitted from the cumulative outputs of this, prior, and complimentary ACIAR projects that have supported successful pearl sector development. Pearl production, for example, increased from around 3,700 to around 4,680 (a 73% increase), over a three-year period within this project, with a corresponding increase in production value from around

⁷ ASEM/2014/095 "Improving opportunities for economic development for women smallholders in rural Papua New Guinea"

\$260,000 to \$732,000 per annum (182% increase). The number of people engaged in pearling activities increased more than five-fold since 2013, with 43% of those engaged being women. An expert projection of potential pearl industry value in Tonga, based on its current trajectory, suggests that pearling could become one of Tonga's most significant export industries.

Cost-benefit analysis of mabé pearl production in Tonga has shown that annual pearl production from only 100 oysters can generate an income of around USD 9,338 (more than twice the average annual income) and required less than 10 hours input (labour) per week ensuring compatibility with other subsistence activities (Johnston et al., 2020b). This analysis is based solely on pearl production and there will be substantial additional benefits derived from the post-harvest value adding by artisans, which is yet to be modelled.

Tonga's mabé pearl farmers and artisans secured a valuable contract for online product sales in Hawaii following a COVID19 impacts marketing workshop, run by the Ministry of Fisheries, Tonga and World Bank in late 2020. A quarterly five-year mabé pearl product sales contract was signed in February 2021 with Jewels of Polynesia (<https://jewelsofpolynesia.com/>), for regular export of value-added mabé pearl pieces.

Fiji: Financial literacy training provided to the members of Raviravi Women's Group has enabled them to establish the group as an independent business. The members are now well trained to manage their finances and can pay themselves for working on their spat and mabé pearl farms. In addition, Raviravi Women's Group now also employs the men of the village to carry out heavy works such as spat collector and mainline deployments when needed. To be able to generate economic activity and provide employment to local coastal communities where employment opportunities are normally scarce is a significant achievement of the project. Following the success achieved by the Raviravi Women's Group, other groups in Fiji are keen to follow their footsteps and are not far behind. The fact that spat collection and mabé pearl culture can generate significant income and help alleviate poverty in remote coastal communities has led the Ministry of Fisheries to strengthen support for expansion of these activities to other communities, for which there is considerable demand. Management of such expansion in a sustainable manner will be a key requirement of future sector development.

Economic modelling of a Fijian spat farm with four 100 m spat collector lines estimated recruitment of 2,332 saleable *P. margaritifera* spat, generating USD2,648 in gross revenue with an estimated capital cost of USD1,245. It had a cost-benefit ratio of 1.52, and a payback period of 4 years. A Fijian mabé pearl farm modelled with two 100 m longlines having 2,000 *Pt. penguin* oysters was estimated to produce 5,400 pearls, generating a gross revenue of USD49,754. It had a cost-benefit ratio of 7.24 and a payback period of 3 years. These are very healthy economic projections that would benefit further from value adding and production of mabé pearl and pearl shell handicrafts.

Papua New Guinea: Better organisation of the shellcraft sector under the NIACA had a positive economic impact on member artisans. Initiated by the Project, the NIACA is now responsible for organising and hosting the biannual craft exhibitions in Kavieng held in association with the Easter and Christmas holidays. These events showcase products developed by the Project to the public and offer market opportunities to artisans. Donor organisations, NGOs (e.g., WCS), government agencies (e.g., NFA, IPA), and service providers (e.g., Bank of South Pacific) have opportunity (and are encouraged) to participate in these events to help artisans access information of relevance to their livelihoods. The Project has assisted the NIACA in producing reports which document the impact of these events. Between 2018 and 2020, four exhibitions were held which generated a total revenue of 45,830 PGK (~17,000 AUD) in product sales. The success and popularity of these events are likely to grow once COVID-19 related restrictions ease.



Artisans participating in the first NIACA craft exhibition held in Kavieng in 2018.

With sales through the craft exhibitions, retail partners, and other markets, weekly income from shellcraft sales averaged 146 PGK for artisans. This equates to a 5% increase from 2017 which, in combination with the 29 % increase in participation, led to 28 % increase in the value of the New Ireland shellcraft sector (valued at 379,500 PGK in 2019). The increased cash flow resulting from handicraft sales led to a 25% increase in the number of artisan households with a bank account and a similar increase in the number of artisans reporting shellcraft income was important in meeting education expenses for their children.

“Shell-based handicraft was a primary or supplementary income source for 6% of the region’s population, and the weekly income of artisan households exceeded the regional average by an additional 78%.” Simard et al. (2019)

8.3.2 Social impacts

Fiji

Spat collection and mabé pearl farming have brought a sense of confidence in the women and youth groups involved. The members of the groups are now able to make independent decisions regarding development of their pearling businesses and have their voices heard in important consultations during village meetings. The business model established by the Raviravi Women’s Group has encouraged individual families in the village to follow similar models to better manage their own finances, assisting with their management of daily expenses and compulsory savings. There has also been a major change in the behavior of the husbands towards their wives involved in the pearl livelihoods sector. When the project first started, the husbands of some women disapproved of their involvement in project training activities. However, this changed over time as the benefits from their involvement became clearer. In addition, women involved in the pearl livelihoods activities have gained respect from their husbands by proving what they can achieve if afforded novel opportunities in the pearl livelihoods sector. The project has also motivated school children in the communities involved, some of which now want to take up marine related courses at university.

The socio-economic impacts of pearl-based livelihood development addressed in this project in Fiji and Tonga were investigated and documented in a dedicated ACIAR Small research and development activity (FIS/2018/129 “Monitoring and evaluation of socio-economic impacts of pearl-based livelihood development”) as detailed below.

Tonga

Pearl farming has provided opportunities for Tongan island communities to be involved in enterprises that fit well with their remote location, their culture, and may produce additional income, with minimal labour input, allowing participants to continue to engage in their other livelihood activities.

Pearl farming is highly compatible with Tonga's major Special Management Area (SMA) initiative and in recognition of this, the governing legislation has made provision to allow pearl farming activities (with the appropriate community support) within all SMAs. This is essential for the future of pearl farming in Tonga, as there are currently more than 70 SMAs issued, representing more than half of Tonga's coastal communities, and the program aims to include all coastal communities by 2025. Almost all of Tonga's coastline will then be held within SMAs.

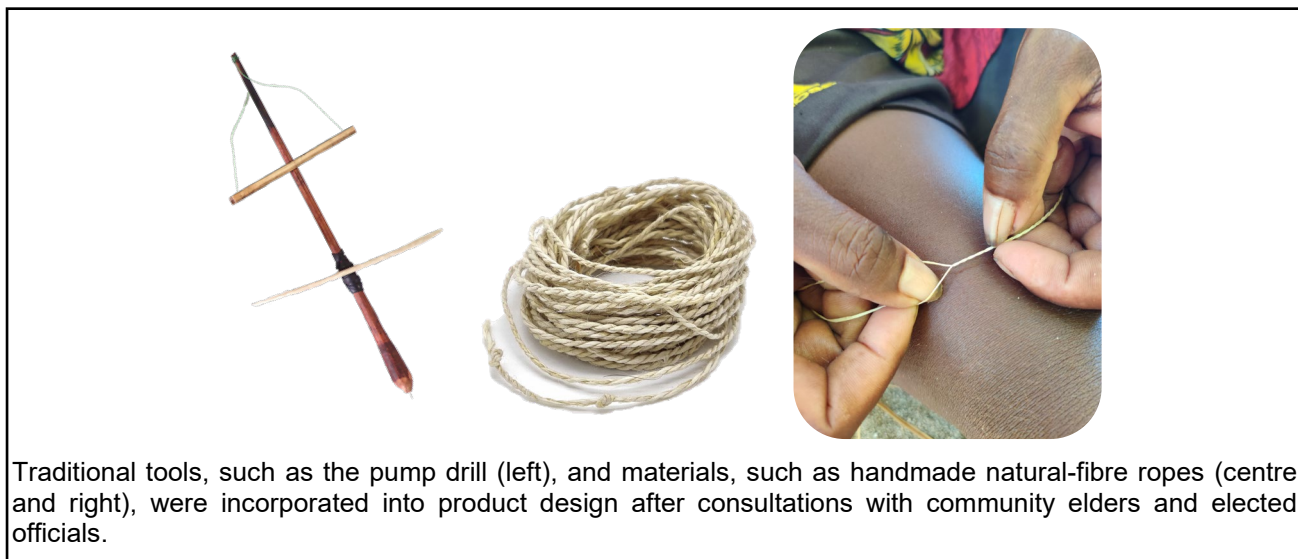
Additional social benefits include: provision of employment opportunities for women and youth in communities with high unemployment; engendering a feeling of increased self-worth and empowerment within the women members as a result of learning new skills; and contributing financially to the wider community, yet still being able to meet their normal daily community and family commitments.

Papua New Guinea

In New Ireland, participation in shellcraft-based livelihoods for income generation increased by 28.8% between 2017 and 2019, with 52 households (representing 225 dependents) now engaged in production and sale. Participation of women and girls has also increased, with 90% of households identifying a female member of the family as the primary artisan. The increased agency afforded by a weekly income which exceeds the regional average by an additional 78% has facilitated further social change associated with improved housing. For example, artisans reported that transitioning from a bush house to an elevated timber house had afforded their families greater security against theft and violence.



Several artisans also expressed satisfaction in Project training because it afforded them an opportunity to participate in a culturally important, skilled occupation. This benefit has been amplified through a culturally-sensitive approach to product development which involved panel discussions with community elders, key informant interviews, and consultation of the literature on New Ireland ethnography to incorporate the use of traditional techniques, tools, and artistic design. This approach helps preserve cultural heritage within communities and reduces the reliance on imported tools and materials for shellcraft production, maximising the local accrual of economic benefit from product sales. Examples include replacement of modern drills with the *galgal* (pump drill) and replacement of synthetic rope in macramé designs with *kinolong* (hand-made natural fibre rope).



8.3.3 Independent assessment of socio-economic impacts

Mikhailovich et al. (2023) assessed the socio-economic benefits to individuals and groups engaged in mabé pearl culture and handicraft production in Tonga and Fiji, through this project, and considered how these benefits contribute towards women’s empowerment. They reported that “women and men can earn supplementary incomes that are important for supporting diverse rural livelihoods in a manner that is culturally compatible and rewarding” and that “*social and cultural aspects of these initiatives enabled many women to think differently about themselves, their capabilities, and their aspirations for the future*”. They also reported that involvement in the sector contributes to a range of socio-economic and cultural benefits including acquisition of new and specialised skills, enabling diversification of livelihood opportunities for individuals, families, and communities. They found that development of a unique handicraft sector contributes cultural products, which have cultural value within gift and exchange economies as well as economic value. Although the processes by which women experience and move along pathways towards empowerment varies between individuals and between cultural contexts, engagement in pearl-based enterprises has, *for many women, improved their confidence and capacity to earn income independent of their families and enhanced their standing in families and the community* (Mikhailovich et al., 2023).

“Before I felt like a failure. But now, I feel like I can fly.”
(the words of Ms. Nuaa Lakai, mabé pearl farmer and artisan, Vava’u, Tonga)

8.3.4 Environmental impacts

Pearl culture is an environmentally benign form of aquaculture. It is a form of suspended culture which minimises benthic impacts and it is usually conducted away from coral reefs to minimise predation of farmed oysters. Pearl farming often has positive environmental impacts including: (1) pearl oyster culture equipment may act as fish aggregating devices and can result in increased local availability of food fish; (2) cultured pearl oysters breed and contribute to local stock; (3) cultured pearl oysters are able to remediate turbid waters and remove harmful materials as a result of filter-feeding activity (O’Connor and Gifford, 2008); and (4) routine hatchery production of culture stock for pearl farmers does not deplete wild stocks and is likely to reduce collecting pressure on local wild oysters.

Fiji: The project has enabled community members to develop better stewardship towards their marine resources after realising potential benefits. Spat collectors attract a wide range of marine organisms which adds diversity to the ecosystem created. There is also a complete halt to the harvest of adult oyster harvest from the wild which, overtime, could have resulted in stock depletion. Mabe pearl production is entirely based on spat collection from the wild.

Tonga: has achieved success over recent years in delivering its fisheries sustainability objectives through engaging with coastal communities and villages to establish Special Management Areas (SMAs). The community gains exclusive use of the fisheries resources in the SMA and are responsible for managing, monitoring and enforcing the SMA. Most SMAs comprise large areas as marine reserves where fishing is prohibited. Pearl farming is a particularly attractive proposition for communities that manage SMAs because it provides sustainable income and livelihood opportunities without negatively impacting other activities, and without depleting SMA resources. Because of this, most recent pearl farms in Tonga have been established within SMAs and have been developed as community-based ventures with obvious benefits relating to security, governance and community engagement.

Papua New Guinea: Project research has raised concerns of potential resource access limitation due to the expanding shellcraft sector in PNG (Simard et al., 2019). Perceptions held by many artisans that the pearl-oysters and other shells used in shellcraft have declined in abundance suggests possible environmental impacts. The pearl oysters *Pinctada margaritifera* and *Pteria penguin* are among the most important shells supporting shellcraft in New Ireland, but neither species is currently farmed in PNG. This requires artisans to rely on wild harvests of these species from artisanal fisheries. More than half the fishers harvesting these species have perceived population declines, and more than half the artisans purchasing these species at markets is due to absent or declining stocks within their community's marine tenure. The introduction of community-based production of pearl-oysters through spat-collection is being proposed as an activity to address these concerns.

8.4 Communication and dissemination activities

The primary means of disseminating project findings were via publication in scientific journals (section 9.2) and social media (Appendix 1).

In all partner countries regular communication between project personnel and partner agencies and communities was ensured by the presence of country-based project staff. Clear and frequent communication between project stakeholders was facilitated by regular visits to partner countries by the Australian Project Leader. Towards the end of the project the COVID pandemic forced project scientists based in PNG and Tonga back to Australia and regular on-line meetings became an important mode of communication between project partners. This was less impacted in Fiji where the project scientist was a Fiji-based national.

The project constructed a range of dissemination, training and extension materials to support project training activities (e.g., technical/training workshops); these include culture manuals for all stages of pearl oyster capture and culture, pearl production, construction of culture units and their maintenance, mabe pearl production, grading and valuation, handicraft production and sales. In Fiji and Tonga, the project assisted with design and production of educational materials (e.g., posters, information leaflets) and point-of-sale information/materials and billboards in partner communities.

Fiji's Prime Minister, Hon. Frank Bainimarama, pictured at the billboard unveiling of the Navatadua Women's Group (Raviravi), along with members of the Women's Group (left); the Viani Youth Group pose with their billboard (right)



Fiji: Mabé pearl and pearl shell handicrafts made by the Marama Shellcraft Fiji (MSF) in Ba, were featured at major tourist retail outlets (Tapoo and Jacks) in Nadi town and at Nadi Airport.

The women of Marama Shellcraft Fiji (MSF) inspect displays of their products at a major retail outlet in Nadi (Tappoo).



Products from MSF were showcased Sydney's SHAPIRO'S Gallery at the sixth annual Maketi Ples promoting Pacific Island based artists and artisans and supported by Pacific Trade & Invest (PT&I), Australia. The event featured representation from nine Pacific Island nations including; Fiji, Niue, Papua New Guinea, Republic of Marshall Islands, Samoa, Solomon Islands, Tonga, Vanuatu and Yap. It was the first time Fiji mabé pearl products from MSF were presented outside of Fiji, which created strong interest.

Marama Shellcraft Fiji display at the Maketi Ples at the Shapiro Gallery, Queen Street, Woolahra, Sydney

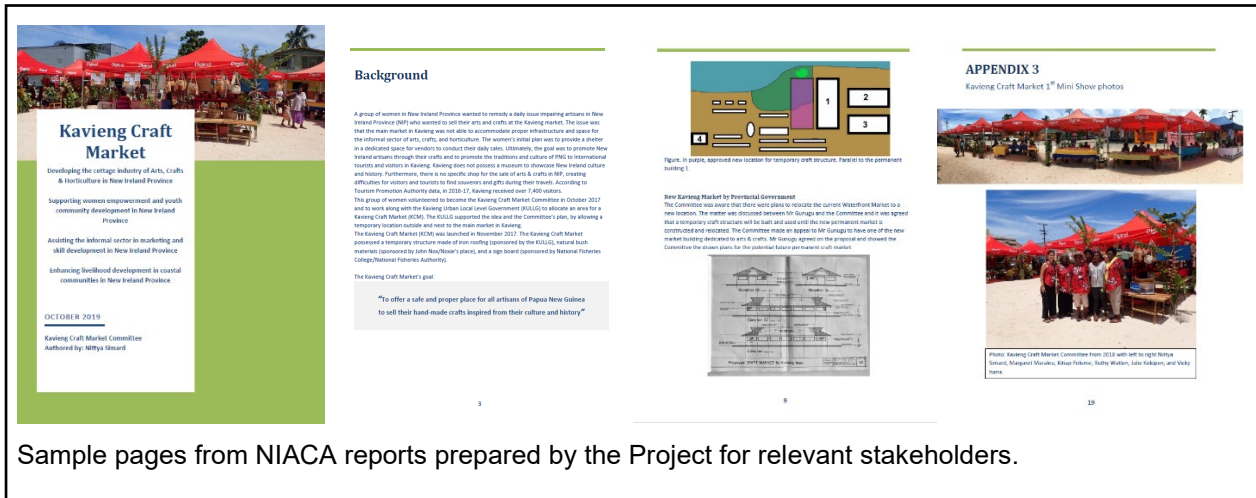


Tonga: The project has supported prizes, exhibits and pearl product design and quality competitions at the annual Royal Agriculture, Fisheries and Tonga Made Show. The event show cases Tongan pearl products and local mabé pearl farmers and artisans. The show celebrates local industry and is a way for local farmers, fishermen and craftsmen to display their wares and trade to the community and their King, before selling their stock to the general public, and travels to all islands groups in Tonga. Prizes are awarded across three categories (pendants, necklaces and jewellery, handicrafts referencing traditional Tongan design and an open category, including mabé shell handicraft). Artisans competed as 'beginner' or 'experienced'.

High quality entries from local mabé pearl artisans in the Tongan Royal Agricultural Show

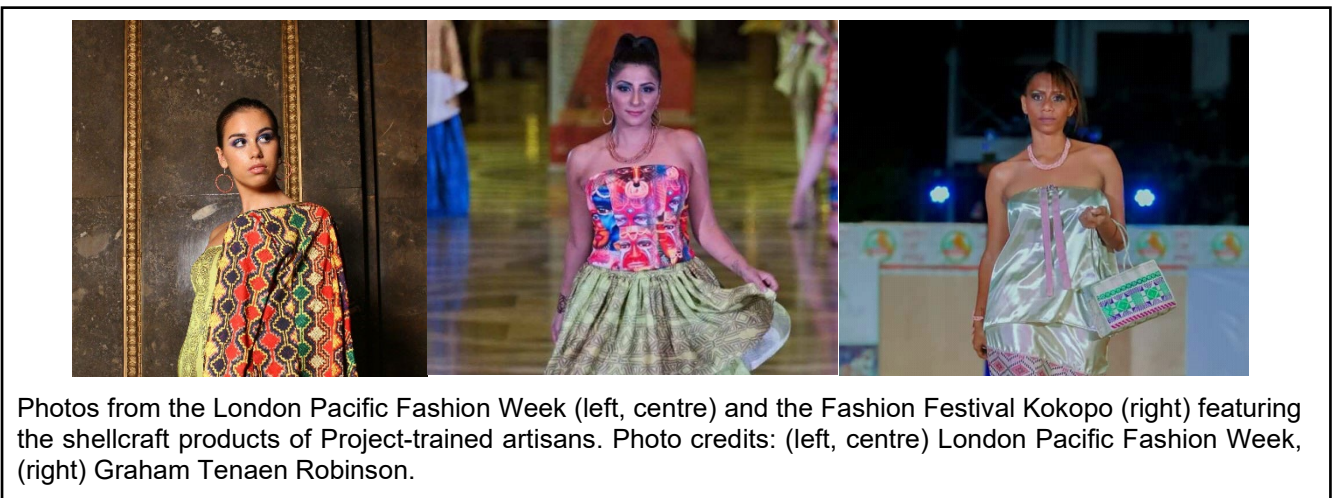


PNG: The Project has assisted the NIACA in preparing a series of reports to document their activities and the impact of their biannual craft exhibitions. These reports are provided to relevant stakeholders and donors who help make NIACA activities possible.



Sample pages from NIACA reports prepared by the Project for relevant stakeholders.

Project-trained artisans have had their products featured in domestic and international fashion shows, raising the profile of Papua New Guinea shellcraft. As part of the London Pacific Fashion Week in 2018, designer Sarah Todd incorporated New Ireland shellcraft in her collection. Similarly, designer Lyniata Anana featured Project shellcraft designs as part of the Dahana Haus Bilas collection at the Fashion Festival Kokopo in 2019.



Photos from the London Pacific Fashion Week (left, centre) and the Fashion Festival Kokopo (right) featuring the shellcraft products of Project-trained artisans. Photo credits: (left, centre) London Pacific Fashion Week, (right) Graham Tenaen Robinson.

Conclusions

This project was successful in demonstrating the potential livelihoods opportunities associated with pearl oyster collection, mabé pearl production and handicraft production based on mabé pearl, pearl shell and mollusc shells more broadly. The three partner countries vary in their engagement with these activities and their approach:

Fiji has considerable opportunity for expansion of both the cultured pearl and mabé pearl sectors because of the ready availability and sustainable supply of spat using technologically simple spat collection methods, appropriate to many coastal communities. Community and farmer familiarisation with the culture infrastructure required for spat collection is an excellent basis for transition to mabé pearl culture at appropriate sites. Demonstration of production of high quality mabé pearl and pearl shell handicrafts by two previously unskilled women's group during this project, as well as successful uptake of business operation skills, indicates a bright future for this activity in Fiji, particularly considering the high value of this sector within the domestic tourism market, estimated at around \$8.5 M per annum (ACIAR, PARDI).

Wild spat collection is not an option for mabé pearl farmers in Tonga who rely on government supplied hatchery produced spat, which is a potential bottleneck for future expansion of the sector. Recent reports of oyster recruitment in Vava'u possibly result from the currently high level of cultured oyster stock held on mabé pearl farms in Vava'u. This requires investigation as another potential source of oysters for Tongan pearl farmers. There is a strong artisan history in Tonga and this is demonstrated by the high quality mabé pearl and pearl shell products. Currently, artisans sell primarily into domestic markets such as cruise ship tourists and local Tongans, with some sales targeting Tongan diaspora in New Zealand, Australian, the US and elsewhere. Opportunity for limited but regular export of Tongan mabé to Hawaii has been demonstrated with good feedback. Future research should focus on sustainable expansion of mabé pearl farming that perhaps restricts farm numbers or farm size, appropriate governance mechanisms to accommodate pearl farming within SMA's, investigation of markets and market access and, should regular export markets be targeted in future, development of a quality control mechanisms and the potential for branding.

Consumer surveys and market diagnostics indicate sales of mabé pearl and MoP handicrafts in PNG are limited by supply, not demand. With community-based shellcraft presently reliant on capture fisheries and project research raising concerns of potential resource access limitation there is need to increase local production of mabé pearls and MoP shell if the full-benefit of pearl and shell-based livelihoods is to be realised. Future research should focus on establishing community-based culture of pearl oysters and mabé pearl production. As a priority, the feasibility of adapting the technologies developed in Fiji and Tonga during this project for implementation in PNG should be explored. This would require fine tuning existing methods for the different sociocultural systems and marine environments of PNG. Both New Ireland and Milne Bay are seen as priority areas for this development, given the existence of skilled artisans (many trained in this project) and established tourism markets.

8.5 Concluding statement

The findings of the project provide a very strong basis for continued development of the 'pearl livelihoods' sector in partner countries. The models developed in Fiji, Tonga and PNG are economically viable, sustainable, compatible with community life-styles and have regional application. This project was externally reviewed in 2020. The review recommended further investment in the sector by ACIAR and a new project was developed (see section 8.6).

9 Recommendations

Based on Review recommendations, a follow-on project was developed (FIS/2019/122: “Towards more profitable and sustainable mabé pearl and shell-based livelihoods in the western Pacific”) supporting further development of the pearl livelihoods sectors on Fiji, Tonga, Papua New Guinea and Samoa. The project aim is to improve and expand production and sales, develop improved business structures and opportunities, and to strengthen governance frameworks and markets for the artisanal mabé pearl and pearl shell handicraft sectors in the Pacific. The objectives of FIS/2019/122 are to:

- Improve market knowledge and market access;
- Develop production best practice (Fiji and Tonga);
- Further develop the mabé pearl and shellcraft sectors in Papua New Guinea;
- Support transition to self-sustaining small businesses; and
- Improve in-country capacity supporting sustainable sector development.

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11 Appendixes

11.1 Appendix 1: USC Tropical Aquaculture Research project Facebook posts