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Tini a Tangaroa

Assessment of impacts of mechanical spat harvesting on the surf clams of Te Oneroa-a-Tōhē

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Much of the mussel spat used to seed mussel aquaculture farms throughout New Zealand is sourced from Te Oneroa-a-Tōhē (Ninety Mile Beach) in Te Hiku (far north of New Zealand). The mussel spat washes ashore attached to seaweed and hydroids where it is collected by spat harvesters and transported to mussel farms around the country to be on-grown. The collection of Te Hiku spat and seaweed was originally done by hand. However, the methods used have evolved over time and mussel spat is now primarily collected using mechanical loaders operating in the surf zone. Local iwi, hapū, and the wider community have recently voiced their concerns about the impacts of this harvesting method. Specifically, there are concerns about the impact of loaders operating on top of toheroa (*Paphies ventricosa*) and tuatua (*Paphies subtriangulata*) beds or other shellfish inhabiting in the intertidal and subtidal areas of Te Oneroa-a-Tōhē. Consequently, research into the ecological impacts of mechanical spat harvesting was conducted to address the concerns of the community and inform the management of the Te Hiku spat fishery.

This research aimed to examine the ecological impacts of a 'worst case scenario' by (1) simulating an intensity of spat harvesting activity much greater than would be anticipated in the 'real world' and (2) conducting the research at high density tuatua beds where impacts would potentially be greatest. Adult toheroa were not targeted in the experiment to avoid unnecessary impacts on already depleted toheroa populations. At each of three sites on Te Oneroa-a-Tōhē, nine spat harvesting loaders were repeatedly driven in and out of the surf, over shellfish beds, for 75 minutes leading up to the low tide. Once loader activity ceased, a sampling team of mana whenua, local primary school children, spat harvesters, and staff from Fisheries New Zealand, Te Ohu Kaimoana, and the University of Waikato collected clams from the intertidal area. Collections were made from both impact and control (non-impact) sites, where (a) the number of crushed shells was quantified and (b) the self-righting and burying abilities of tuatua from impact and control areas were compared to provide an estimate of sub-lethal effects.

There was no detectable impact of mechanical spat harvesting loaders on tuatua (or the juvenile toheroa that were present in the sampled tuatua beds) when these surf clams were either fully or partially buried in sands of Te Oneroa-a-Tōhē. Rates of shell damage were less than 6.1% and were similar in impact and control areas indicating much of the observed shell damage was caused by the sediment corers that were used to extract samples from the beach. Similarly, being driven over by loaders did not affect the ability or speed at which tuatua were able to right and bury themselves in the sediment. When standing on end these clams appear robust to the forces exerted by loaders upon the sediment surface. However, beach cast clams (both tuatua and toheroa), lying on top of the sediment on their sides are vulnerable to crushing by vehicles. This includes juvenile clams that 'float' to the beach surface where multiple loader passes liquefy the surface sediment. Mortality in these beach cast clams was not well captured by the sampling methodology used in this study, but was observed at two of the three sites sampled. It was not possible to quantify this type of mortality during this study. However, the number of clams crushed on the beach surface was small relative to the high abundances of clams within the sediment and the impact is not considered ecologically significant at the scale the individual shellfish beds or the entire beach.

Overall, there was nothing observed during this experiment to suggest that mechanical harvesting is having a significant ecological effect on the toheroa or tuatua of Te Oneroa-a-Tōhē. Mechanical spat harvesting did result in some clam mortality during this experiment, and it is likely that some mortality will occur in the future when clams are present on the beach surface. However, the level of mortality observed, and anticipated, is unlikely to compromise the viability of either clam species.

To minimise clam mortality caused by spat harvesting, loader operators should endeavour to avoid areas where large numbers of surf clams are either beach cast or are observed washing around in the shallow subtidal zone. It would also be prudent, because of the depressed state of toheroa populations on Te Oneroa-a-Tōhē, for spat harvesters to have up-to-date information about the location of toheroa beds and avoid them where possible.

It should be noted that concerns have been raised as to whether the driving of loaders during this study was equivalent to real world operations. However, the collection of operational data during this experiment, the proposed installation of Global Positioning System trackers on all loaders, and the use of observers will allow for monitoring and enforcement of operating procedures established in the industry code of practice.

1. INTRODUCTION

Between 70 and 80% of the mussel spat used to seed mussel (*Perna canaliculus*) aquaculture farms throughout New Zealand is sourced from Te Oneroa-a-Tōhē (90 Mile Beach) in Te Hiku (far north of New Zealand). The mussel spat washes ashore attached to seaweed and hydroids (Alfaro & Jeffs 2002) where it is collected by spat harvesters and transported to mussel farms for on-growing (Figure 1). The collection of mussel spat from beach cast seaweed was originally done by hand. However, the methods used to harvest spat have evolved over time and mussel spat is now primarily collected using mechanical loaders operating in the surf zone (Figure 1). Local iwi and hapū and the wider community have become concerned about the impact that this mechanical harvesting method may be having on toheroa (*Paphies ventricosa*), tuatua (*Paphies subtriangulata*), or other marine life inhabiting in the intertidal and subtidal areas of Te Oneroa-a-Tōhē.

Several studies have documented the negative impacts that vehicles driven on beaches can have on intertidal organisms, including surf clams (Godfrey & Godfrey 1980, Schlacher et al. 2008, Moller et al. 2009). For example, Moller et al. (2009) examined the impact of recreational vehicles driven on Oreti Beach in Southland and concluded that vehicles could cause as much as 23% mortality of juvenile toheroa across the entire beach and estimated that this may reduce the adult toheroa population by as much as 79%. The study also found that different vehicle types caused different levels of impact, with utility and four wheel drive vehicles having approximately half the impact of cars and motorbikes. No studies have been conducted that examine the impacts of vehicles similar to the loaders used in mussel spat harvesting. Consequently, there is a need to understand the impacts of these particular vehicles to address the current concerns of the Te Hiku community and inform the management of mussel spat harvesting.

There are currently three models of loader being used to harvest mussel spat at Te Oneroa-a-Tōhē. The Hitachi LX20 which weighs approximately 2400 kg and the larger Yanmar V4 and Hitachi LX30 which weigh approximately 3400 kg (Figure 2). The modifications made to loaders for spat harvesting include raising the vehicle body by between 0.3 and 0.5 m, replacing the forward-reverse solenoid with a hydraulic system, removing non-essential electrical systems (the only electrics are lighting and starter motor), making the fuel gravity fed, and adding a basket to the front end for scooping seaweed out of the ocean. Loaders are fitted with 0.405-m wide tyres. A total of 19 loaders are owned by mussel spat harvesters. However, it is unlikely that more than 13 are used at any one time. Mussel spat collection typically takes place over less than 30 days each year with the normal season running from the start of June to the end of October. On average, approximately 50% of spat is collected by the end of August and 86% by end of October. Although some spat may be collected in later months, the spat tend to be smaller and have a lower rate of survival when moved onto mussel farms. Patterns of spat fall vary from year-to-year and there have been occasions when less than 22% of a year's spat has been collected by the end of August. There is currently no detailed spatial information to provide an understanding of how much of Te Oneroa-a-Tōhē is potentially impacted by harvesting operations. Changes currently being proposed for an industry code of practice, including Global Positioning System (GPS) monitoring, will ensure that better data are collected in the future. Spatial data, combined with the findings of this study, will provide a more complete assessment of the impacts of the fishery.

A study conducted in 2007 examined the impact of a single loader pass on shellfish in the intertidal zone and recorded no negative impacts (Sim-Smith et al. 2007). However, spat harvesting operations have changed significantly since this assessment was conducted. Therefore, a new assessment is needed to (a) account for the current spat harvesting approach (multiple loader passes and multiple loaders) and (b) assess the impact of loaders on surf zone shellfish. The purpose of the research documented in this report was therefore to assess the impacts of the current mechanical harvesting methods on shellfish beds on Te Oneroa-a-Tōhē.

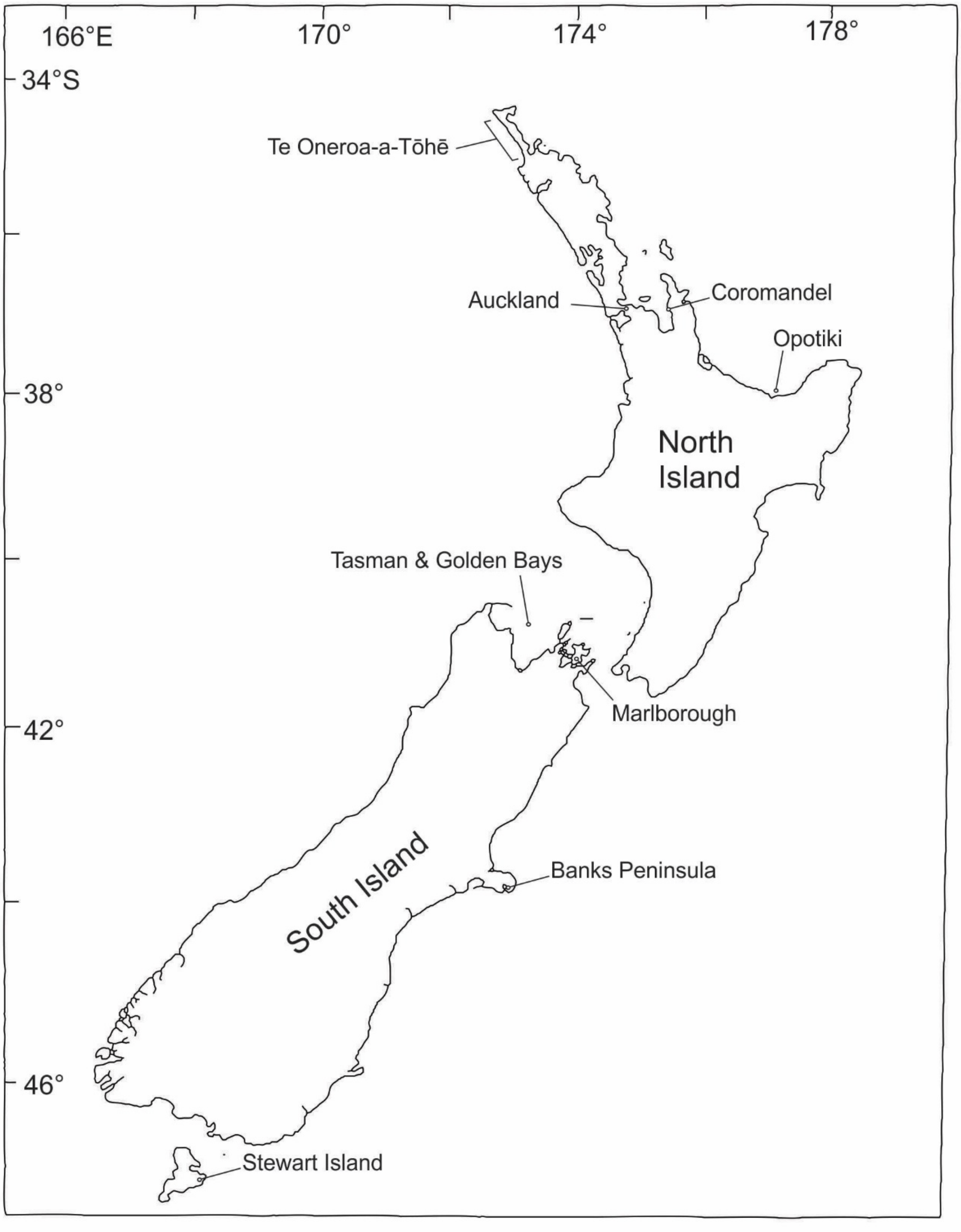

Figure 1: Map of New Zealand showing the location of Te Oneroa-a-Tōhē (90 Mile Beach) in Te Hiku (far north) and the main mussel farming locations around New Zealand.

Figure 2: Mechanical loaders used to harvest mussel spat from beachcast seaweed at Te Oneroa-a-Tōhē.

Although mechanical spat harvesting may have a variety of impacts, including on the natural character or landscape of Te Oneroa-a-Tōhē, on the cultural values of tangata whenua, and the mauri of the beach and environment, the research detailed here focuses on impacts from an ecological perspective. It is not implied that ecological impacts are more or less important than other types of impacts or that this report will provide all, or any of, the answers required to assess those other impacts. However, it is hoped that the findings of this ecological assessment will prove useful in informing further discussions around impacts on a range of values and contribute to the current decision-making process and the sustainable management of mussel spat harvesting at Te Oneroa-a-Tōhē.

This study examines the impacts of a 'worst case scenario' by (a) simulating an intensity of loader activity much greater than would be anticipated in the 'real world' and (b) conducting the research at high density tuatua beds. Adult toheroa were not targeted in the experiment to avoid unnecessary impacts on already depleted toheroa populations. The approach taken was to repeatedly drive spat-harvesting loaders over shellfish beds and then measure the damage caused to tuatua (and any toheroa present within the tuatua beds). The non-crushing (sublethal) injuries were also assessed by measuring the time taken for impacted vs. non-impacted shellfish to bury themselves in the sand. This test is an unsophisticated but effective method for determining if shellfish are experiencing stress or injury that may not be apparent simply by inspecting shell integrity. The cultural appropriateness of this approach was discussed with representatives of Te Hiku iwi at Te Oneroa-a-Tōhē Spat Working Group meetings and it was determined that the proposed methodology was acceptable and necessary for assessing the impacts of mechanical harvesting on Te Oneroa-a-Tōhē.

2. METHODS

This study was conducted on consecutive days (25–27 November 2019) at three tuatua beds on Te Oneroa-a-Tōhē (Figure 3). These sites were chosen in consultation with iwi representatives on the Te Oneroa-a-Tōhē Spat Working Group, mana whenua, and spat harvesters. Site 1 was located approximately 1.3 km north of Wakatehāua (Bluff). Sites 2 and 3 were located approximately 0.8 km and 2.2 km north of the Hukatere beach access. Site 1 was the only area on the beach where tuatua larger than 40 mm were found. Elsewhere on Te Oneroa-a-Tōhē, the majority of tuatua were in the 25–40-mm size range. Consequently, sites 2 and 3 were selected because they were (a) close to the Hukatere beach access, providing easy access for spat harvesters and other research participants, and (b) representative of tuatua beds observed between Hukatere and Wakatehāua.

Figure 3: Google Earth image of Te Hiku showing sampling sites and other key locations.

The original experimental design called for tuatua to be sampled in both subtidal and intertidal areas. However, no subtidal tuatua beds were found during the site selection process. Instead, all sampling was conducted in the intertidal zone, with impacts measured in the upper and lower parts of the intertidal tuatua bed at each site. Because these shellfish beds would be driven over by loaders travelling across the beach during periods when the lower shore was inundated by the tide, and then again later when exposed by the receding tide, it is likely the results would be representative of the impacts occurring on subtidal tuatua beds.

At each site, two areas of beach 60 m wide were marked out with orange road cones to indicate the position of experimental impact and control zones (Figure 4). The size of these zones was chosen to concentrate loader operations into a relatively small area thus achieving the ‘worst case scenario’. At each site the treatment (control or impact) was randomly assigned to one of the coned off areas (Figure 4). The control zone was not disturbed, whereas simulated harvesting was conducted in the impact zone, as described below.

1. Nine loaders (a number that reflects a high level mussel spat harvest pressure) were towed on trailers to a sampling site. Five of the loaders carried full water containers of a weight equivalent to a scoop of seaweed.
2. Handheld GPS units were given to each loader driver to carry for the duration of each harvesting simulation to record the movements of their vehicle.
3. Ninety minutes prior to low tide, simulated harvesting began and loaders were driven in and out of the surf zone, in the same way they would during actual harvesting operations (Figures 5 & 6).
4. After 75 minutes (fifteen minutes before low tide) of simulated harvesting activity, loader activity ceased and loaders were returned to their trailers.
5. Before sampling commenced, the shellfish bed was inspected to determine the vertical extent of the bed and decide where on the beach clam sampling would be conducted. This inspection involved digging small holes by hand, while moving from the upper beach towards low tide, and was done to ensure that sampling transects were not placed above or below the bed.

Figure 4: Experimental set up at Hukatere showing impact (orange) and control (green) zones. Loaders can be seen entering and exiting the surf in the impact zone.

Sampling was conducted by a team consisting of mana whenua, local primary school children, spat harvesters, and staff from Fisheries New Zealand, Te Ohu Kaimoana, and the University of Waikato. Within each zone at each site, sampling was conducted as follows.

1. Fifty metre transect tapes were placed parallel to the shoreline across the upper and lower sections of the intertidal tuatua bed (Figure 7). Both transects were submerged when simulated harvesting commenced, but were exposed by the time loader activity ceased 15 minutes before low tide.
2. Twenty pegs (with pink flagging tape labels attached) were inserted into the sand alongside each transect tape to indicate the positions where sediment cores would be extracted (Figure 7). These sampling positions had been previously determined using the random number function in Microsoft Excel.
3. At each sampling position, two sediment cores (13 cm diameter, 0.013 m^2 surface area per core, and 15 cm depth) were extracted from the beach surface. Sediment corers were gently pushed into the sand, a rubber bung inserted into the top hole of the corer to create suction, and the corer gently removed from the sediment (Figure 8).

4. Sediments from each pair of cores were then placed into a sieve (1-mm mesh size) and sieved in a plastic tub full of seawater (Figure 8). All material remaining in the mesh after sieving was placed into a zip-lock bag with a pink flagging tape label to indicate the details (site, zone, tidal height, and core position) associated with each set of cores.
5. The contents of each zip-lock bag were emptied onto a plastic tray (Figure 9). Clams were separated into small and large size classes. Large clams were all tuatua, whereas small clams (3–18 mm) were predominantly toheroa but did include some tuatua. With the time available it was not possible to train all research assistants to differentiate between juvenile clam species (subsequent examination of these small clams confirmed the majority were toheroa, although the ratio of toheroa to tuatua was not quantified). Therefore, for the purposes of this report it will be assumed that all small clams were toheroa.
6. All large clams were measured and identified as being intact or damaged (Figure 10). Where large numbers of small clams were present in a sample, all clams were counted, all damaged small clams were identified and measured, and a subsample of the entire small clam sample was measured (at least 30 individuals). Subsamples were obtained by placing all small clams in a pile on a sorting tray and then using a plastic ruler to split the sample in half and then in half again until a subsample of approximately 30 individuals was obtained.

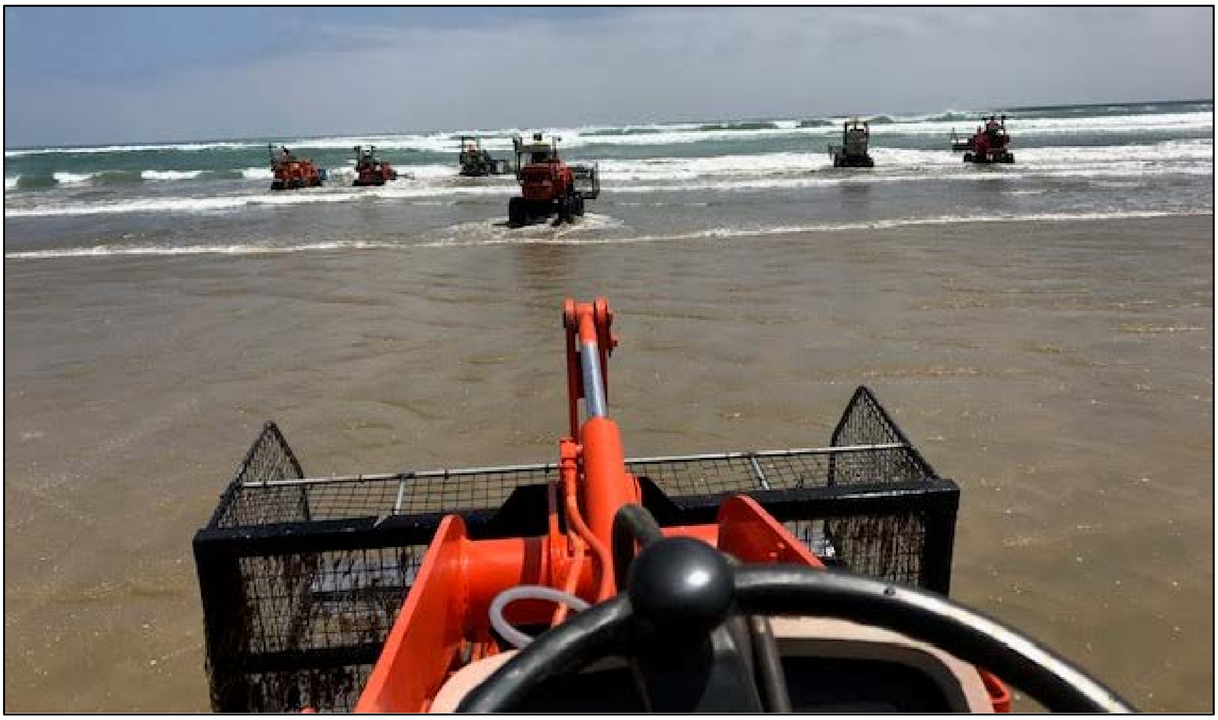

Figure 5: Driver's view from a mechanical harvester during simulated seaweed harvesting.

Figure 6: Nine loaders simulating seaweed harvesting during the experiment.

Figure 7: The sampling team about to begin extracting sediment cores from the impact zone. The positions of transects are illustrated by overlaid yellow lines. Inset panel shows transect tape and pegs with pink flagging tape to indicate randomly assigned position.

Figure 8: Series of photographs illustrating the process of collecting and then sieving of sediment cores.

Figure 9: Juvenile toheroa and tuatua about to be counted and measured.

Figure 10: Photos showing research team counting and measuring clams and recording data.

Non-crushing (sublethal) effects

At sites 2 and 3, 50 tuatua (mean length = 33.1 (± 0.1 s.e.) mm; range = 21–46 mm) with no visible shell damage were haphazardly collected from along the length of each transect (two impact and two control samples from each site) and temporarily held in buckets of seawater. Prior to the collection of tuatua, plastic boxes (32 cm x 32 cm x 12 cm) had been prepared to house the experiment. Sand, from same area of beach where tuatua were to be collected, was added to a depth of 6 cm and each box was completely filled with seawater (Figure 11). A battery powered air bubbler was used in each box to keep the water oxygenated. The 50 tuatua were then spread evenly across the sand surface in each box thereby commencing the experiment. The numbers of buried vs. unburied tuatua in each treatment (impact vs. control) were then recorded at set intervals for the next 60 minutes. Burial was measured every minute from 1 to 6 minutes, every two minutes from 8 to 20 minutes, and every 5 minutes from 25 to 60 minutes. Tuatua were classed as buried once they had attained a vertical orientation and at least half their shell was buried beneath the sand surface.

Figure 11: Reburial experiment. Observers intently recording the numbers of buried vs. unburied tuatua from the two treatments (control vs. impact).

3. RESULTS

Loader GPS tracks viewed in Garmin Basecamp indicated that loader traffic was evenly distributed across the impact zones and that loaders had not entered the control areas (Figure 12). Individual loaders covered between 4 km and 6.2 km over the 75-minute experimental period. The total combined distance travelled at each site by the nine loaders was 34.7 km, 49.4 km, and 47.2 km for sites 1, 2, and 3, respectively (Figure 13). The average moving loader speed ranged from 4.4 km h^{-1} to 5 km h^{-1}.

3.1 Clam sampling

A total of 24 681 clams were sampled, of which 2538 were tuatua and 22 143 were assumed to be predominantly juvenile toheroa. Densities of both tuatua and toheroa varied between sites. Tuatua were recorded at 123 (± 62) m^{-2}, 678 (± 339) m^{-2}, and 429 (± 215) m^{-2} at sites 1, 2, and 3 respectively (Table 1). A single juvenile toheroa was recorded at site 1, and 12 393 and 9749 juvenile toheroa were recorded at sites 1 and 2 at densities of 5957 (± 561) m^{-2} and 4746 (± 367) m^{-2}, respectively.

3.2 Size frequency

The size-frequency distribution of the sampled clams varied between sites (Figure 14). Site 1 was occupied almost exclusively by large tuatua (28–60 mm), whereas shellfish beds at sites 2 and 3 consisted of both smaller tuatua (19–40 mm) and juvenile toheroa (3–18 mm). Size-frequency distributions were comparable between impact and control zones at each site (Figure 14).

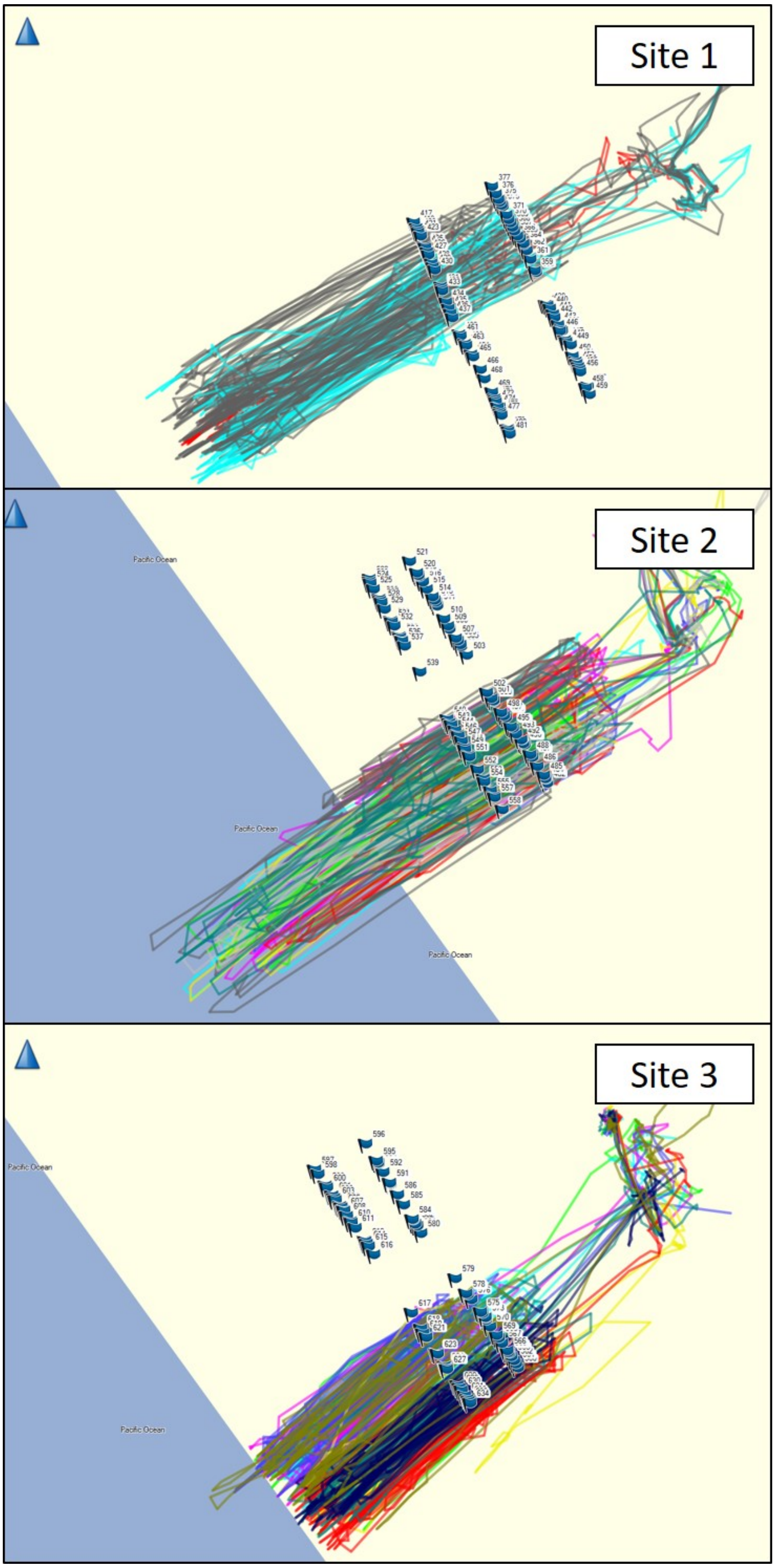

Figure 12: GPS tracks of loaders at each site and positions of each individual sediment core collected. Tracks are viewed in Garmin Basecamp and the representation of the beach water interface in the software does not reflect actual conditions.

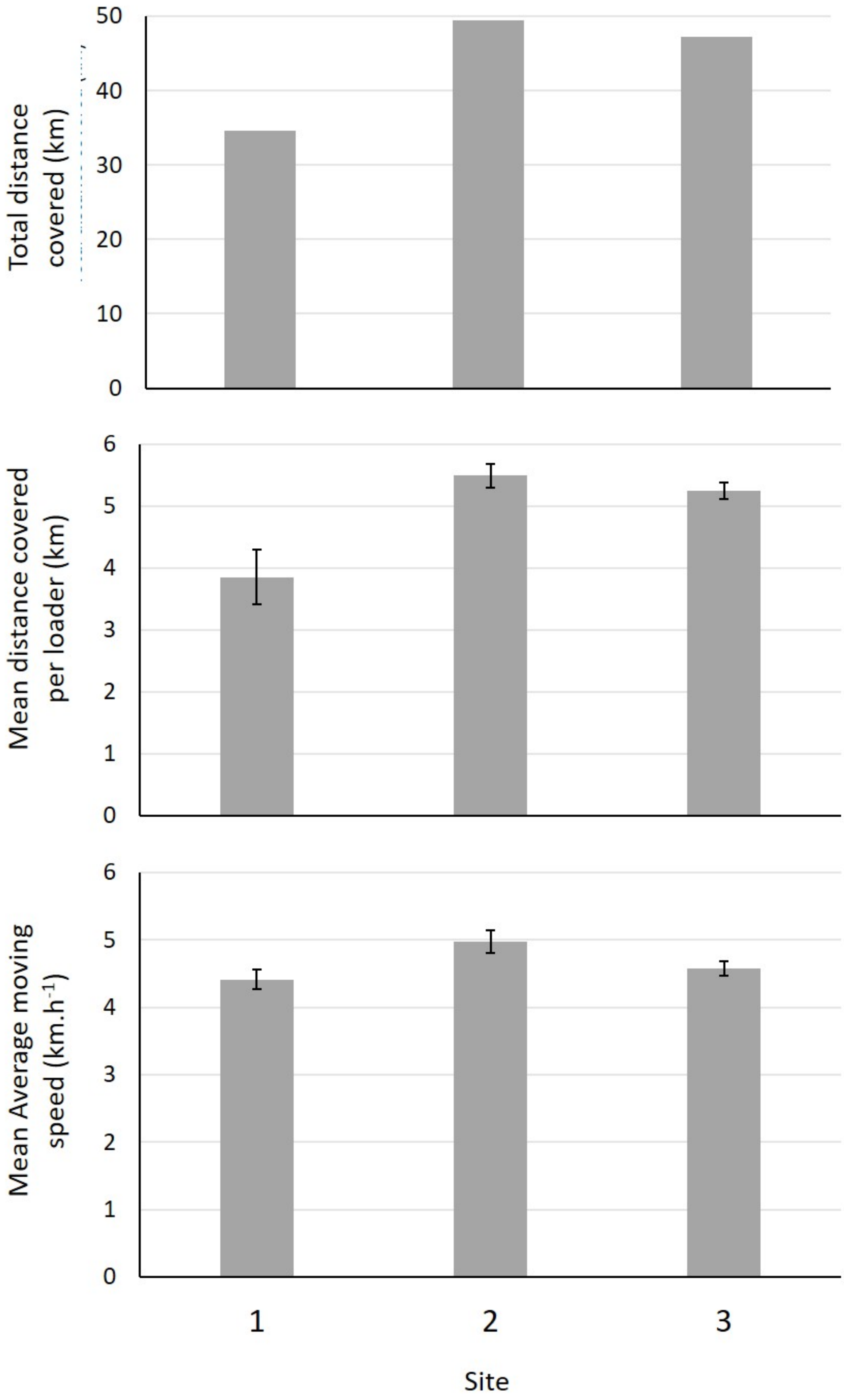

Figure 13: Graphs showing loader activity (total combined distance travelled by all loaders, mean distance covered per loader and average moving speed (± s.e.)) for each site.

Table 1: Total counts, densities, number broken, and percentage of broken clams recorded at each site.

				Toheroa				Tuatua			
Site	Date	Treatment	Strata	Total count	Density (m^{-2})	No. Broken	% Broken	Total count	Density (m^{-2})	No. Broken	% Broken
1	25-10-19	Control	High	1	1.9	0	0	49	94	3	6.1
1	25-10-19	Control	Low	0	0	0	-	54	109	2	3.7
1	25-10-19	Impact	High	0	0	0	-	89	171	2	2.2
1	25-10-19	Impact	Low	0	0	0	-	55	118	1	1.8
2	26-10-19	Control	High	1 686	3 242	35	2.1	576	1 108	23	4.0
2	26-10-19	Control	Low	7 034	13 527	96	1.4	268	515	4	1.5
2	26-10-19	Impact	High	1 753	3 371	39	2.2	306	619	18	5.9
2	26-10-19	Impact	Low	1 920	3 692	41	2.1	265	510	3	1.1
3	27-10-19	Control	High	582	1 178	4	0.7	313	634	6	1.9
3	27-10-19	Control	Low	2 751	5 290	37	1.3	192	369	11	5.7
3	27-10-19	Impact	High	2 320	4 461	24	1.0	215	413	0	0
3	27-10-19	Impact	Low	4 096	7 876	104	2.5	156	300	5	3.2

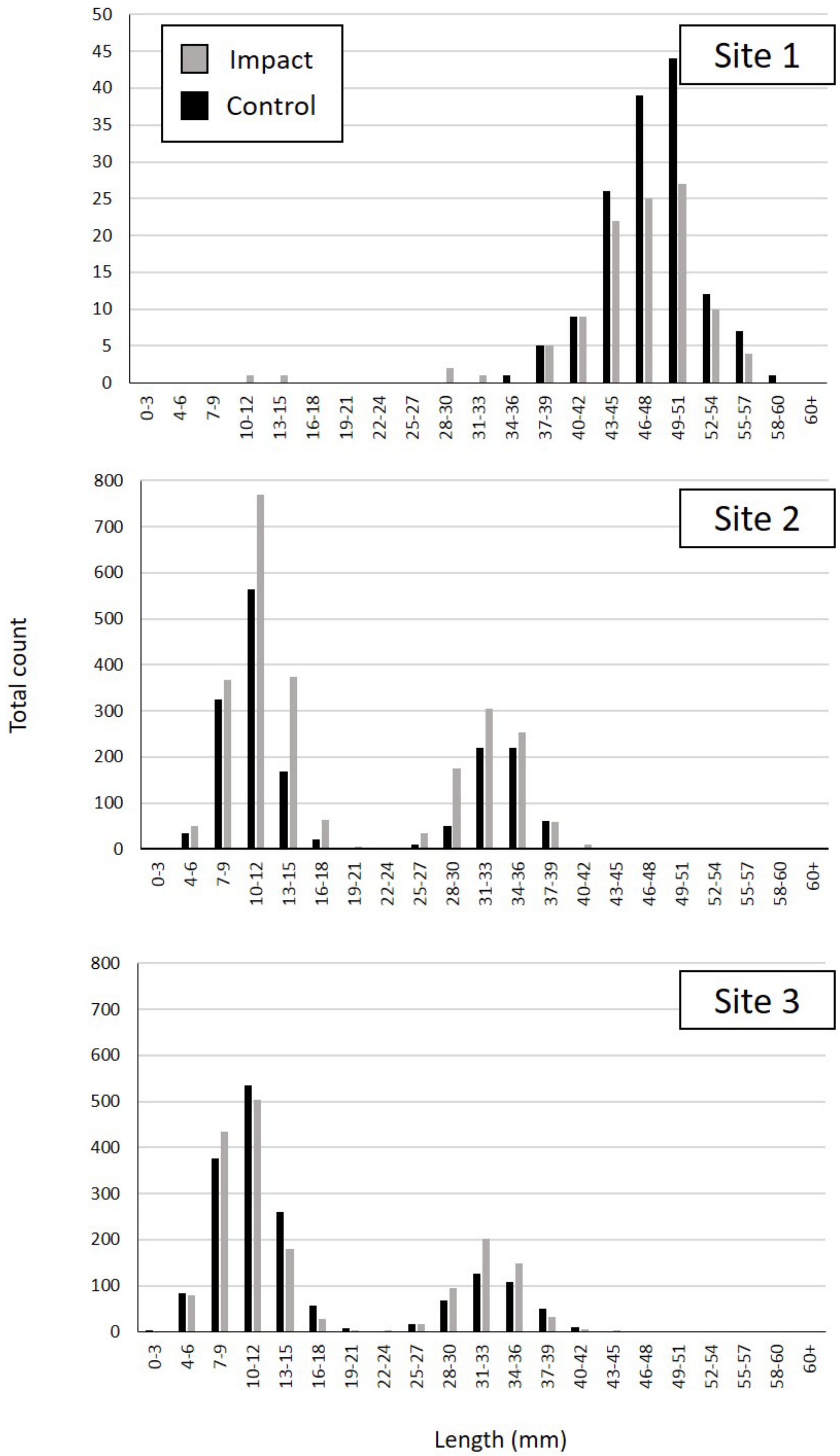

Figure 14: Size-frequency graphs showing the total number of clams recorded at each sampling site. Site 1 consisted almost exclusively of tuatua (*Paphies subtriangulata*), whereas at sites 2 and 3 juvenile toheroa (*Paphies ventricosa*; 3–18 mm) and smaller tuatua (19–42 mm) were recorded.

3.3 Shell damage and mortality

Rates of shell damage were low (≤ 6.1%) across all treatments and tidal heights and for both toheroa and tuatua. Overall, a greater proportion of tuatua were damaged than toheroa (3.1% vs. 1.7%). For grouped data there were no differences in mortality between upper and lower transects and between impact and control treatments (Figure 15). When sites were examined individually (Figure 16), fractionally more toheroa were damaged in the impact zones at sites 2 and 3 (1.5% and 1.2% vs. 2% and 2.1%) and more tuatua were damaged in the control treatment at sites 1 (4.8% vs. 2.1%) and 3 (3.4% vs. 1.3%). In all cases, rates of shell damage were low and were comparable between impact and control treatments.

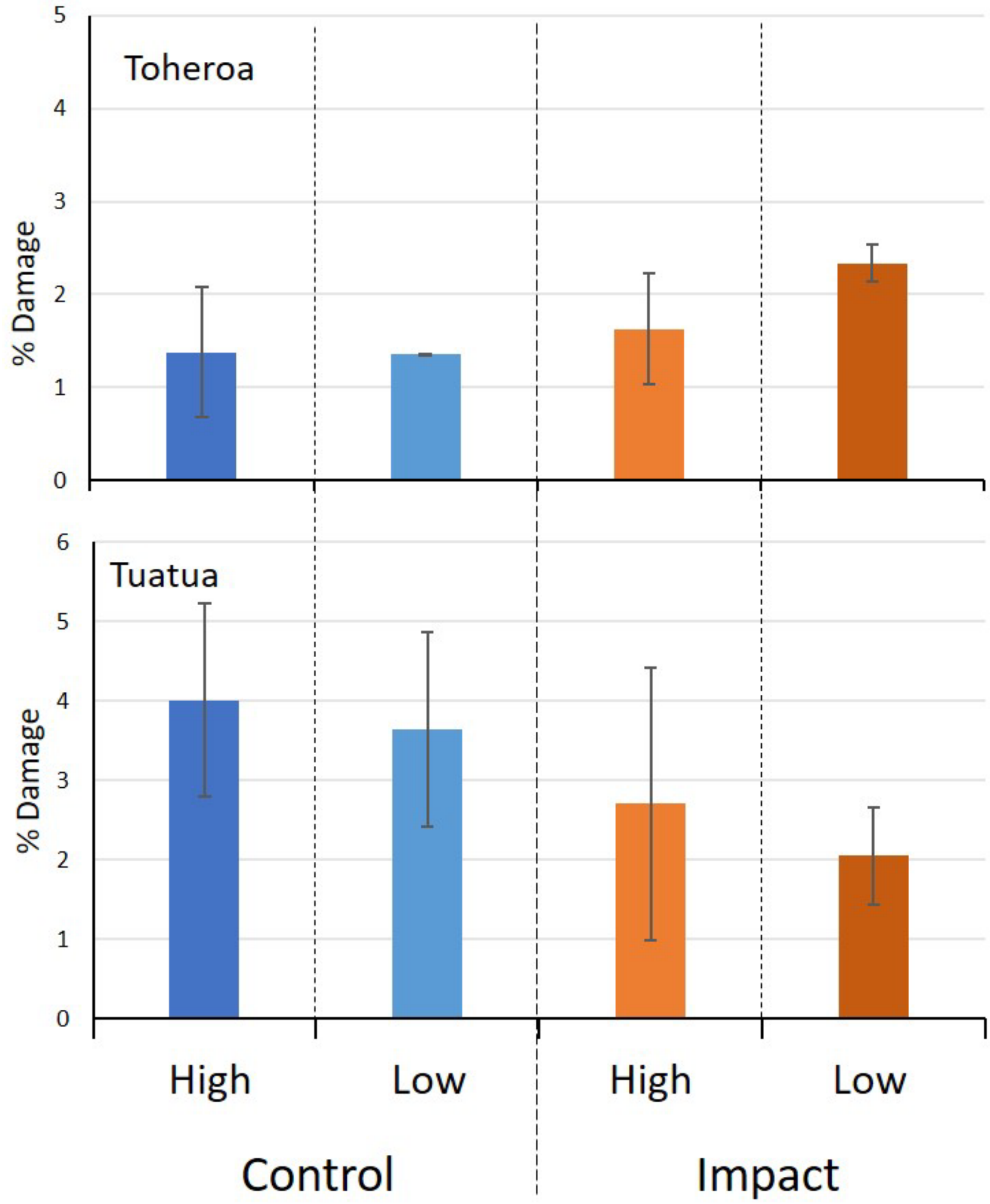

Figure 15: The grouped percentage (± s.e.) of broken toheroa (upper panel) and tuatua (lower panel) recorded in impact and control zones and in upper and lower transects.

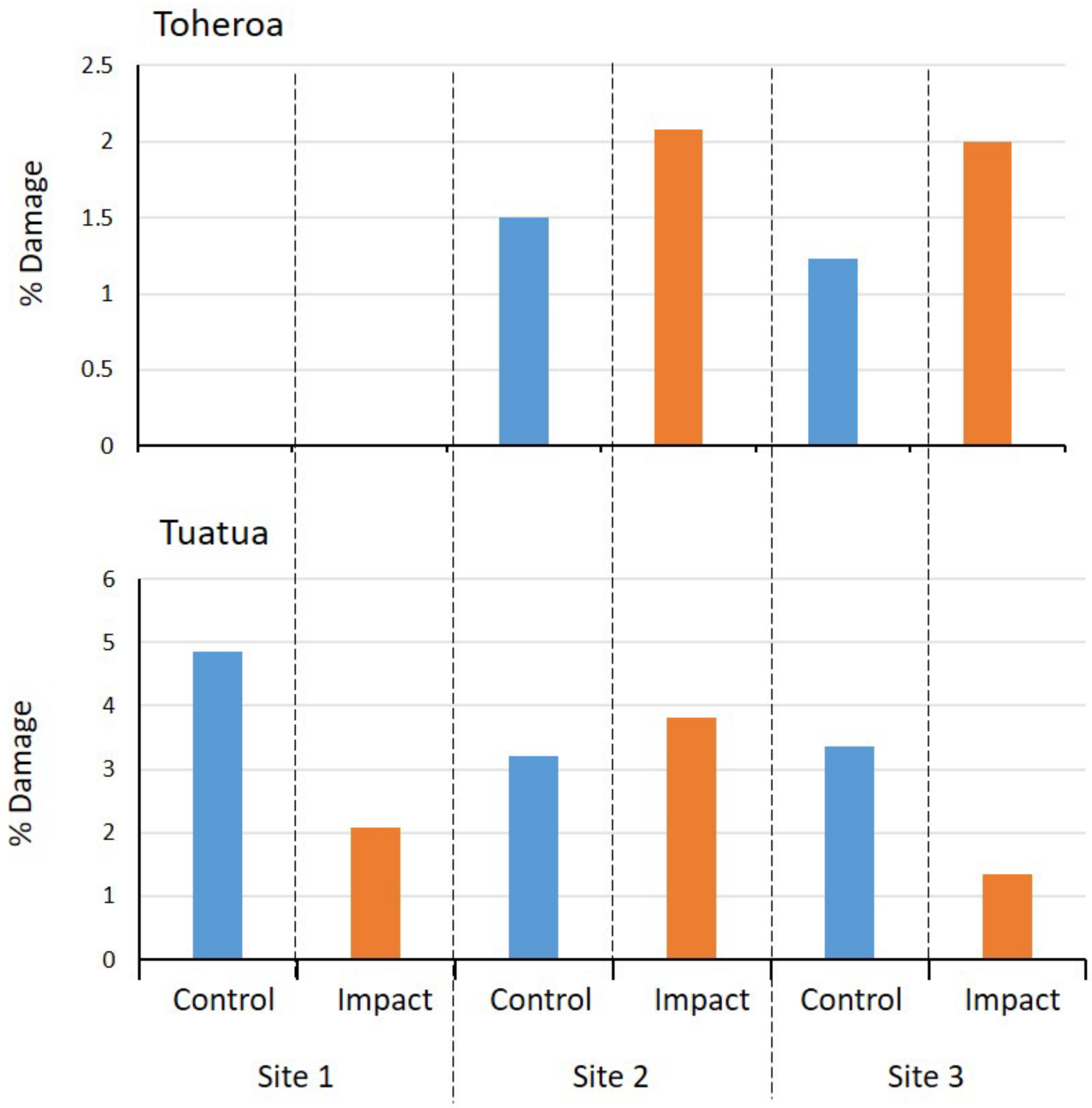

Figure 16: The percentage of broken clams recorded at each site, displayed for impact and control treatments. See Table 1 for additional details.

3.4 Non-crushing impacts

The reburial experiment was conducted on tuatua at sites 2 and 3 with two impact vs. control trials run at each site. On average, half (n = 25) of the tuatua in either treatment had righted and buried themselves within the first 12 minutes of the experiment (Figure 17). From that point onwards, the rate at which tuatua buried themselves slowed and few, if any, tuatua buried themselves beyond the 40-minute mark. At the end of the 60-minute experiment, around 30% of tuatua (n = 15) remained unburied in each experiment. There was no difference in burial ability, speed, or the total number of tuatua buried between impact vs. control treatments or between upper and lower transects (Figure 17).

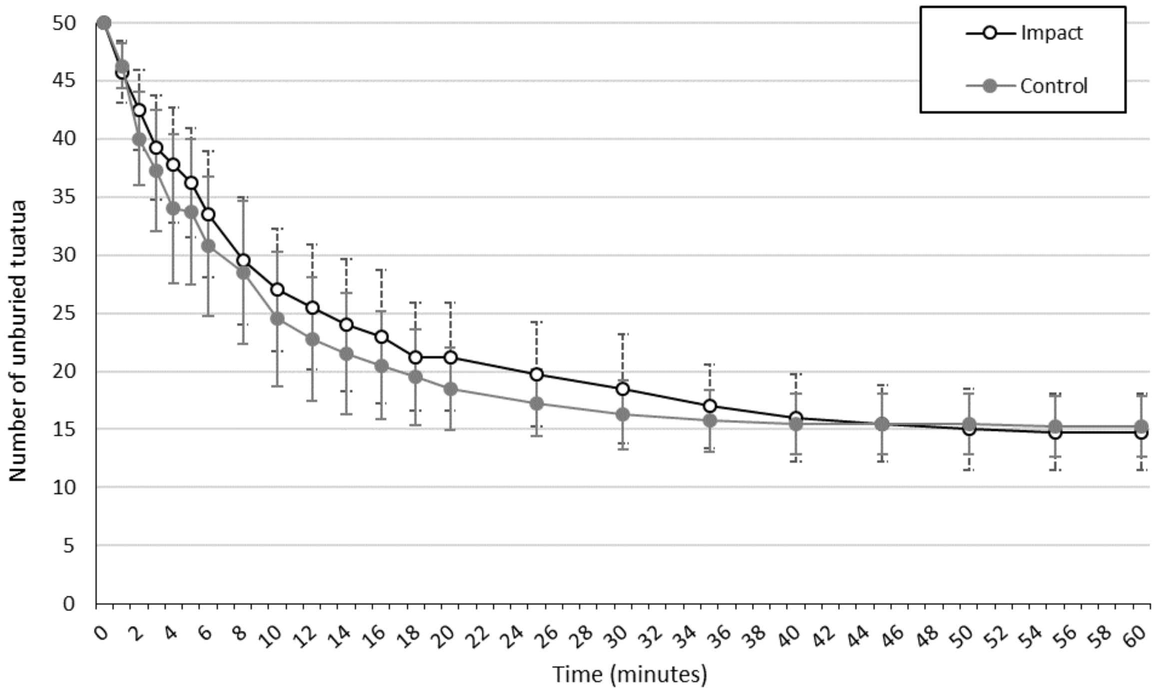

Figure 17: Mean number of tuatua (± s.e.) remaining unburied over the 60-minute experimental period for impact vs. control groups.

4. DISCUSSION

The results of this study indicate that mechanical spat harvesting is unlikely to be having any significant ecological effect on the shellfish beds of Te Oneroa-a-Tōhē. The mortality and shell damage recorded for clams present in sediment cores extracted from the beach surface was low (≤ 6%) and was similar in both impact and control areas. These results suggest that the observed damage was most likely a consequence of the sampling method used (sediment corer) rather than crushing caused by loaders. Clams buried on end, either fully or partially submerged within the sediment, appear to be robust to the forces exerted by loaders passing over them. Even where multiple loader passes caused tuatua at site 1 to protrude from the sand, they were not damaged by subsequent passes (Figure 18). Furthermore, the burial experiment, in which impact and control tuatua were equally able to right and bury themselves, provides additional evidence that clams buried within the beach sediment are not adversely impacted by loader traffic.

Moller et al. (2009) found that wide tyres reduced the impact of vehicles on juvenile toheroa on Oreti Beach in Southland. The loaders used to harvest mussel spat at Te Oneroa-a-Tōhē are configured with 0.405-m wide tyres which appear to distribute the weight of the loaders and reduce their penetration of the sand and impact on shellfish. Future research examining other types of vehicles being used on Te Oneroa-a-Tōhē will be useful in determining whether different vehicle and tyre width configurations have similarly minor effects.

Figure 18: Tuatua at site 1 partially forced out of the sand by the pressure exerted by repetitive loader passes.

Loaders did cause some mortality in clams that were not buried but were present on the beach surface. This included (a) juvenile clams that ‘floated’ to the surface where the upper layer of sediment had been liquefied by multiple loader passes, and (b) some of many hundreds of thousands of tuatua and juvenile toheroa observed washing around in the surf zone at sites 2 and 3 (Figure 19). As the tide receded many of these clams did not bury themselves but were left stranded on their sides on the beach surface where they were vulnerable to being crushed (no attempt was made to quantify differences in the number of beach cast clams at impact vs. control areas). Unfortunately, the experimental design did not adequately sample crushed beach cast clams because the sampling unit (13-cm diameter corer) was small and the density of crushed clams on the beach surface was low. For example, at site 3 (where a count of surface crushed clams was conducted) only 60 damaged clams were counted over an area of 400 m^2 beach surface (within which eighty 0.013 m^2 cores were extracted). Over the same area of beach, it is estimated, based on densities of clams recorded in cores, that the sediment was occupied by approximately 2.5 million juvenile toheroa and 143 000 tuatua. It is certain that there were more clams crushed both in the intertidal zone and in the shallow water at the foot of the beach than were counted that day at site 3. However, many of these damaged clams will have been lifted off the beach by the surf and carried away by the sweep of the surf and the receding tide. It would be difficult to measure this type of mortality because of the high energy environment the loaders work in. But given the density of clams present in the sediment, this unquantified mortality is likely to be relatively minor.

It is uncertain why the clams present on the beach surface had failed to bury themselves. Poor health or exhaustion from fighting against the surf to stay buried in the sand have been suggested as possible explanations, but this is only speculation. Whatever the cause, these beach cast clams will be vulnerable to beach traffic, desiccation, and predation by birds (or fish once the tide is in). At this stage, the fate of these particular clams is unknown. However, it is clear that the key to minimising vehicle related impacts on these beach cast clams will be by avoiding them. Because spat harvesting activity is not typically conducted during summer months, when juvenile toheroa and tuatua recruitment is greatest and when incidences of clams being mobile in the surf are most common, this avoidance should largely happen without needing much modification of mussel spat harvesting behaviour.

Although the results of this study indicate that mechanical spat harvesting is unlikely to be having any significant ecological effect on the shellfish beds of Te Oneroa-a-Tōhē, questions have been raised about the operation of loaders during this experiment and whether it is a good reflection of harvesting operations in the ‘real world’. Several observers suggested that loaders were travelling at much lower speeds than normal and that this would invalidate the study. Particular concerns were raised about loader tyres digging deep into the sand (and shellfish beds) during high speed turns. Although there are currently no data available to describe ‘real world’ loader operations, the speeds at which loaders were driven during this study have been documented (GPS data) and could be used to develop standard operating procedures for the industry. The proposed installation of GPS tracking units on loaders and the use of fisheries observers will facilitate the monitoring and enforcement of operating procedures established in the industry code of practice.

Another criticism of the experimental design was that loader buckets never contacted the beach surface. It has been said that when seaweed washes into the shallows, that loader buckets may be placed on the beach surface and be used to push the seaweed into deeper water where it can be more easily collected. This scenario could cause additional mortality through (a) bycatch of clams, or (b) crushing of clams that would otherwise be buried beneath the beach surface. If this is a common practice, some additional assessment of effects may be required.

Figure 19: Tuatua and toheroa deposited on the beach surface by the outgoing tide. Upper panel shows tuatua crushed by loader.

One of the most interesting results of this study was the presence of vast numbers of toheroa spat and juveniles on Te Oneroa-a-Tōhē. Although toheroa were once abundant along much of the beach (Williams et al. 2013a, Ross et al. 2018a), beds of adult toheroa are now only found in a few key locations. The presence of so many juvenile toheroa clearly indicates that larval supply is not limiting the recovery of toheroa, but suggests other factors are preventing juvenile toheroa from surviving through to adulthood. Disease (Ross et al. 2018b) or the availability of suitable habitat are likely candidates (Cope 2018). One of the main areas where adult toheroa are presently observed in large numbers is a section of beach south of Wakatehāua where the pine forest is set well back from the coast and where natural wetlands remain behind the sand dunes. This observation is consistent with current thinking around linkages between the flow of freshwater to the beach and the presence of toheroa beds (Williams et al. 2013b, Ross et al. 2018a, Cope 2018). There are suggestions that particular land uses, including forestry, may impact on quantity or quality of water reaching coast and that this might in turn impact the suitability of the beach to sustain toheroa populations. More research is required to understand these linkages.

4.1 Recommendations for future research

- There is currently limited detailed information available regarding the operation of the Te Hiku mussel spat fishery. Future research should include an analysis of loader GPS data to (a) provide more detailed spatial information about the fishery, including an analysis of how much of Te Oneroa-a-Tōhē is potentially impacted by harvesting operations, and (b) provide a better understanding of real world loader operations.
- One of the major remaining concerns expressed since the completion of this experiment is the potential impact of loaders on recently recruited toheroa and tuatua spat. Because mussel spat harvesting activity is not typically conducted during summer months, when juvenile toheroa and tuatua recruitment is greatest, avoidance of this potential impact should largely occur without the need to modify mussel spat harvesting operations. To confirm this assumption (limited temporal overlap between clam recruitment and loader operations) and help identify further opportunities to minimise potential impacts, it may be necessary to collect some additional data on the recruitment dynamics of toheroa and tuatua (spatial and temporal recruitment patterns).
- A variety of different types of vehicles are driven on Te Oneroa-a-Tōhē, including buses, loaders, cars, SUVs, motorbikes, and quad bikes. These vehicles vary considerably in terms of their weight and tyre width and type, and the way they are driven (both straight line and turning speed). Future research should include an assessment of the potential impacts of different vehicle types and driving behaviours.
- The consequences removing seaweed from Te Oneroa-a-Tōhē are unknown. Beach cast seaweed can play a significant role in coastal ecosystems, including supporting a diverse ecology of organisms through nutrient cycling and decomposition (Zemke-White et al. 2005). Beach cast seaweed can provide habitat for pioneering, dune forming vegetation and when washed back into the sea can become available as a food source for a variety of organisms including sea urchins and pāua (abalone). The floating component of the drift algae may also play a significant role in the dispersal of beach invertebrate species and juvenile fish. Seaweed decomposition has also been identified as an important nitrogen source for coastal waters due to the relatively rapid release of nutrients during breakdown, with flow-on effects to primary productivity (phytoplankton) and on up the food chain. Future research should include an assessment of the consequences of removing algal biomass through the harvesting of mussel spat.

5. CONCLUSIONS

When these surf clams were either fully or partially buried in sands of Te Oneroa-a-Tōhē there was no detectable impact of mechanical spat harvesting loaders on tuatua or toheroa. When standing on end these clams appear robust to the forces exerted by loaders upon the sediment surface. However, when they are on top of the sediment, lying on their sides, both tuatua and toheroa are vulnerable to being crushed by all forms of vehicle traffic. These vulnerable clams included those that were deposited on the beach surface by the receding tide, and juveniles (mainly toheroa during this study) that floated to the surface where the top layers of beach sand were liquefied by multiple loader passes. Although not quantified by the sampling methodology used here, this type of crushing of beach cast clams was observed at sites 2 and 3. However, the data reported here indicate that the number of clams crushed on the beach surface was small relative to the high abundances of clams present and unharmed within the beach sediment.

The intensity of spat harvesting simulated here was several times greater than what could be expected to occur in the ‘real world’. It should be reassuring for the community and environmental managers that there was nothing observed during this ‘worst case scenario’ experiment to indicate that mechanical harvesting is having a significant ecological effect on the toheroa or tuatua of Te Oneroa-a-Tōhē. Some mortality was observed during the study and is expected to occur during mussel spat harvesting. However, rates of mortality are expected to be small relative to the size of the clam population and not likely to compromise the viability of either clam species when assessed at the scale of either an individual shellfish bed or the entire beach.

To minimise clam mortality caused by spat harvesting, loader operators should endeavour to avoid areas where large numbers of surf clams are beach cast or observed washing around in the shallow subtidal. It would also be prudent, because of the current depressed state of toheroa populations on Te Oneroa-a-Tōhē, for spat harvesters to avoid areas of known toheroa beds where possible to minimise impacts on this species.

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