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Increased effectiveness of mariculture hatchery systems in the Pacific

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Summary

1. Mariculture hatcheries in the Pacific, produce at least the following commodities: giant clams, shrimp/prawns, pearl oysters, sea cucumbers, marine finfish, and some propagation of seaweeds.

2. Mariculture hatchery technology has been developed since the 1970s. The larval mariculture of marine animals requires, the maintenance of broodstock, the production of live feed (microalgae, rotifers, copepods and *Artemia* are all used) for the larval culture in filtered seawater, until the settlement of larvae in the case of bivalves and holothurians or the weaning onto feed pellets for finfish and shrimp.

3. The operation of mariculture hatcheries requires expertise in biological management, aquaculture engineering and biosecurity, but also personnel and financial management. In the Pacific, marine hatchery operations must also manage risks to production exacerbated by supply chain issues and the impacts of tropical climates on their infrastructure.

4. While general production methods are established, management of mariculture hatcheries involves the writing of standard operating procedures (SOPs), specific for each site. Financial management includes Production Planning to quantify a hatchery's biological assets and a determination of a unit cost of production, so that a price for seedstock produced can be established to ensure their sustainability.

Mariculture

Mariculture development

5. Mariculture (saltwater and brackish water aquaculture) is a more recent development than freshwater aquaculture, but mariculture accounts for around 50% of world aquaculture production, for both plants (seaweed) and animals. Freshwater aquaculture may be up to 90% of animal aquaculture production.

6. 'Capture based mariculture', collecting and on-growing juveniles from a fishery, has had a longer development history than 'full cycle mariculture', where the whole of the cultured plant or animal's life cycle is part of managed production. Capture based mariculture has a long history in the Pacific Island countries and territories (PICTs), with the holding of wild caught marine finfish and invertebrates in coastal ponds or marine areas close to habitation, for food security in times of rough weather and storms, a traditional practice in many countries.

7. Full cycle mariculture allows an effective development of genetic improvement (domestication), a major advantage of controlling the full life cycle of the species. The selection and maintenance of broodstock in contained aquaculture systems, and the graded (mass selected) rearing of their offspring, can improve the efficiency of mariculture production systems rapidly.

8. Marine farming systems for mariculture include structures such a sea cages, floating and submerged longlines, bottom cages and sea ranching (the release of cultured stock into ecosystems with minimal marine farm constructions). Marine farms may be established from both capture based and full cycle aquaculture.

9. Land-based systems for mariculture include coastal and saline ponds, flow-through and/or recirculating aquaculture systems (RAS) with tanks. Land-based mariculture systems are primarily established for full cycle mariculture and mariculture hatcheries are almost exclusively land-based.

10. Land-based flow-through systems pump or inlet seawater, pass it though the cultured species and then discharge it, while RAS recirculates most of the inlet water by mechanically filtering and biologically treating it, so its quality is suitable for reuse. RAS systems allow for the most efficient control of environmental conditions, principally temperature and nitrogen levels. This allows for an intensification of investment and stocking densities, to increase production from the same space or volume.

Marine hatcheries

11. Marine hatcheries are land-based mariculture systems, principally flow through systems. There are difficulties using RAS, mechanical filtration applied to water containing microscopic larvae with live food is difficult, and optimal water quality can be more difficult to achieve, marine larvae are particularly susceptible to any change from optimal.

12. Marine hatcheries may have the following operational components:

- Broodstock quarantine and maintenance with gamete collection
- Live feed production
- Larval rearing
- Settlement (of shellfish) or weaning (first feeding of shrimp and finfish)
- Juvenile ongrowing in land-based nurseries
- Size grading

13. Marine hatcheries can be ‘small scale’ with a lower capital investment and no vertical integration, selling seedstock into a wider industry, such as many milkfish hatcheries in southeast Asia, or they can be larger scaled capital investments, vertically integrated into a business that may also have marine farm/s and processing facilities such as some barramundi hatcheries in Australia.

Mariculture hatcheries in the Pacific Island countries and territories

Mariculture species produced by hatcheries in the PICTs

14. The following groups are produced by marine hatcheries in the PICTs:

- Giant clams
- Shrimp or prawns
- Pearl oysters
- Sea cucumbers
- Marine finfish
- Trochus

15. These groups generally also require the production of live feed (a progression of microalgae, rotifers, copepods and *Artemia*, depending on the group) or the use of preserved feed. The use of preserved microalgae feed (microalgae pastes or freeze-dried powder) has been shown to reduce productivity from that obtained from live feed, although its utility in isolated areas unable to establish live food production facilities is improving.

16. Seaweed propagation to produce seaweed seedstock is also undertaken in land-based mariculture facilities, with a smaller number of operational components.

17. 'Mini' or very small-scale hatchery development is only reasonable currently, for species that have larval cycles amendable to preserved feed or don't require feed. In the PICTs this includes giant clams and sea cucumbers. Mini hatchery development in the PICTs may reduce investment to a level accessible by communities, that have traditional marine tenures to develop marine farms in appropriate coastal areas.

Mariculture hatchery management systems

18. Operation of a mariculture hatchery includes the management of the following workflows or systems:

- *Biological management*
  (Water quality, species physical characteristics, behaviour, growth, nutrition, disease susceptibility).
- *Aquaculture engineering*
  (Design standards, quantity surveying, construction methods, mechanical/electrical/plumbing systems (MEP), materials, energy efficiencies, mass balance (inputs = outputs), wastewater treatment).
- *Personnel management*
  (Communication, empowerment and trust, fairness and equity, standard operating procedures, team building, after hours work).
- *Financial management*
  (Budgeting, planning, accounting, production planning, risk management)

19. Biological management has acquired the most research interest, development, and training in the PICTs, while aquaculture engineering, personnel and financial management skillsets can be sourced from other business systems, their availability to mariculture may be inhibited, as these skills are of interest to most public and private sector industry in the Pacific.

Biological management

20. The 'biological imperative' describes the need to respond with management, within the time frame that the biology of the species under culture demands. The biological needs or processes of the species, and the time frame experienced for their deterioration, must be essentially accommodated by mariculture hatcheries operations.

21. Ammonia (NH_3) is excreted by and is a toxic compound for animal mariculture species, particularly ionized ammonium (NH_4^+). It is important to control ammonia levels in marine hatcheries to reduce stress and prevent mortalities, this is done using monitoring and testing, biological filtration (nitrification) and aeration, water exchanges and feed management.

22. Flow through larval culture of bivalves (Figure 1) has replaced the static culture (where larvae are removed, tanks cleaned, new water added and larvae replaced) of marine bivalves commercially and offers advantages of water quality maintenance and higher stocking densities, giving higher productivity from smaller volumes with infrastructure and staffing efficiencies increased. This method may be partly applicable to other groups, particularly at late larval stages.

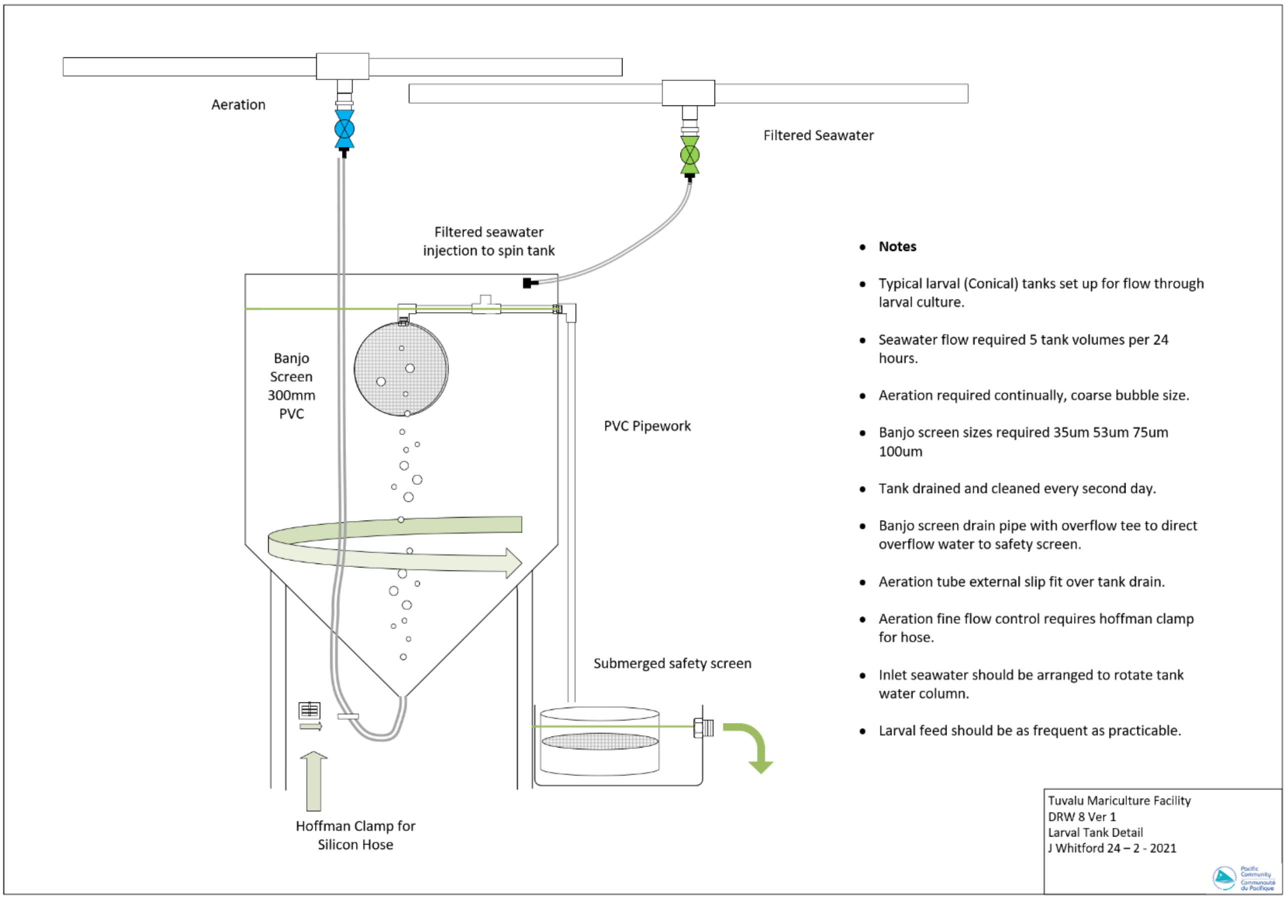

Figure 1 Example of flow through larval culture

23. Ammonia elevation and oxygen depletion, in containers and tanks of marine larvae concentrated during volumetric counting of larval numbers and static larval tank water changes, may severely stress larvae. Arrangements can be made to either reduce the time these tasks take or to flow water through these containers to improve water quality.

24. Live food production is needed for many mariculture species and is both capital and labour intensive, with engineering requirements including, air-conditioning, seawater sterilisation or disinfection, and laboratory equipment. Live feed production in commercial systems now routinely involves the use of industrial control networks (PLC networks) to automate culture densities, inputs, and outputs.

25. Preserved larval diets, principally preserved microalgae, limit productivity and require the adaption of established larval rearing methodologies developed for live food production but circumvent the

capital and operational requirements of live microalgae production. They are also used for the partial enrichment of the other live feeds.

26. 'Continuous culture' of marine microalgae has replaced 'batch' culture in many mariculture hatcheries, and significantly reduces labour input for volume/cells produced. It requires the successful implementation of pasteurisation for incoming seawater and nutrients. Axenic (single species/uncontaminated) culture is harder to maintain, but the magnitude of the production increase from the same space, allows for maintenance of broodstock and extended breeding seasonality and land-based nursery culture. Continuous culture systems (bioreactors) are available 'off the shelf' with automation and can achieve extremely high densities for a small footprint and reduced labour input.

27. The use of copepods as live feed for marine finfish is advancing and their nutritional and size advantages for marine finfish larvae are compelling, although their culture is not yet routine.

28. The novel use of 'plankton pumping' concentrating naturally occurring planktonic live feed into marine farm larval cultures reared in sea cage like structure, moored at a marine site may be applicable to the Pacific and success would significantly reduce the capital and technology required in land-based mariculture hatcheries.

29. Biosecurity and larval culture contamination are difficult risks to manage in mariculture hatcheries in the PICTs. The infestation of larval cultures with copepods and ciliates and other planktonic plants and animals is common, via their intake with larval culture seawater, aerosol contamination in humid conditions and the transfer of contaminants from inappropriately stored equipment (equipment haphazardly stored around hatchery areas are 'fomites', contaminated surfaces that are cumbersome to disinfect in hatchery facilities).

30. The control of people and equipment entering hatchery areas is important to preserve biosecurity. Mariculture hatchery staff are often also working in the sea and can transfer disease and competitive marine plankton, on their clothing and bodies. It is important to providing staffing and facilities to enable the maintenance of a reasonable level of hygiene in marine hatcheries.

Aquaculture engineering

31. Aquaculture engineering is both a significant capital and operational expenditure, alongside staffing and feeding, in both marine farms and land-based mariculture systems. The site, architecture, and engineering design of land-based mariculture systems, strongly influences their cost of operation and productivity.

32. The aquaculture engineering in marine hatcheries is exposed to considerable risk, principally because of saltwater corrosion. In the tropics this risk is exacerbated due to high saltwater temperatures increasing ion mobility and cyclic thermal expansion and contraction, increasing metal stress and crevice corrosion and pitting. The performance of the same equipment in cold seawater, is much better than in the tropics. Saltwater corrosion is difficult to manage without a considerable increase in investment in component materials, such as duplex stainless steel and titanium. Developments in plastic and ceramic manufacturing are improving the economics of the management of saltwater corrosion.

33. General supply chain issues (parts interpretation, communication, and transportation and import barriers) for the PICTs, impact on the operation of marine hatcheries and are of increased importance

due to the extreme corrosive environment, difficulties in obtaining engineering skillsets and the expense of implementing routine maintenance programmes.

34. Aquaculture engineering calculations (or calculators) are required to correctly size pipes and pumps for suitable water and air flows for cultured species and scale, and to maintain water and air quality and to size electrical distribution for electrical equipment. Calculations involving nutrient cycling and balance (N_2 and CO_2 mass balance) are also needed in the case of RAS and waste stream management.

35. Mariculture hatcheries can be subject to rapid environmental changes that are often caused by equipment failure or changes to a seawater intake site water quality. Many commercial aquaculture systems have investments in control networks (programmable logic controller (PLC) and alarm systems to reduce this risk. The decreasing cost of this technology has enabled its implementation at a medium scale of investment, (swimming pools and garden irrigation) that may be applicable to mariculture hatcheries in the Pacific. Establishment of control and monitoring systems can also reduce staffing and transportation and so lower carbon footprints.

36. Maintenance planning is required in marine hatcheries to pre-empt mechanical or electrical failure and to plan for maintenance and replacement of equipment. Maintenance requires additional operation funds to implement, but equipment failure during larval cycles may be a larger cost. Risk and criticality analysis is important to designing a maintenance plan.

Personnel management

37. Marine hatcheries operate under a biological imperative, where the timing and duration of tasks is dictated and constrained by the biological characteristics of the cultured species. Larval development timing and stages, rates of water quality deterioration, etc. may require the transfer of larvae to clean tanks, and the changing of in tank screens that contain larvae, for instance. These tasks must be carried out at times that often encompass weekends, holidays, and periods of personal obligation. Arranging personnel to be available and accessible to respond requires weekend rosters or shiftwork for staff.

38. Honest communication is essential in a marine hatchery, to ensure clarity and understanding of complex information needed to manage biological and engineering systems. Good engagement of both staff and management is necessary to achieve production, feedback and improvement for standard procedures, and adaptation to changes that are encountered. Informed decision making for staff and management, relies on the communication of accurate and timely information.

39. The establishment and use of standard operating procedures (SOPs) allows for the site-specific amalgamation of biological, engineering and personnel information, that encourages a standardisation of decision making, and a replication of effort. While manuals providing culture methods for the species are useful, information needs to be tailored for each site, as there are differences in the interaction of biological, engineering, personnel (and financial) systems.

40. The formation of a team or teams is critical for the successful operation of mariculture hatcheries. Conflict resolution and leadership (effective communication principally), allows for staff to express their ideas and provide feedback openly and constructively. This improves creativity and problem solving, both important in a developing industry with a brief history and subject to a difficult engineering and financial environment in the region.

Financial management

41. Informed budgeting, for both the capital establishment (CAPEX) and operation (OPEX) of marine hatcheries, is essential. CAPEX requires accurate quantity surveying (identification of individual components and their cost) for a design. An understanding of marine hatchery workflows, the staff and equipment required and the frequency of the occurrence for each operational task, is required to estimate reasonable operational costs. In addition, estimations of electricity load, from motor sizes and period of operation, and maintenance costs, need to be accommodated in a marine hatchery budget. Many marine hatcheries in the Pacific are established with sufficient CAPEX but their operational budgets are modest, this impacts their productivity.

42. Structured and accurate accounting is needed as a reference to further inform the development of operating budgets. Recording accurately the expenditure a marine hatchery, provides actuality that is needed for informed financial planning, and the provisioning for the costs of risk management.

43. Production planning, the determination and prediction of the number or quantity (biomass) of the 'biological assets' (animals or plants) that may be produced by a marine hatchery, is a critical component of its financial (and biological) management. For this is necessary to know the density of larval culture, the volume of the larval rearing space (larval and land-based nursery tanks) available, and the rate of growth at least. Determining the production potential (through planning) of a marine hatchery, allows the correct scaling of marine farms that seedstock may be transferred to. Production planning also allows the determination the unit cost of the marine species produced. This enables a unit price to be set, that reinforces the sustainability of a marine hatchery operation, either through full cost recovery or the acquisition of industry development funding or business investment.

Conclusions

44. Marine hatcheries are a necessary component of mariculture industry development for most species of interest in the Pacific, with the exceptions of the capture-based mariculture of bivalves in some countries (pearl oysters in French Polynesia, Cook Islands, Fiji and cupped oysters in Fiji and New Caledonia) and the propagation of seaweed in Solomon Islands, Kiribati, Tonga, and Papua New Guinea.

45. The operation of a marine hatchery requires competency in biological management, aquaculture engineering, personnel management, and financial management. While often in the PICTs and emphasis is placed on biological management, the performance of the others will impact the sustainability of a marine hatchery operation.

46. Very small scale 'mini mariculture hatcheries', with applicable live feed alternatives, may be appropriate for community investment, enabling the development of traditional marine tenure rights. Mini hatchery sustainability still requires some competency in biological management, aquaculture engineering and personnel and financial management.

47. Medium and large-scale marine hatcheries for marine species require a significant investment and are often established with substantial vertical integration to incorporate marine farming and processing and sale of the end products of their output. This scale of production is expensive to finance and some thought to establishing regional mariculture hatcheries may result in more consistent seedstock availability for marine farming across the region.

Recommendations

48. That Members update SPC on their public and private sector marine hatchery development and production bottlenecks, risks or problems that may be experienced categorised as biological, engineering, personnel or financial.

49. Members are asked to consider their countries capability for these categories of mariculture hatchery operation (biological, engineering, personnel, and financial management) and advise SPC on areas identified and preferred for capacity development.

50. Members are advised to develop SOPs and production plans for their mariculture hatcheries and advise SPC if templates, models, and assistance are required for their development.

51. Members are encouraged to analyse the budgets and operating costs of their public sector marine hatchery operations to attempt to establish a unit cost of production of the marine species that they produce.

52. Members are asked to submit these technical details to SPC to incorporate into the development of the Pacific regional aquaculture strategy.