Advice on the Enhancement of Infaunal Shellfish in Poverty Bay

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1. SUMMARY AND RECOMMENDATIONS

Enhancement and re-introduction of infaunal shellfish in Poverty Bay is feasible provided there is:

1. Sufficient community consultation to identify shellfish species that are of particular importance, and to gauge community support for enhancement projects.
2. Sufficient ecological monitoring to assess the current state of shellfish populations identified in 1, and to determine possible reasons for current population status.
3. Sufficient ecological monitoring to identify potential sites for re-introduction or enhancement of shellfish species identified in 1.
4. Scientific input to determine appropriate methods for re-introduction/enhancement and to ensure the success of the reintroduction/enhancement process can be measured.
5. Continued management of enhanced areas, and monitoring of shellfish health and water quality within Poverty Bay

2. THE BRIEF

To provide advice on:

- Previous attempts to enhance infaunal shellfish in New Zealand
- The potential for shellfish enhancement in Poverty Bay
- Basic background information required before shellfish enhancement should be attempted
- Basic information required during any shellfish enhancement attempts in Poverty Bay

3. BACKGROUND

Cawthron Institute was commissioned by the Gisborne District Council (GDC) through Envirolink grant 747-GSDC61 to give advice on options for the enhancement of infaunal shellfish in the Poverty Bay region. With upgrades to the Gisborne City waste-water outfall due to be completed in the near future, it is hoped that improved coastal water quality will increase the chances of successful shellfish enhancement and local shell-harvesting abilities. Initial discussion with GDC revolved around the enhancement/re-introduction of a single species, the New Zealand pipi, *Paphies australis*, but further discussion revealed a need to determine a list of species that were important at the community/user group level and the background ecological and environmental information required. As such, the information detailing considerations for the re-seeding of *Paphies australis* is provided in Appendix 1, and highlights the potential for further study, while a summary of the gaps in knowledge required to progress with enhancement of infaunal shellfish in Poverty Bay are summarised in table format in Section 5.

4. ADVICE

4.1. Examples of infaunal shellfish enhancement

Infaunal shellfish like cockles (*Austrovenus stutchburyi*), tuatua (*Paphies donacina and P. subtriangulata*), toheroa (*P. ventricosa*), and pipi (*P. australis*) are particularly at risk to human influences because their intertidal and shallow-subtidal habitats overlap with human populations. As such, many populations of infaunal shellfish in New Zealand are known to be greatly affected by increases in coastal sedimentation and over harvesting (Grant & Hay 2003; Cummings & Thrush 2004; Norkko *et al.* 2006). Enhancement, therefore, may provide managers and community groups with an option to ensure remaining shellfish populations can be harvested in a sustainable manner in the future.

Enhancement is generally seen as the manipulation of the local biological and physical environment to increase harvests; often by supplementing natural recruitment through the introduction of new stock (Booth & Cox 2003). Although Maori traditionally practiced enhancement as part of their management of kai moana (seafood) (Booth & Cox 2003), infaunal shellfish enhancement in New Zealand has only recently been attempted on large scales (Marsden & Adkins 2009).

In the mid-1990s scientists worked with local iwi to investigate small-scale, low-cost methods for transplanting and enhancing infaunal shell-fish beds at Te Moana o Whaingaroa (Raglan Harbour) (Turner *et al.* 1998). In another example, local community groups and scientists attempted several re-seeding and enhancement projects with the cockle, *Austrovenus stutchburyi,* in Whangarei Harbour following extensive research into potential sites, transplant densities and methods (Cummings *et al.* 2007). They identified that caging of transplanted cockles was not necessary, and even larger-scale transplants were likely to be more successful than the smaller plot transplants.

In a recent review of cockle bed restoration in New Zealand, Marsden & Adkins (2009), suggest that the transplanting of adult stocks has the greatest potential for successful reseeding (although hatchery reared and wild spat can also be used, Stewart & Creese (1998)), but they also highlight the importance of background habitat information prior to transplantation, and the continued management of reseeded areas through community involvement and support. While the methodologies for transplants and re-seeding areas can differ, most studies agree that transplanting adult shellfish on very large scales is likely to be the most effective method for enhancement purposes (Stewart & Creese 2002; Grant & Hay 2003; Marsden & Adkins 2009). Furthermore, because many infaunal shellfish species are highly mobile and likely to move away from unsuitable habitat (Hooker 1995), identifying suitable habitat is critical to ensure transplanted shellfish remain at transplant sites and eventually form self-sustaining populations (Stewart & Creese 1998).

4.2. Potential for shellfish restoration in Poverty Bay

The Gisborne District Council is both a district and regional council and because the council manages a large region with a comparatively small population, collecting environmental monitoring data in the region is a challenging task. However, the Gisborne District Council currently collects the following data relevant to potential shellfish restoration projects:

- Bathing/swimming water standards in the marine environment (*i.e.* water sampling for faecal *coliforms* at eight beaches used for swimming)
- Monitoring of water quality at seven shellfish-gathering areas from measurements of faecal *coliforms* in seawater samples
- Measuring offshore water quality from measurements of faecal *coliforms* at 11 sites surrounding the current city outfall diffuser in Poverty Bay

These data provide some insight into the quality of the water within Poverty Bay. Projects that further characterise the river plumes and hydrodynamic environment will also enhance knowledge of the broad-scale coastal environment; and Envirolink applications to fund three broad-scale projects that address these gaps in knowledge are currently being prepared by Cawthron. However, finer-scale environmental and substratum data at the beach/estuary scale will be required to select suitable sites for the re-introduction and enhancement of shellfish beds within Poverty Bay.

We believe that the next step in such a reintroduction or enhancement programme should be to consult with community groups to determine the level of support and to identify the key species to the region. Following appropriate consultation, the key species can be assessed in terms of their general suitability for enhancement, *i.e.* removing any species that are clearly impractical in terms of a need and/or efficacy perspective. The remaining candidate species can then be targeted for fine-scale sampling of potential sites; possibly through further Envirolink medium-term advice grants to investigate options for specific species (see example in Appendix 1). This more targeted sampling will determine the current population structure of key bivalve species at potential sites, and identify those most suitable for re-introduction. Further species-specific studies will be required to determine the correct methods and scale of transplants.

Several experimental studies have examined the effects of sediment type and burial depth on the survival and recruitment of infaunal bivalves, including *Austrovenus stutchburyi, Paphies australis* and *Macomona liliana* (*e.g.*(e.g. Hull *et al.* 1998; Cummings & Thrush 2004; Norkko *et al.* 2006). These studies found that, while there were some inter-specific differences in the magnitude of effect, all of the species tested were negatively affected by large amounts of terrestrial sediment deposition. Consequently, any efforts to re-establish or enhance bivalve populations will require knowledge of past and present levels of sediment deposition and characteristics to ensure suitable, sustainable shell-fish habitats are selected. This may prove to be an important observation, given the significant influence of rivers along the Gisborne coastline.

Once suitable sites have been identified, significant community involvement and support will be necessary to ensure re-introduction/enhancement experiments can be done at suitably large scales; and continued monitoring and management of enhanced areas will be necessary to determine the success of such efforts (see Section 5 below).

5. KNOWLEDGE GAPS AND SCOPE FOR RESEARCH INTO SHELLFISH RE-INTRODUCTIONS IN POVERTY BAY

5.1. Before transplanting

Gaps in knowledge that should be addressed before attempts to re-introduce and enhance infaunal shellfish species in Poverty Bay are summarised below. Combinations of these can be combined into Envirolink Medium Advice Grants (MAG).

Gaps in knowledge	Scope for future research (MAG?)
1. What shellfish species are of greatest importance to community groups within Poverty Bay? And are these groups interested in helping with the re-introduction/enhancement process?	Consultation with user groups to determine shellfish species of importance? And the level of support for enhancement/restoration of selected shellfish populations?
2. What is the current state of selected intertidal and subtidal shellfish populations within the area?	Subtidal and intertidal population surveys of selected species to determine current population structure.
3. Can some information be gathered to determine the cause of the population decline at specific sites?	Sediment analysis to determine past and present deposition events, and the presence of contaminants through time. Analysis of harvesting records from local sources. Assemble any evidence on historical population size.
4. Do the factors that caused the decline still exist, or was it a one-off event? Are the factors manageable in the foreseeable future?	Monitoring of environmental variables, such as sediment deposition and contaminants at potential sites.
5. What is the current state of the habitat at potential sites?	Measuring sediment physico-chemical composition, and variability of suspended sediments.
6. Does the hydrodynamic regime of sites suggest retention of larvae of key species could occur?	Measuring water column stratification and current data at potential sites. Develop fine-scale hydrodynamic model. Evaluate predominant coastal processes, *i.e.* long-shore drift, net erosion/accretion.

5.2. When transplanting

Below are gaps in knowledge that will need to be addressed once background environmental and population data are collected and the level of support for restoration projects has been determined.

Gaps in knowledge	Scope for future research (MAG?)
Where will seed-stock come from?	Benefits and consequences of using natural versus hatchery reared seed-stock will be investigated.
What methods should be used when transplanting?	Experiments testing various methods that ensure correct depth and orientation of transplants can be achieved, or protection during self-burial.
What densities should be transplanted and when?	Experiments testing effects of transplant densities on survival, growth, reproduction and spat production.
Would subtidal or intertidal transplants be most effective and what sizes should be transplanted?	Experiments testing survival and growth of different size classes in subtidal and intertidal areas.
Will transplanted populations become self- sustaining?	Continued before and after surveys of population densities in subtidal and intertidal areas

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7. APPENDIX 1: INFORMATION RELEVANT TO TRANSPLANTING THE NEW ZEALAND PIPI (*PAPHIES AUSTRALIS*)

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1. BACKGROUND

The New Zealand pipi (*Paphies australis*) belongs to the family Mesodesmatidae (superfamily Mactridae) and is closely related to the tuatua (*P. subtriangulata* and *P. donacina*) and the toheroa (*P. ventricosa*). *Paphies australis* are generally found on sandbanks along sheltered beaches and at the mouths of harbours and estuaries (Creese 1998); occurring in the upper 8-10 cm of coarse sediments (Morton & Miller 1973). *Paphies australis* reach a maximum size of *c.* 80 mm in length (Creese 1998), and are sexually mature at sizes greater than 40 mm (Hooker & Creese 1995). Populations on the north-eastern coast of the North Island spawn from early spring through to late summer (Hooker & Creese 1995), and larvae settle 18-22 days after fertilisation (Hooker 1995a). Settlement is usually into clean coarse sediments, and can be greatly affected by local hydrodynamic conditions (Hooker 1995a).

While *Paphies australis* is often thought of as an intertidal species, they also occur in subtidal channels down to depths of 6-8 metres (Creese 1998). In fact, several studies suggest that the subtidal may be the main habitat of adult *P. australis*; (Venus 1984; Hooker 1995a; Cole *et al.* 2000) although other intertidal populations have been found to contain larger adults than those of subtidal populations (Pawley *et al.* 1997). However, (Hooker 1995b) found *P. australis* in the Whangateau Harbour had distinct habitat segregation based on size and age. Wherein, juvenile *P. australis* occurred high on intertidal shores, and fully mature adult animals (over 40 mm in shell length) were found at highest densities (up to 4400 m^{-2}) in subtidal beds in the main harbour channels.

Recruitment of *Paphies australis* appears to vary considerably between years. Both Hull (1996) and Cole *et al.* (2000) concluded that the temporal variation in sub-tidal adult *P. australis* population densities in Tauranga Harbour (Centre Bank) were related to large differences between annual recruitment events. They also found that post-settlement mortality and dispersal were important factors in regulating population size structure. Evidence also suggests that juvenile and adults stages of *P. australis* have the ability to move away from unsuitable habitats using mucus parachutes, and that they may travel considerable distances using this method (Hooker 1995a; Cummings & Thrush 2004). For example, Hooker (1995a) collected 509 drifting pipi in nets in a harbour in northern New Zealand. Drifting pipi were mainly juveniles (<15 mm shell length), but a small number of adults (up to 58 mm shell length) were found. While highly variable, there was a trend for more drifting pipi to be caught on the flood tide than the ebb tide.

1.1. Potential factors affecting populations

A review by Grant & Hay (2003) investigated the large number of natural and anthropogenic factors that can potentially affect the survival and growth of infaunal bivalve populations like *Paphies australis*. They highlighted considerable knowledge gaps in the potential effects of factors like anti-fouling paints, heavy metals, organochlorides, polyaromatic hydrocarbons, increased sediment loads, nutrient enrichment, climate change, harvesting, algal blooms, disease and parasites, invasive species and other pharmaceutical products. The factors most relevant to transplanting are summarised below.

1.1.1. Sediment loading and composition

The effects of sediment loading and composition have been relatively well studied and are known to have significant impacts on infaunal bivalve populations. The maximum depth at which infaunal bivalves live in the sediment is determined by the length of their siphon, through which water containing oxygen and food is drawn. Because pipi (*P. australis*) have short siphons and normally live near the sediment surface, they may be particularly sensitive to large inundations of sediment (Grant & Hay 2003). For example, Creese (1998) using manipulative laboratory experiments tested the effects of several factors relating to *P. australis* reorientation to the surface following burial including: the impact of different depths of sand applied to the surface; *P. australis* orientation upon burial; and the effects of continued *P. australis* reburial over five days. His results showed that all sizes of *P. australis* were able to withstand disturbance and inundation to depths of 10 cm (Creese 1998). Medium sized *P. australis* (30-45 mm shell length) could even withstand burial in up to 40 cm of sand and continued reburial in less than 15 cm of sand over four days. However, and most relevant to translocation experiments, when *P. australis* were placed upside down into the surface of the sediment, they were not able to use their foot to right themselves, and did not survive.

In another set of laboratory experiments, Norkko *et al.* (1999) tested the ability of three infaunal bivalves, including *P. australis*, from the Okura estuary to surface and feed through different thicknesses of mud. In treatments of 3, 6 and 9 cm of clay, only *P. australis* were able to extend their siphons up through the 3 cm layer allowing them to survive. However, none of the species tested survived burial in 6 and 9 cm of clay.

In a study of the Upper Waitemata Harbour, Cummings *et al.* (2002) found that the bivalves *P. australis* and *Macomona liliana* were not present at sites containing >67% mud. A study by Norkko *et al.* (2001) investigated the sensitivity of macrofaunal species to fine sediments in the Whitford embayment. Their results suggest that *P. australis* are highly sensitive to increased silt/clay content (optimum range and distribution range *c.* 0-5% silt/clay content).

Furthermore, Cummings & Thrush (2004) found that juvenile *P. australis* were less likely to recolonise and burrow into areas in which terrestrial sediments had accumulated.

Paphies australis is an active burrower and is able to respond rapidly to inundation and uncovering from sediments (Hull *et al.* 1998). Field experiments in two areas of north-eastern New Zealand by Hull *et al*. (1998) showed that *P. australis* were able to re-bury themselves within 40 minutes when exposed on the sediment surface. Though pipi were capable of ascending through as much as 50 cm of sand in laboratory experiments, they found evidence of a decreased ability to respond to repeated burials over five and eight day periods.

1.1.2. Suspended sediment

The concentration of suspended sediments has increased along many parts of the New Zealand coastline; largely due to changes in land-use and farming practices. In a series of laboratory and field experiments, Hewitt *et al.* (2001) investigated the effects of changes in suspended sediment concentrations on *Austrovenus stutchburyi*, *P. australis* and *Macomona liliana*. Although adult *A. stutchburyi* and *P. australis* both had the ability to continue feeding in high levels of suspended sediment over one week, their physiological condition was adversely affected by prolonged elevation of suspended sediment concentrations. The effect on the condition of *P. australis* was greatest; with decreases in condition in all sediment treatments when concentrations >80 mg/l persisted for 14 days. Previously, Wood (1962) noted that *P. australis* siphons lack the filtering circlet of tentacles of *A. stutchburyi*, and suggested that this may make *P. australis* more susceptible to the impact of increased suspended sediment concentrations. More recently, Teaioro (1999) showed that, due to their inability to clear its feeding apparatus, *P. australis* could only feed efficiently in low concentrations of suspended sediments (>20-32 mg l^{-1}).

2. SUMMARY

There are several key questions that must be considered when endeavouring to transplant the New Zealand pipi, *Paphies australis*, into areas that once sustained viable populations. First, there are questions relating to the past and present population structure. For example, what was the original cause of the decline? Given the species is highly susceptibility to factors like sedimentation and suspended sediment concentration, have there been identifiable environmental changes in the habitat that continue to affect population viability and replenishment, or is it simply related to sustained over-harvesting? If sustained over-harvesting is the main cause, do viable subtidal populations still exist? As most studies point to highly variable patterns in settlement, recruitment and population structure of *P. australis*, it is possible populations have simply moved to different areas along the shore, or further into the subtidal. If other environmental variables are responsible for the decline, will they continue to affect the survival of transplanted populations? For example, if the silt/clay concentrations in the area have increased to >5%, and to thicknesses greater than 3 cm, it is unlikely that transplanted pipi will survive.

Second, there are several questions relating to the sizes and densities that should be transplanted, when and where transplants should occur, and whether transplanted populations will ever become self-sustaining? Given that subtidal populations usually consist of larger individuals, would transplants of smaller individuals into the subtidal grow faster, or would the conditions there increase mortality? Because *P. australis* has a planktonic period of up to three weeks, does the hydrodynamic regime of the transplant area lend itself to larval retention? Will multiple transplants to areas up and down a coastline increase the chances of self-replenishment of some areas? In some areas, sexually mature (>40 mm) *P. australis* have been found to reach densities of over 4000 per m^2, and as such, may require high density transplants to increase chances of successful reproduction and population replenishment. Will the timing of transplants be important? Given that spawning occurs in late spring – summer, will stressing pipi by transplanting them during this time increase or decrease survival, and reproductive output?

Finally, there are questions relating to the methods of transplant. For example, should pipi be deposited on the surface and allowed to self re-bury. Given that reburial can take up to 40 minutes, pipi may need to be protected from predators in some way during this time. Or would direct transplant more effective? If directly transplanted, can pipi be introduced into the sediments in the right orientation and at the correct depth? *P. australis* are highly sensitive to sediment type, depth and orientation. Therefore, if direct transplants are done they must be carried out in such a way that pipi are introduced in coarse sand, at 5-10 cm depth and ensuring that the foot is facing down.

Key points for *Paphies australis* transplants:

- It is important to quantify both subtidal and intertidal population structure at transplant sites.
- Pipi transplants into subtidal habitat may affect survival and growth (less disturbance, greater feeding time).
- With a 15-22 day planktonic period few settlers are likely to return to the transplant area.
- Pipi must be transplanted into the correct habitat type (more sand/less than 0-5% clay).
- Pipi must be transplanted at the correct depth (5-10 cm); although they may be deposited on the surface and allowed to re-bury. However, as this can take up to 40 minutes some initial method of protection should be provided.
- It is essential to transplant pipi in the correct orientation to allow re-burial (foot down).
- Pipi have the ability to move to more suitable habitats, so while they may disappear from transplanted areas they may have moved into other areas nearby.
- Pipi cannot withstand high suspended sediment concentrations and should be transplanted to areas of relatively low turbidity.

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