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EVALUATION OF A NEW TAGGING TECHNIQUE FOR MONITORING RESTORATION SUCCESS

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ABSTRACT  Venerid clams, Austrovenus stutchburyi, were tagged with small aluminum discs, enabling relocation using a metal detector. Tag loss varied between treatment types, being highest for small, densely packed clams. Over three sites the mean tag loss across all treatments was 10% (± 2.87) after 7 months. This is likely to be an overestimate as only a subsample of individuals was recaptured. Laboratory studies showed no significant difference in survival, growth, or condition between tagged anduntagged clams. Ability to reburry was not affected by tags; all tagged and untagged individuals burrowed within 24 h of being placed in tanks. The technique was also found effective for a deeper burrowing tellinid bivalve. The extensive movement of four whelk species made relocation difficult, but the technique still holds potential for the tag and recapture of these gastropods. Studies previously considered difficult are feasible with this technique.

KEY WORDS:  Austrovenus stutchburyi, clam, restoration, metal detector, monitoring, tag and recapture, New Zealand.

INTRODUCTION

Austrovenus stutchburyi (Wood 1828) is a shallow-burrowing, filter-feeding clam found in sheltered, soft-shore, intertidal habitats around New Zealand. Adult clams have an average shell length of 30–40 mm. Populations of A. stutchburyi are vulnerable to increased sedimentation from coastal development and overharvesting. Consequently, this popular resource has declined at many locations throughout New Zealand, although the extent of this decline has only recently been recognized. Our research investigates the potential for restoration of infaunal clams through studies of the ecology of A. stutchburyi; the study included manipulative field experiments to assess movement patterns, predation rates, and responses to translocations. Despite being used increasingly overseas, restoration is a novel technique for New Zealand.

Restoration requires monitoring of biological parameters to determine success (Pratt 1994). In the long term, reproductive output and the ability to establish self-maintaining or sustaining populations are the most critical considerations, but in the initial stages of shellfish enhancement the important parameters are survival and growth. Estimates of these can be obtained at the population level by using cohort analysis or through the analysis of growth rings (Lutz and Rhodes 1980). More direct estimates can be obtained by tag and recapture techniques (Brousseau 1978, 1979; Craig 1994). In high latitude marine environments, bivalves often lay down annual rings that correspond to seasonal growth spurts (usually in summer). This phenomenon has been reported for some A. stutchburyi populations in southern New Zealand (Couatts 1974, Marsden and Pilkingston 1995), but many other studies have shown that shell rings are too variable to be relied upon for calculations of age or growth (Larcombe 1971, Couatts 1974, Blackwell 1984, Martin 1984). Tag and recapture procedures are considered more likely to provide accurate estimates of survival and growth for this species.

There are several methods of externally marking shells for later recapture of known individuals; for example, paint (Dobinson et al. 1989), alizarin red, a calcium stain (Peterson et al. 1995), or numbered tags. New Zealand bivalves commonly been tagged with numbered plastic tags glued to the shell (e.g., A. stutchburyi, Martin 1984, Paphies subtriangulata, Grant 1994, P. australis, Hooker 1995). The tag and recapture technique requires a reasonable recapture rate, which can be difficult to achieve for infaunal bivalves. Conventionally tagged animals often migrate out of the area where they were released and it takes considerable time and effort to sieve through large amounts of sediment to find them. This also makes estimates of mortality difficult, as there is no way of knowing how many tagged animals were missed.

One way to avoid this is to cage bivalves on the shore, which is a common experimental technique (Hurlberg and Oliver 1980; Vuurstein 1980; Martin 1984). However, this procedure is difficult to implement on beaches visited by large numbers of people and in areas impacted by harvesting. In soft-sediment habitats, cages can influence water flow and sedimentation in experimental plots and these effects must be assessed using appropriate controls (Hurlberg and Oliver 1980). A new technique with the potential to avoid these problems is bivalves with small aluminum tags glued to the shell, and relocates them using a highly sensitive metal detector run over the surface of the sediment. This technique was pioneered in South Africa for the highly mobile surf clam, Donax serra (Dugan and McLaughlan, 1999). Tag loss in their study was around 4% and tagging was found to have no significant effect on condition or behavior. Such a tagging method would enable A. stutchburyi to be relocated over a wide area, without caging. Prior to this, Neves et al. (1989) tested techniques of telemetry on the freshwater mussel Actinonaias ligamentia. Using epoxy resin, magnets were secured to the valve, the mussels were placed at known locations, and a systematic search conducted with a magnetometer. The degree of successful relocation of tagged mussels in their study was not given.

Estimation of growth and mortality depends on the assumptions that tagging does not affect behavior, increase the probability of predation or disease, or negatively affect growth or longevity (Southwood 1966). Many infaunal bivalves, including venerids, are well suited to external tagging because they are hardy, have a heavy shell (a tag therefore adds little weight), are reasonably large (tags can therefore be positioned so as not to interfere with opening or closing of the valves or protrusion of siphons), and their burrowing behavior means tags are not visible to predators.

This paper evaluates the potential use of aluminum tags and a
metal detector in tag and recapture studies of *A. stutchburyi*. Field and laboratory studies were used to test assumptions about tag loss (as recommended by Trebble et al. 1993) and the effects of tags on clam condition and behavior (as recommended by Martin 1984). Preliminary trials were also carried out on co-occurring bivalves and whelks.

**METHODS AND MATERIALS**

**Tagging**

*Austrovenus stutchburyi* were collected at low tide as this is when the clams are accessible in the field and least active (Beenetjes and Williams 1986; Williams et al. 1993). After blotting with a paper towel, the clams were air-dried to provide a clean dry surface for attachment of tags. Aluminum tags were attached to the valve away from the apex and shell margin, using a clear, two-part epoxy resin (Araldite). Tags were 1 × 5 × 5 mm and weighed 69 mg (± 1.7 mg). All clams were also given a second tag consisting of a dot of enamel paint, which had been found previously to remain on the shell for at least 10 months. This allowed later estimates of the rate of loss of the aluminum tags. Enamel paint rather than plastic tags, was used because of the large number of shellfish in the experiment. After the glue had hardened and set, tagged clams were returned to the tank, prior to use in various experiments. The large clams were removed from the water for approximately 1.5 h in total and smaller clams for a shorter time.

**Assessing Tag Effect**

Tagged (treatment) and untagged (control) *A. stutchburyi* were kept in aquaria (320 × 250 × 150 mm) and monitored to determine the effect of tagging on mortality and growth. A 3-cm layer of sediment was placed in each aquarium prior to adding clams in order to mimic the natural environment. Sediment had been sieved through 2-mm mesh sieve to remove large macrofauna. Each aquarium held 10 small clams (10–18 mm) and 10 large clams (25–32 mm). Clams in control aquaria were subject to the same drying process as those tagged. Before being placed in the aquaria, all clams were measured (to the nearest 0.1 mm) and weighed before and after the addition of tags. Three randomly positioned replicate treatment and control aquaria were used.

The burrowing behavior of tagged and untagged clams was observed over the first 48 h. Aquaria were checked for mortality weekly, and clams were re-measured monthly. After 5 months, the physiological status of the tagged and untagged clams was compared using condition indices. To ensure that the potential effects on different components of the condition analyses were detected, three separate indices were used. These were dry weight condition index (CI-dry), gravimetric condition index (CI-grav), and body condition index (BCI).

\[
CI\text{-}dry = \frac{\text{dry tissue weight (g) \times 100}}{\text{shell weight (g)}}
\]

(Crosby and Gale 1990, Marsden and Pilking 1995)

\[
CI\text{-}grav = \frac{\text{dry tissue weight (g) \times 100}}{\text{internal shell cavity capacity (g)}}
\]

Where internal shell cavity capacity = total whole live weight - dry shell weight (Crosby and Gale 1990)

\[
BCI = \frac{\text{dry tissue weight (g) \times 100}}{\text{shell cavity volume}}
\]

Where volume = π/6 (shell height × length × breadth) (Savari et al. 1991)

**Tag Loss and Tag Relocation**

Loss of aluminum tags was assessed both in the laboratory experiment on tag effect and in the field as part of a transplant experiment. Field studies were carried out at two intertidal sites, Point Wells and Lewis Bay in the Whangatea Harbour near Leigh, in northeastern New Zealand (Fig. 1). A total of 4500 cockles were double-tagged and returned to the Whangatea Harbour (see Fig. 1), where they were transplanted to three separate sites (two at Point Wells and one at Lewis Bay). Each group of 1,500 clams consisted of equal numbers of small (10–18 mm) and large (27–35 mm) individuals. Within each size category, the clams were transplanted into either packed, high-density plots (200 clams/0.25 m²) or spaced out, low-density plots (50 clams/0.25 m²). There were three replicates of each combination of treatments (clam size and density), giving an orthogonal multifactorial design. Tag loss was assessed during the experiment from marked cluckers (empty valves still attached at the hinge) retrieved in visual searches at the transplant sites (conducted weekly where possible). The assumption was made that tag loss from cluckers was representative of tag loss from live cockles.

The transplant experiment enabled the effectiveness of tag relocation to be assessed. A metal detector (Minelab sovereign XS) was moved across the sediment surface and when a tag was detected (signalled by an increased tone), the area was marked and the sediment was carefully excavated to expose the tagged clam.

**Applications to Other Species**

Preliminary trials were conducted to test the effectiveness of the aluminum tagging methodology for *Macomona liliana* (Iredale 1915) and several species of whelks. *M. liliana* was chosen for comparison with *A. stutchburyi* as it is found in similar habitats, but it is deep-burrowing, living approximately 20 cm below the surface. Whelks were chosen to test the method on co-occurring species that are highly motile.

*Macomona liliana* were collected from the field and then tagged using the same method as for *A. stutchburyi*. They were

![Figure 1. Transplant experiments using the aluminum tags were conducted at Lewis Bay and Point Wells in the Whangatea Harbour (≈ 36°26'S, 174°46'E) in northeastern New Zealand.](image-url)
held in salt-water, flow-through tanks overnight and then returned to the field on the next low tide. Three replicate plots were set up, each containing 20 adult *M. liliacea.* These plots were checked regularly using the metal detector.

Four species of whelks were collected from the field. These were tagged using the same method as for *A. stutchburyi* and released in the same area they were collected from. The release site had a permanent marker from which movement by whelks could be calculated. This tag and release process was repeated twice. On the first, 15 each of *Cominella maculosa* (Martyn 1784), *C. adspersa* (Brugiere 1789), *C. virgata* (Adams 1863), and *C. glandiformis* (Reeve 1847) were tagged. On the second occasion, 30 *C. maculosa*, 50 *C. glandiformis*, 20 *C. virgata*, and 11 *Lepsiella scobina* (Quoy and Gaimard 1833) were tagged. As with the clams, the metal detector was swept over the sediment surface to locate the whelks. When a whelk was detected the location was marked with a plastic straw. When no more whelks were detected, each whelk marked by a straw was identified and recorded.

## RESULTS

### Tag Effect

Ability to rebury was not affected by the tags. All tagged and untagged *A. stutchburyi* burrowed within 24 h of being placed in laboratory tanks, and they remained burrowed for the entire experiment.

Mortality was not significantly different between tagged and untagged *A. stutchburyi,* for both the small and large clams (Fig. 2). However, there is an apparent difference in mortality between small, tagged clams and control clams. But the fact that the trend is toward higher mortality for control clams (36.7% versus 16.7% for tagged clams), certainly does not indicate an effect of the tag and is most likely due to problems with water supply. A two-way ANOVA (data pooled across tanks) showed no significant difference in mortality between treatments ($P = .3336$) or sizes ($P = .0736$) and no treatment *×* size interaction ($P = .3336$).

Although there was no obvious affect of the tagging procedure on mortality, there may have been a more subtle, sublethal impact. This was investigated by examining three indices of physiological condition. Three-way ANOVAs (treatment, size of cockle, tank) for each index revealed there were no significant interaction terms ($P < .05$ for all three indices). There was no significant tank affect and therefore data were pooled across the three replicate tanks for graphical representation (Fig. 3). There was no significant effect of treatment ($P < .05$ for all three indices), for tagged clams versus control clams, which was the comparison of interest. There was, as expected, a significant effect of size for all three indices, an artifact of the indices used.

There was no difference in growth between tagged and untagged clams, principally due to the fact that the clams did not grow significantly over the study period (Table 1). Dobinson et al. (1989) also found a lack of growth for *A. stutchburyi* within the time frame of their experiment. Tagged clams that had been in the field for nearly a year were just beginning their summer growth spurt, with small clams having grown 2 mm or more over the months of September to October. This suggests that the tag had little, if any, effect on growth, even for small clams.

### Tag Loss and Tag Relocation

No tag loss occurred during the 5 months that *A. stutchburyi* were held in the laboratory. Mean tag loss in the field over three sites, across all treatments, was 10% (± 2.87%). Because of the low.

![Figure 2](image-url)  
**Figure 2.** Percent mortality of tagged and untagged clams after 5 months. Error bars are standard error. (n = 3).

![Figure 3](image-url)  
**Figure 3.** Condition indices for tagged and untagged clams after 5 months in the laboratory. Error bars are standard errors. (n = 14 small clams. n = 26 large clams). Replicates have been pooled.

<table>
<thead>
<tr>
<th>Size</th>
<th>Treatment</th>
<th>Month 1 Mean</th>
<th>Month 1 SE</th>
<th>Month 5 Mean</th>
<th>Month 5 SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Tag</td>
<td>15.4</td>
<td>0.65</td>
<td>15.2</td>
<td>0.65</td>
</tr>
<tr>
<td>Small</td>
<td>Tag</td>
<td>14.8</td>
<td>0.66</td>
<td>14.5</td>
<td>0.58</td>
</tr>
<tr>
<td>Small</td>
<td>Tag</td>
<td>15.3</td>
<td>0.54</td>
<td>15.3</td>
<td>0.65</td>
</tr>
<tr>
<td>Small</td>
<td>Control</td>
<td>15.3</td>
<td>0.73</td>
<td>15.1</td>
<td>0.11</td>
</tr>
<tr>
<td>Small</td>
<td>Control</td>
<td>15.3</td>
<td>0.65</td>
<td>15.8</td>
<td>0.70</td>
</tr>
<tr>
<td>Small</td>
<td>Control</td>
<td>15.0</td>
<td>0.67</td>
<td>15.5</td>
<td>0.76</td>
</tr>
<tr>
<td>Large</td>
<td>Tag</td>
<td>29.6</td>
<td>0.56</td>
<td>29.3</td>
<td>0.72</td>
</tr>
<tr>
<td>Large</td>
<td>Tag</td>
<td>29.3</td>
<td>0.59</td>
<td>29.1</td>
<td>0.64</td>
</tr>
<tr>
<td>Large</td>
<td>Tag</td>
<td>28.9</td>
<td>0.80</td>
<td>28.8</td>
<td>0.81</td>
</tr>
<tr>
<td>Large</td>
<td>Control</td>
<td>29.8</td>
<td>0.63</td>
<td>29.9</td>
<td>0.70</td>
</tr>
<tr>
<td>Large</td>
<td>Control</td>
<td>29.7</td>
<td>0.62</td>
<td>29.2</td>
<td>0.57</td>
</tr>
<tr>
<td>Large</td>
<td>Control</td>
<td>29.1</td>
<td>0.48</td>
<td>29.3</td>
<td>0.59</td>
</tr>
</tbody>
</table>
mortality of transplants (and therefore low numbers of cluckers retrieved), tag loss among treatments could not be compared statistically using this method. However, observational data suggest tag loss was greatest for small, densely packed clams. Although experimental plots were never permanently marked, it was possible to relocate plots on every sampling occasion. Relocation was accurate enough to avoid disturbing large areas of sediment.

Applications to Other Species

*Macomona liliana* were successfully relocated in the field after 2 months and there was no evidence of mortality for tagged individuals in the field. There has been a low return rate for the whelks, which is attributed to them moving away from the area, between tides, too quickly to be tracked. On the first sampling, only 16% of all whelks were relocated 1 day after release. All of these were either *C. adspersa* or *C. maculosa*. Three days later only one or two whelks were relocated. On the second sampling, there was a 4.5% incidence of tag loss before release. After 2 days, 10.8% of all whelks were relocated. Relocation rates were highest for *C. virgata* (20%) and *L. scobina* (18%) (Table 2). After 6 days, total relocation was only 1.8%, but relocation for *C. virgata* increased to 30% and remained at 18% for *L. scobina* (Table 2). After 10 days no whelks were detected. During this experiment, the whelks that were relocated were invariably solitary individuals, illustrating that the metal detector was sensitive enough to pinpoint a single tag approximately 5 cm under the sediment surface.

**DISCUSSION**

The aluminum tags had no detectable effect on growth, mortality, or behavior of *A. stutchburyi*. In addition, no effect on condition was found for three separate condition indices, including the gravimetric condition index (CI-grav), which is the recommended condition index to assess whether animals have been under stressful conditions (Crosby and Gale 1990). However, the time of year when tags are attached may affect growth and condition. Growth for shellfish is often seasonal, and attaching the tags during a period of high growth may have more effect than attaching them at another time of year. A long-term study of tag effect is required to investigate this, but the laboratory studies conducted here (in summer) suggest that any effect is likely to be small, irrespective of season. The advantage of using aluminum for the tag is that it is light enough not to affect behavior and is rust-resistant in saline conditions.

The fact that no clams held in the laboratory lost their tags may have been due to an absence of abrasive forces such as currents and the movement of abutting shellfish (which would be experienced in nature). These laboratory trials do confirm that the glue and tag are able to remain bonded to the shellfish in salt water for at least 5 months. Tag loss in the field was relatively low and did not reduce the effectiveness of the method. Because *A. stutchburyi* were in clusters, only a few tags were required to locate the plots. The metal detector is sensitive enough to locate a single tagged clam, but as no individuals moved away from the experimental plot this was unnecessary. In terms of evaluating the performance of restoration, this technique worked well for the ongoing monitoring of experimental transplants. With minimal effort it was possible to relocate experimental plots without the necessity of permanently marking them. For a full-scale restoration project, the time and effort required to tag all individuals would obviously be prohibitive. However, the technique would still work well if even a small proportion of the seed shellfish for enhancement were tagged for ongoing monitoring and treated as representative of the population. Also, this technique holds potential for ecological studies that seek to provide more information on which to base decisions about restoration alternatives.

The technique pioneered by Dugan and McLachlan (1999), and further developed in this paper, has allowed the recapture and tracking of bivalves. Dugan and McLachlan (1999) were able to

**TABLE 3.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Maximum Size</th>
<th>Burial Depth</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Macomona liliana</em></td>
<td>wedge shell</td>
<td>50–60mm</td>
<td>±20cm</td>
<td>Morton &amp; Miller (1973)</td>
</tr>
<tr>
<td><em>Austrovenus stutchburyi</em></td>
<td>cockle</td>
<td>30–40mm</td>
<td>Top few cm</td>
<td>Morton &amp; Miller (1973)</td>
</tr>
<tr>
<td><em>Nucula hartvigiana</em></td>
<td>nut shell</td>
<td>&lt;10mm</td>
<td>Top few cm</td>
<td>Morton &amp; Miller (1973)</td>
</tr>
<tr>
<td><em>Paphies ventricosa</em></td>
<td>toheroa</td>
<td>&gt;150mm</td>
<td>=30cm</td>
<td>Hooker (unpubl. data)</td>
</tr>
<tr>
<td><em>Paphies australis</em></td>
<td>pipi</td>
<td>=50mm</td>
<td>Top 8–10cm</td>
<td>Morton &amp; Miller (1973)</td>
</tr>
<tr>
<td><em>Paphies subtriangulata</em></td>
<td>tuatu</td>
<td>=90mm</td>
<td>Top 8–10cm</td>
<td>Hooker (1995)</td>
</tr>
</tbody>
</table>

**TABLE 2.**

<table>
<thead>
<tr>
<th>Day</th>
<th>Total Relocation</th>
<th>All Species</th>
<th>C. virgata</th>
<th>C. maculosa</th>
<th>C. glandiformis</th>
<th>L. scobina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n = 111</td>
<td>n = 20</td>
<td>n = 30</td>
<td>n = 50</td>
<td>n = 11</td>
</tr>
<tr>
<td>2</td>
<td>10.8%</td>
<td>20%</td>
<td>3%</td>
<td>10%</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.8%</td>
<td>30%</td>
<td>0%</td>
<td>2%</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>
track the longshore movement of individuals. In this paper, we were able to use a metal detector to successfully monitor clams transplanted for small-scale experimental restoration. The metal detector used (Minelab Sovereign XS), has a detection range of approximately 20–30 cm below the surface for a 1 mm × 5 mm × 5 mm aluminum tag. The detection range is a function of tag size and burial depth of the target organism. The detection range can be improved by increasing the size of the tag, but this will ultimately be limited by the size and shape of the bivalve. Reported burial depths of some common New Zealand soft sediment bivalves suggest that aluminum tags may possibly be used for all these species (Table 3). Further experiments are needed to test for tag effects and the relocation efficiency of these other species, many of which live deeper in the sediment than A. stutchburyi. However, as reported here, the burial depth of M. liliana (± 20 cm) did not hamper the relocation of this species.

There was a low return rate for the whelks, as they rapidly move away from an area between tides, too quickly to be tracked. However the whelks that were relocated illustrated that the metal detector was sensitive enough to pinpoint a single tag. The capture rate varied between the species tagged, being greatest for C. virgata. Therefore, while it may not be possible to follow movements of whelks over the long-term, the technique may still yield important information on movement patterns of other species.

Overall we believe that the simplicity, reliability, and versatility of this metal detection technique opens many new avenues for researchers in the area of soft-sediment ecology and restoration monitoring.

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LITERATURE CITED


