# CHAPTER 2: VEHICLE USAGE OF THE STUDY BEACHES

## 1. Introduction

Few studies have looked at the level of vehicle usage on beaches. In Queensland, Australia, Schlacher and Thompson (2008) measured ruts caused by vehicles on the beach at North Stradbroke Island up to 28cm deep, with a mean rut depth of 5.8±4.7cm, and found that up to a maximum of 90% of the beach-face was covered by tyre tracks. Also on North Stradbroke Island, Schlacher & Morrison (2008) found that 15% of the intertidal area of the beach was rutted by just 10 vehicle passes, with 85% of the surface rutted after 100 vehicle passes. These studies have looked at the typical case of 4WD vehicles use on intertidal beaches, where vehicles will access beaches via a ramp or dune track, drive along the beach with reduced tyre pressures (i.e. 20psi on the beach rather than pressures used on sealed roads of around 40psi) and often in low gear range, especially on softer sands. Vehicle access to the beach in this way is generally for the purpose of fishing, camping or to travel to remote locations. In contrast, the level and patterns of vehicle usage on beaches in the southern Adelaide metropolitan region appear to be quite different. These metropolitan beaches are a popular destination for recreation in the summer months, especially on weekends, public holidays and days of high temperatures. Access to the beaches by vehicle does not require a 4WD, so many vehicles on the beach are 2WD (e.g. sedans and hatchback vehicles), and drivers tend to park their cars for the time they are on the beach rather than traversing the beach for long distances (pers. obs.). Thus, an understanding of vehicle usage levels and patterns specific to the main study beaches (see Chapter 1; Figures 1.3 & 1.5) is needed, firstly to understand and quantify the local situation, and then to interpret the results of investigations in other chapters of this thesis. Thus, the overriding aim of this study was to quantify vehicle usage and identify any usage patterns based on seasons or zones of the beach. Specifically, this chapter will:

- Define the level of vehicle (and pedestrian) usage on the nine main study beaches (see Chapter 1; Figure 1.3), and patterns in usage across all months of the year and among the three different zones on the beach-face (i.e. high-, mid- and low-shore);

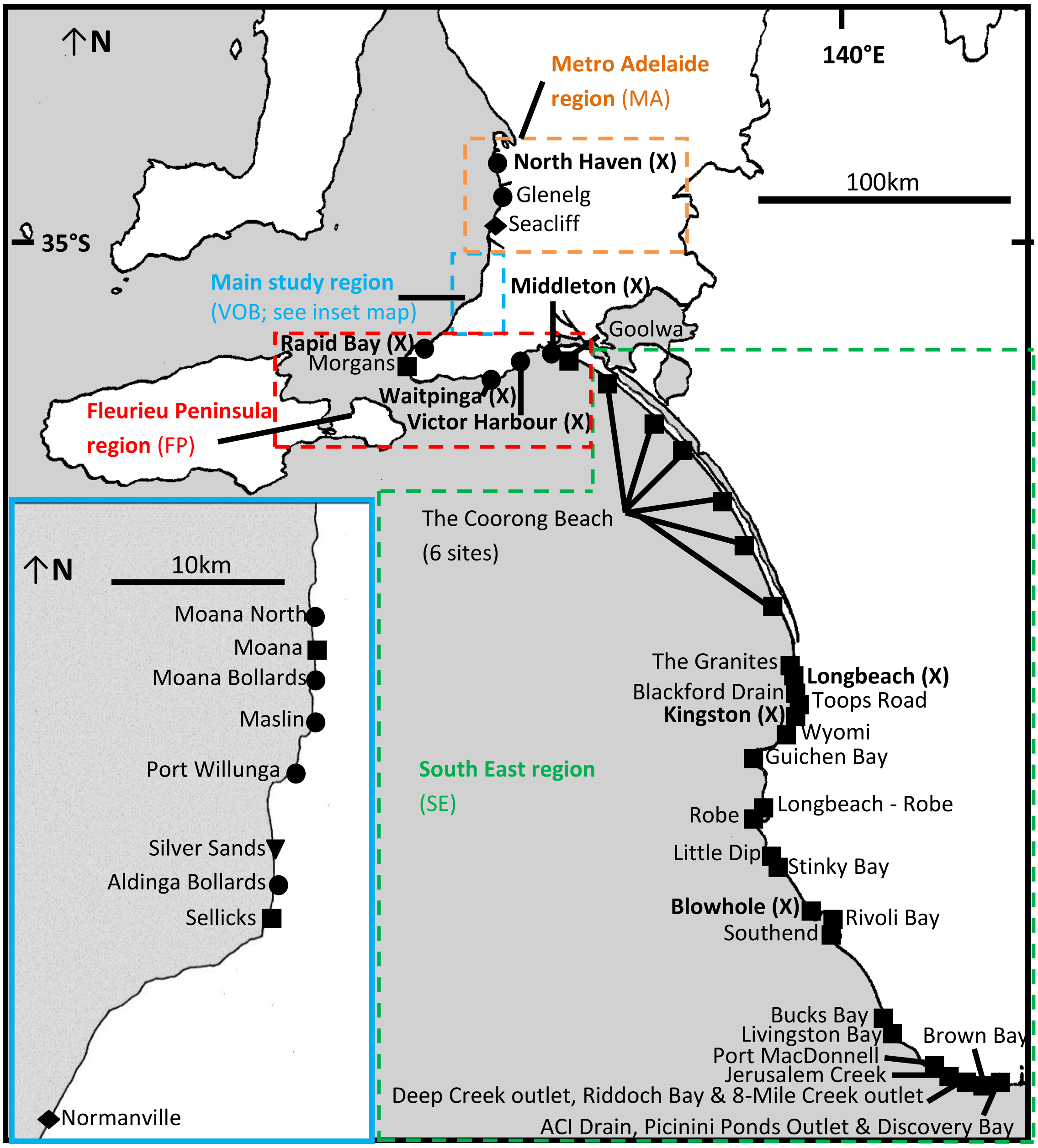
- Define the level and patterns of pedestrian usage and see how these relate to patterns of vehicle usage; and
- Contrast vehicle usage on beaches within the main study region (see Chapter 1; Figure 1.3) with other beaches across south-eastern South Australia.

By doing this, I hope to be able to put the levels of vehicle usage on the southern metropolitan Adelaide beaches (i.e. the nine main study beaches) into a regional context in the general discussion, and also, where possible, to compare levels and patterns of vehicle usage on beaches in south-eastern South Australia (including the southern metropolitan beaches) with levels reported in the literature for other beaches both interstate and overseas.

## 2. Methods

All nine beaches/beach sections used in the main study (hereafter VOB for Vehicles On Beaches main study) (see Figure 1.3) were surveyed for vehicle usage between March 2006 and May 2008 (i.e. 27 months). During each survey, a single transect was set out across the beach, extending between the vegetation line and the swash. Total beach width and the width of each zone (high-, mid- & low-shore, as defined in Chapter 1; Figure 1.2) were measured and transect features (e.g. positions of the cobble bed, wrack drift-line, effluent point etc.) were recorded. A sketch of the profile of the beach was made to track changes in beach profile. The numbers of vehicle tracks, pedestrian footprints and pedestrians in each zone were counted and other signs of human recreational beach usage (i.e. bike tracks & hoof prints) were noted. All vehicles in each zone within 100m either side of each transect were also counted. For Aldinga Bollards, which is only 140m long, any vehicles and pedestrians in the entire section were counted. Surveys were conducted approximately monthly wherever possible, on random days during the week and at random times during the day. In addition, the same information was collected on each of three replicate transects per study site conducted as part of the main study three times each year for three years (see Chapters 4, 5 & 6). Finally, to put vehicle usage data into a larger

**Figure 2.1:** Map of sites surveyed for vehicle usage by region. Symbols represent vehicle access to each beach (open beaches/beach sections = squares; closed beaches/beach sections = circles; seasonal closure = triangle; boat-launch only = diamonds). The few ($n$ = 9) beaches where no vehicle activity (i.e. no vehicles or tracks observed) was ever recorded have names in **bold text** with a cross **(X)** in addition to their type marker.



context, transects were also conducted opportunistically (as part of other research projects) on beaches with different degrees of vehicle accessibility (see Figure 2.1) in the metropolitan Adelaide (hereafter MA) region, the Fleurieu Peninsula (hereafter FP) and the South-East (hereafter SE) of South Australia.

To quantify the area of the beach-face covered by vehicle tracks, line intercept transects were used to measure the width of tracks and the space between tracks on any of the 9 VOB beaches where tracks were recorded during the sampling occasions in July and November 2006.

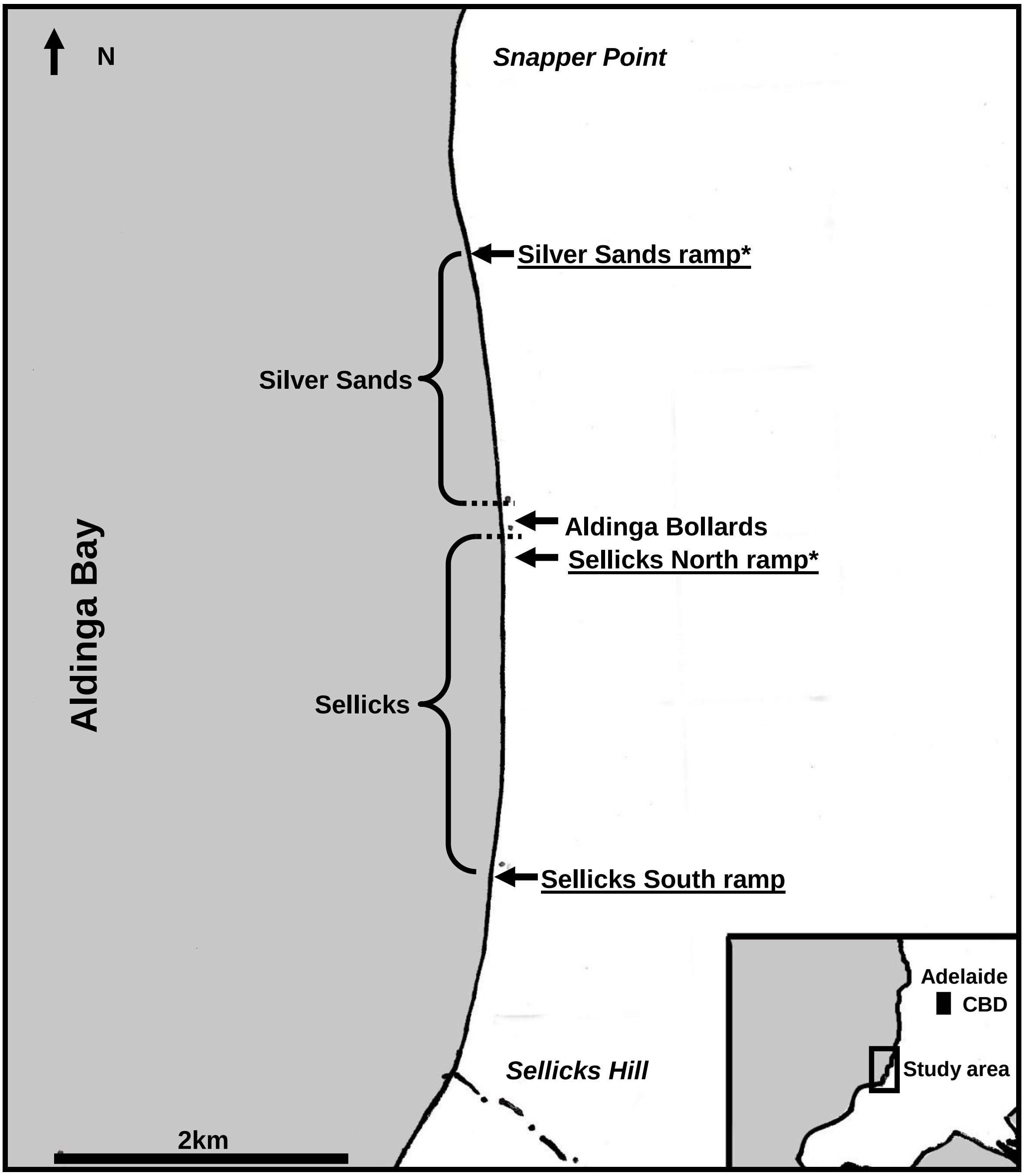
Finally, in 2007/08, the local governing council of the main study region (City of Onkaparinga) placed vehicle traffic counters on two of the Aldinga Bay beach-access ramps, Silver Sands ramp and Sellicks north ramp (Figure 2.2). These counters were set either on the ramp itself or on the roadway leading to the ramp and left for one week (7 full days) at a time during four different months. Traffic counters record all vehicles using the ramps, 24 hours a day, and provided daily totals for ramp usage. These data were then kindly provided to me by the City of Onkaparinga.

*Statistics*

All data were analysed using version 11 of the SYSTAT software package (for univariate analyses).

Graphical comparisons and descriptive statistics (means ±standard error) were generated from the data by vehicle access Types (e.g. open, seasonal, boat launch only, closed or bollarded), Seasons (i.e. austral summer, autumn, winter and spring) and beach Zones (as defined in Chapter 1; i.e. high-, mid- or low-shore) separately for each region (i.e. VOB, MA, FP and SE). VOB beaches are sites that are later used to quantify physical (see Chapter 3) and biological (see Chapter 5, 6), impacts of vehicles using the study design described in Chapter 1 (i.e. with three seasonal sampling occasions; i.e. mid- winter, pre- and post-summer, rather than sampling in each season), and so comparisons were also made using only transects conducted during sampling visits for the main study. Formal statistical tests were not conducted on these data due to the lack of replication (i.e. only one

**Figure 2.2:** Map of the Silver Sands, Aldinga Bollards and Sellicks Beach sections at Aldinga Bay, South Australia. Ramps with asterisks had counters placed on them by the local council. Snapper Point and Sellicks Hill (i.e. names in italics) are both rocky headlands located at either end of a continuous sandy beach; both headlands are impassable by vehicles. Inset map shows study area in relation to Adelaide CBD.



transect per beach per trip). This information is only intended as a means by which to identify times of high- and low-intensity vehicle usage on the study beaches, to determine if there was any usage of beaches that were closed to vehicles (either permanently or seasonally) during the study, and to put the level of usage of the main study beaches into some more regional context.

## 3. Results

In total, 428 transects were conducted on 43 South Australian beaches across 27 months. Of these, the majority (N = 308) of transects were conducted on the 9 VOB beaches, a further 105 transects were taken on 26 beaches in the SE, 8 transects were undertaken on 6 FP beaches and 7 transects from 3 MA beaches (Table 2.1). There was a reasonably even spread of transects across months and seasons for the VOB beaches (Table 2.1). Because trips to the SE, MA and FP beaches were opportunistic, some regions (except VOB) and seasons were either under-sampled or completely missed (Table 2.1), specifically SE beaches in autumn, and the MA and FP regions more generally. Some level of vehicle activity (i.e. vehicles or tracks observed) was recorded on 34 of the 43 beaches surveyed (Figure 2.1). The highest vehicle count was 151 vehicles (along 200m of beach) at Moana in January 2009. Measured track density was greatest at Sellicks Beach in December 2006, with 2.3 tracks per linear metre of beach, equating to 221 tracks in total.

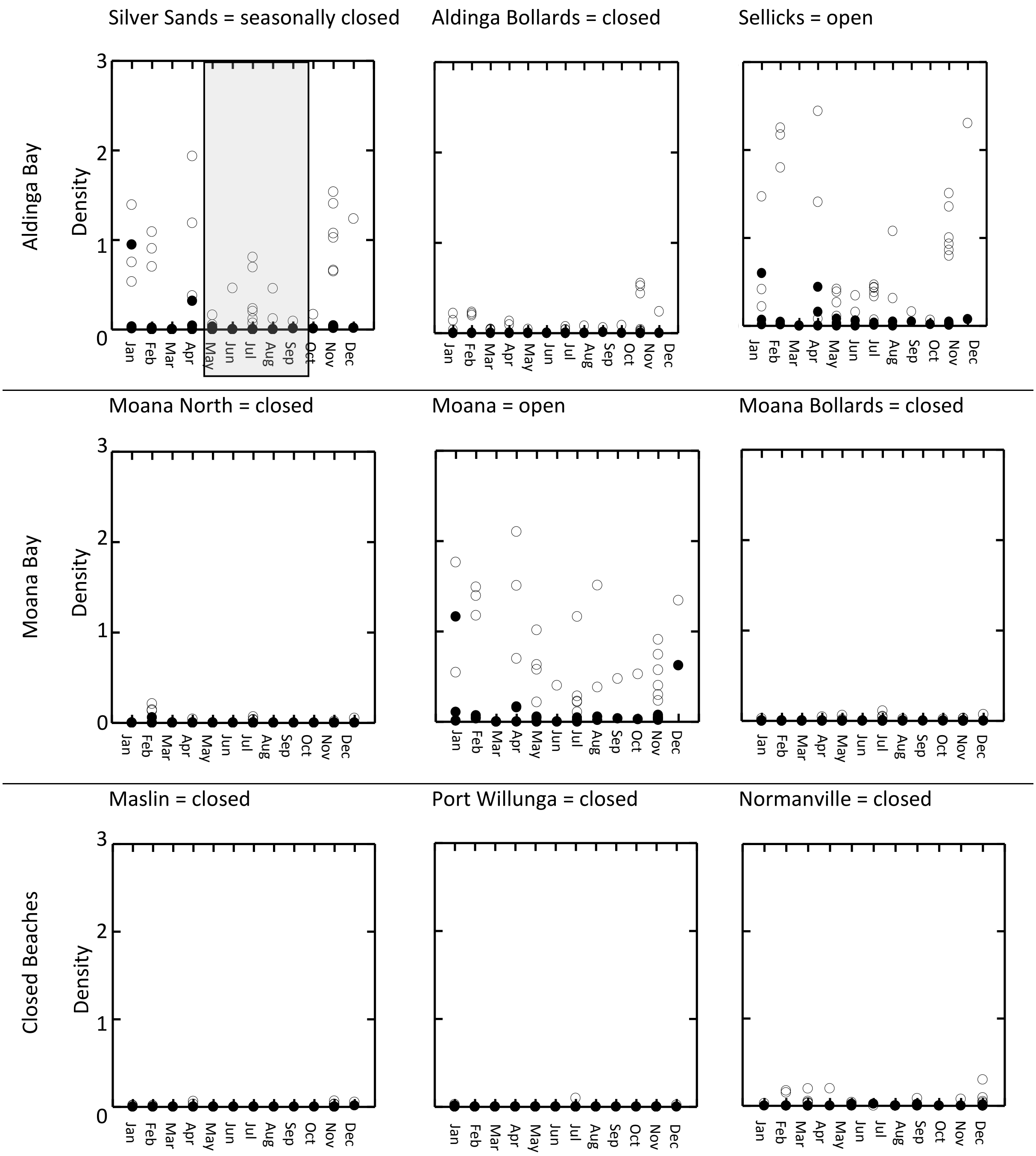
*Vehicle activity on VOB beaches open or closed to vehicles*

All VOB beaches, including those ‘closed’ to vehicle traffic, recorded some vehicle activity during the surveys (Figure 2.1). On closed beaches, mean vehicle density (<0.001 ±0.000 vehicles.200m$^{-1}$; $n$ = 70) and track density (0.007 ±0.013 tracks.m$^{-1}$; $n$ = 70) was negligible, noticeably lower than levels on the open beaches (0.070 ±0.021 vehicles.200m$^{-1}$; 0.704 ±0.079 tracks.m$^{-1}$; $n$ = 70; Figure 2.3). Vehicle activity on open beaches (i.e. Moana and Sellicks) was relatively high throughout the year compared with closed beaches (i.e. Maslin and Port Willunga; Figure 2.3). There was marginally greater activity on open beaches in the austral summer months (i.e. Dec-Feb), especially at Sellicks Beach but, the highest densities of vehicle tracks recorded at both open beaches occurred in April (Figure 2.3),

**Table 2.1:** Number of transects surveyed between March 2006 and May 2008 broken down into seasons, months and regions (VOB = main study beaches; SE = South-East; FP = Fleurieu Peninsula; MA = metropolitan Adelaide). Numbers in brackets (i.e. *N* = x) are number of beaches sampled per region. Asterisks indicate transects conducted on VOB beaches during seasonal sampling occasions for fauna (i.e. data collected for Chapters 4-6).

| Season | Month | VOB (*N* = 9) | SE (*N* = 26) | FP (*N* = 6) | MA (*N* = 3) | ALL (*N* = 43) |
|---|---|---|---|---|---|---|
| **Summer** | December | 8 | 23 | 0 | 0 | 31 |
| | January | 25 | 0 | 0 | 0 | 25 |
| | February | 27* | 14 | 1 | 0 | 42 |
| | **Seasonal total:** | **60** | **37** | **1** | **0** | **98** |
| **Autumn** | March | 28* | 0 | 1 | 0 | 29 |
| | April | 25 | 5 | 3 | 3 | 36 |
| | May | 34 | 0 | 1 | 0 | 35 |
| | **Seasonal total:** | **87** | **5** | **5** | **3** | **100** |
| **Winter** | June | 17 | 16 | 2 | 2 | 37 |
| | July | 54* | 7 | 0 | 0 | 61 |
| | August | 18 | 14 | 0 | 0 | 32 |
| | **Seasonal total:** | **89** | **37** | **2** | **2** | **130** |
| **Spring** | September | 9 | 20 | 0 | 0 | 29 |
| | October | 9 | 0 | 0 | 2 | 11 |
| | November | 54* | 6 | 0 | 0 | 60 |
| | **Seasonal total:** | **72** | **26** | **0** | **2** | **100** |
| | **Grand total:** | **308** | **105** | **8** | **7** | **428** |

**Figure 2.3:** Vehicle activity across months (x-axis) on the nine main-study (VOB) beaches. Each point represents the measured density of either vehicles (per 200m of beach; solid-fill points) or counted vehicle tracks (per linear metre of beach width; unfilled points) for each transect (i.e. there is one solid and unfilled point per transect, values presented are not means). The grey shaded box for Silver Sands indicates when this beach section is closed to vehicles (during austral winter months). The y-axis is consistent across all plots.



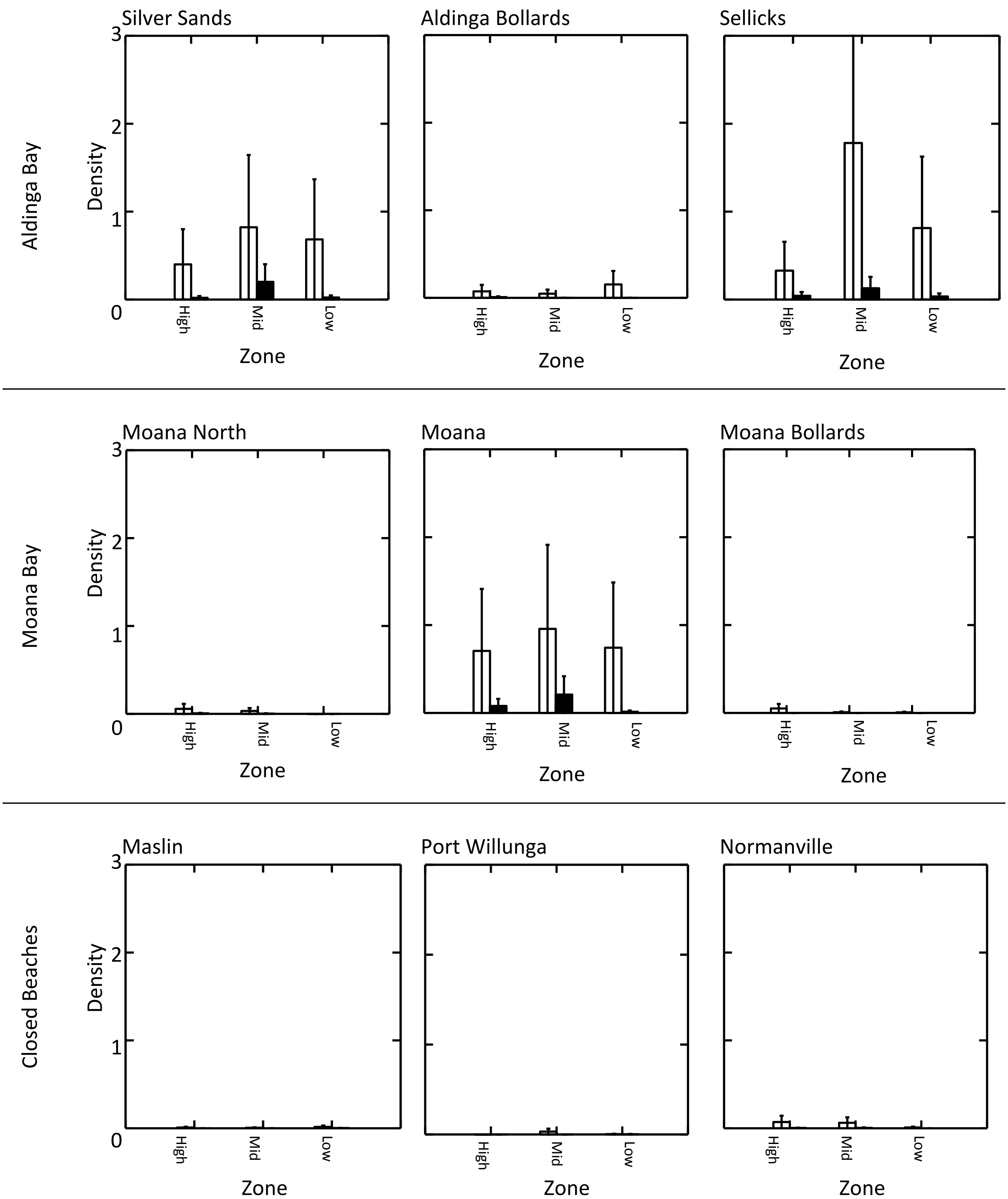
corresponding to the Easter long-weekend holiday in South Australia. The highest vehicle densities observed on the study beaches was recorded at Moana Beach on the Australia Day public holiday (Jan 26$^{th}$) in 2009: with approximately 750 vehicles per km of beach at Moana on this day, and the local council was forced to close the beach ramp due to lack of space for parking on the beach (see Figure 1.4a). Due to this extremely high vehicle density, it was not possible to count tracks or pedestrian activity on this occasion.

Vehicles were seen infrequently driving or parked in the low- or mid-shore zone on the closed beaches (i.e. Maslin and Port Willunga, respectively; Figure 2.4). Tracks on closed beaches were also infrequent; track density was highest in the low-shore of Maslin Beach (0.016 ±0.008 tracks.m$^{-1}$; $n$ = 35) and the mid-shore of Port Willunga Beach (0.032 ±0.027 tracks.m$^{-1}$; $n$ = 35; Figure 2.4). On Sellicks Beach, vehicle activity was similar across the three beach zones, with a tendency for greater activity in the mid-shore zone (Figure 2.4), both for mean vehicle density (0.129 ±0.034 vehicles.200m$^{-1}$; $n$ = 35) and track density (1.781 ±0.039 tracks.m$^{-1}$; $n$ = 35); also, the low-shore zone had higher track density (0.813 ±0.181 tracks.m$^{-1}$; $n$ = 35) than the high-shore zone (0.329 ±0.073 tracks.m$^{-1}$; $n$ = 35), but there were similar numbers of vehicles in the high-shore (0.043 ±0.029 tracks.m$^{-1}$; $n$ = 35) and low-shore (0.035 ±0.016 tracks.m$^{-1}$; $n$ = 35) zones. Similar patterns were observed on the second open beach, Moana (Figure 2.4). Vehicle activity on both open beaches was greatest during the post-summer sampling occasion, and lowest during the mid-winter sampling occasion, but never as low as on the two beaches closed to vehicles (i.e. Maslin & Port Willunga; Figure 2.5).

*Aldinga Bay*

Some level of vehicle activity (i.e. both tracks and vehicles) was recorded in all sections at Aldinga Bay throughout the year (Figure 2.3), including the permanently-closed bollarded section, and during the winter months when the seasonal closure at Silver Sands is in effect (Figure 2.3). Track densities inside the bollards were greatest in summer when both sections either side of the bollards are open to vehicle usage and daylight tides are lowest. Track

**Figure 2.4:** Vehicle activity across shore levels (i.e. zones) on the nine main study (VOB) beaches. The y-axis shows the mean density of either vehicles counted (per 200m of beach; ±SE; solid-fill bars) or vehicle tracks (per linear metre of beach; ±SE; unfilled bars) for each zone across all transects ($n$ = 35 transects per zone per beach). The y-axis is consistent across all nine plots.

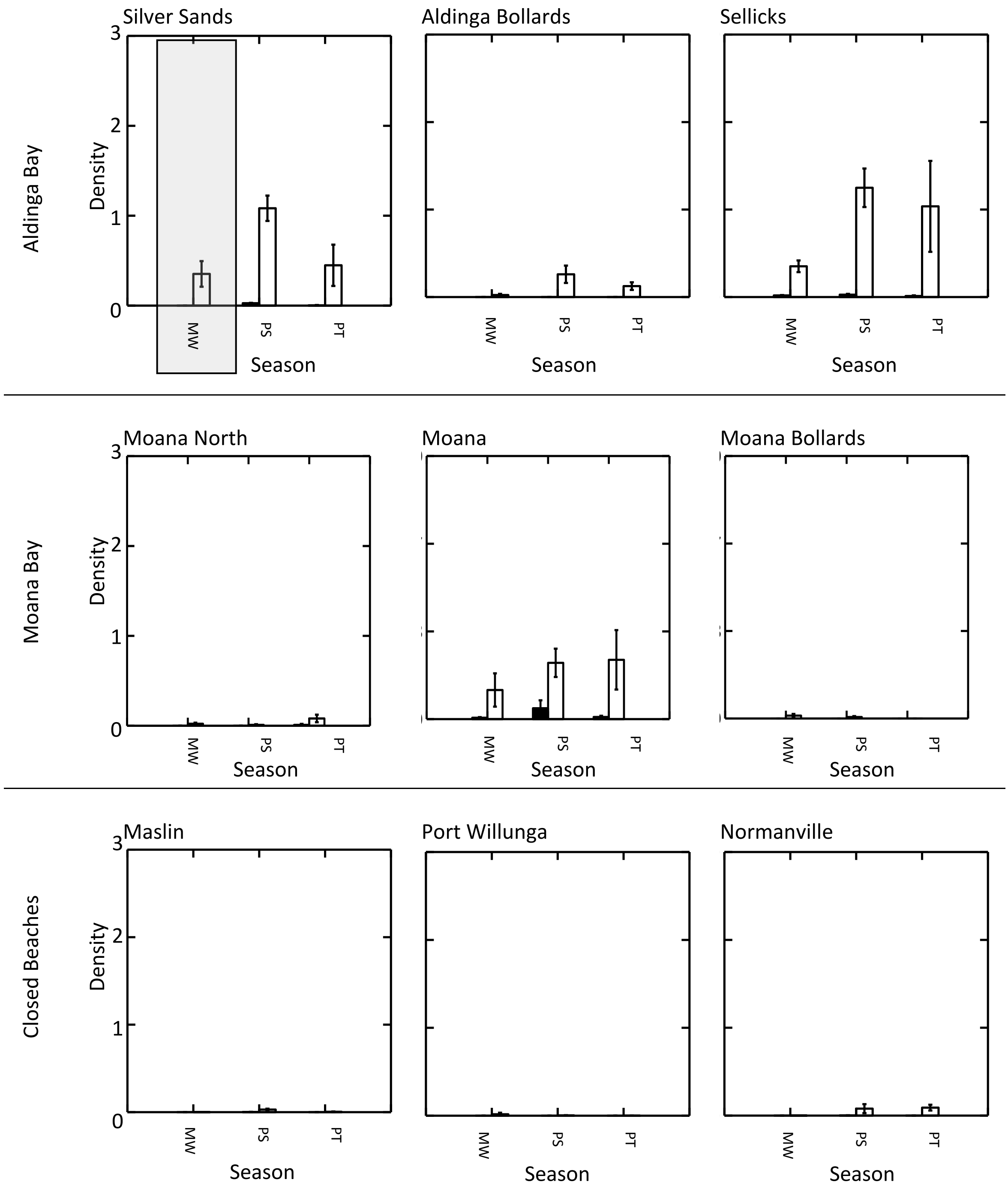


densities were twice as high in the low-shore (0.102 ±0.024 tracks.$m^{-1}$; $n$ = 35) relative to the mid-shore (0.047 ±0.027 tracks.$m^{-1}$; $n$ = 35) or high-shore zones (0.074 ±0.021 tracks.$m^{-1}$; $n$ = 35; Figure 2.4). Like Sellicks Beach, traffic at Silver Sands was concentrated in the mid- and low-shore zones (Figure 2.4). Track density was reduced (but not eliminated) during the winter closure period (0.231 ±0.066 tracks.$m^{-1}$; $n$ = 15) relative to the open season (0.830 ±0.123 tracks.$m^{-1}$; $n$ = 20; Figure 2.5). When tested by one-way ANOVA, there was no significant difference in vehicle activity (source: track density, $4^{th}$ root transformed; $F_{2,15} = 0.531$; $p > 0.05$) during the mid-winter sampling occasion among the three beaches where vehicle access was permitted during the summer months (i.e. among Moana, Sellicks and Silver Sands Beaches; Figure 2.5), a time when one of these beaches, Silver Sands, is closed to vehicles. During the summer open period, vehicle activity (both vehicle and track densities) on Silver Sands section was lower than the southern, year-round open section, Sellicks Beach, for the same period (e.g. Sellicks track density for the period Oct. – May: 1.052 ±0.191 tracks.$m^{-1}$; $n$ = 20). Vehicle track density was significantly lower in the seasonal closure (i.e. Silver Sands) section during the winter closure period compared to the summertime open period (2-sample $t$-test; $t$ for 32.5d.f. = - 3.531; $p < 0.01$).

*Moana Bay*

Again, some level of vehicle activity (i.e. both tracks and vehicles) was recorded in each section of Moana Bay, including the two permanently-closed sections, Moana North and Moana Bollards, but vehicle activity was always much greater in the open section (Figure 2.3). Vehicle activity (both vehicle and track density) on the Moana open section was marginally higher during the austral summer months (i.e. pre- and post-summer sampling occasions; Figure 2.5). Although vehicle activity for all three seasonal sampling occasions (i.e. mid-winter, pre- and post-summer) was very low for both closed sections, there was some activity during mid-winter, when activity on the open section was lowest (Figure 2.5). Moana Bollards was the only beach section where vehicles were never observed; however, vehicle tracks were observed throughout the year (Figure 2.3) and in all zones (Figure 2.4) on this beach section. Track density was greater in the high-shore zone at

**Figure 2.5:** Vehicle activity across seasonal sampling occasions (MW: mid-winter; PS: pre-summer; PT: post-summer) on the nine main study (VOB) beaches. Each bar represents the mean density of either vehicles observed (per 200m of beach; ±SE; solid-fill bars) or vehicle tracks (per linear metre of beach; ±SE; unfilled bars) for each zone across all transects (*n* = 9 transects per season per beach). Silver Sands is closed to vehicles for the mid-winter sampling occasion (grey box). The y-axis is consistent across all nine plots.



Moana Bollards (0.051 ±0.025 tracks.$m^{-1}$; $n$ = 35; Figure 2.4). Unlike the Moana open section, track density inside the bollards was greatest in the winter months (Figure 2.5). Mean track densities recorded at Moana North and inside Moana Bollards were similar (0.021 ±0.008 & 0.014 ±0.004 tracks.$m^{-1}$; $n$ = 35, respectively), and much lower than the open section (0.654 ±0.098 tracks.$m^{-1}$; $n$ = 35).

*Normanville*

The level of vehicle activity at Normanville was quite low (0.002 ±0.001 vehicles.200$m^{-1}$; 0.055 ±0.015 tracks.$m^{-1}$; $n$ = 28; Figures 2.3-2.5). Activity was greater in the high- and mid-shore zones (Figure 2.4) and during the summer seasonal sampling occasions (Figure 2.5). Levels of vehicle usage (both vehicles and tracks) at Normanville were similar to those observed at the two closed beaches, Maslin and Port Willunga, as well as the closure sections at Moana Bay and also Aldinga Bollards closure at Aldinga Bay (Figure 2.3-2.5).

*Pedestrian usage*

Pedestrian usage (measured as counts of pedestrians or their footprints) was relatively similar among the nine main study beaches throughout the year (Figure 2.6). At Moana Bay, pedestrian footprint density was marginally greater in the sections closed to vehicles than the open section (Figure 2.6). Mean pedestrian footprint density was slightly greater on beaches without sections open to vehicles (Port Willunga & Maslin Beaches; Figure 2.6). Mean pedestrian footprint density was highest in the mid-shore zone for all beaches (Figure 2.7), with the exception of Maslin beach (high-shore), and Port Willunga had very high mean footprint densities in both the mid- and high-shores (Figure 2.7). Footprint density did not vary greatly though seasons (Figure 2.8), but was generally slightly lower in winter months, except at Port Willunga (Figure 2.8). In summer months, when vehicle activity at Aldinga Bay was highest, pedestrian foot traffic was higher within the bollards than both of the open sections (Figure 2.8).

**Figure 2.6:** Pedestrian activity across months (x-axis) on the nine main study (VOB) beaches. Each point represents the density of either pedestrians counted (per 200m of beach; solid-fill points) or footprints (per linear metre of beach; unfilled points) for each transect. The y-axis is consistent across all nine plots.

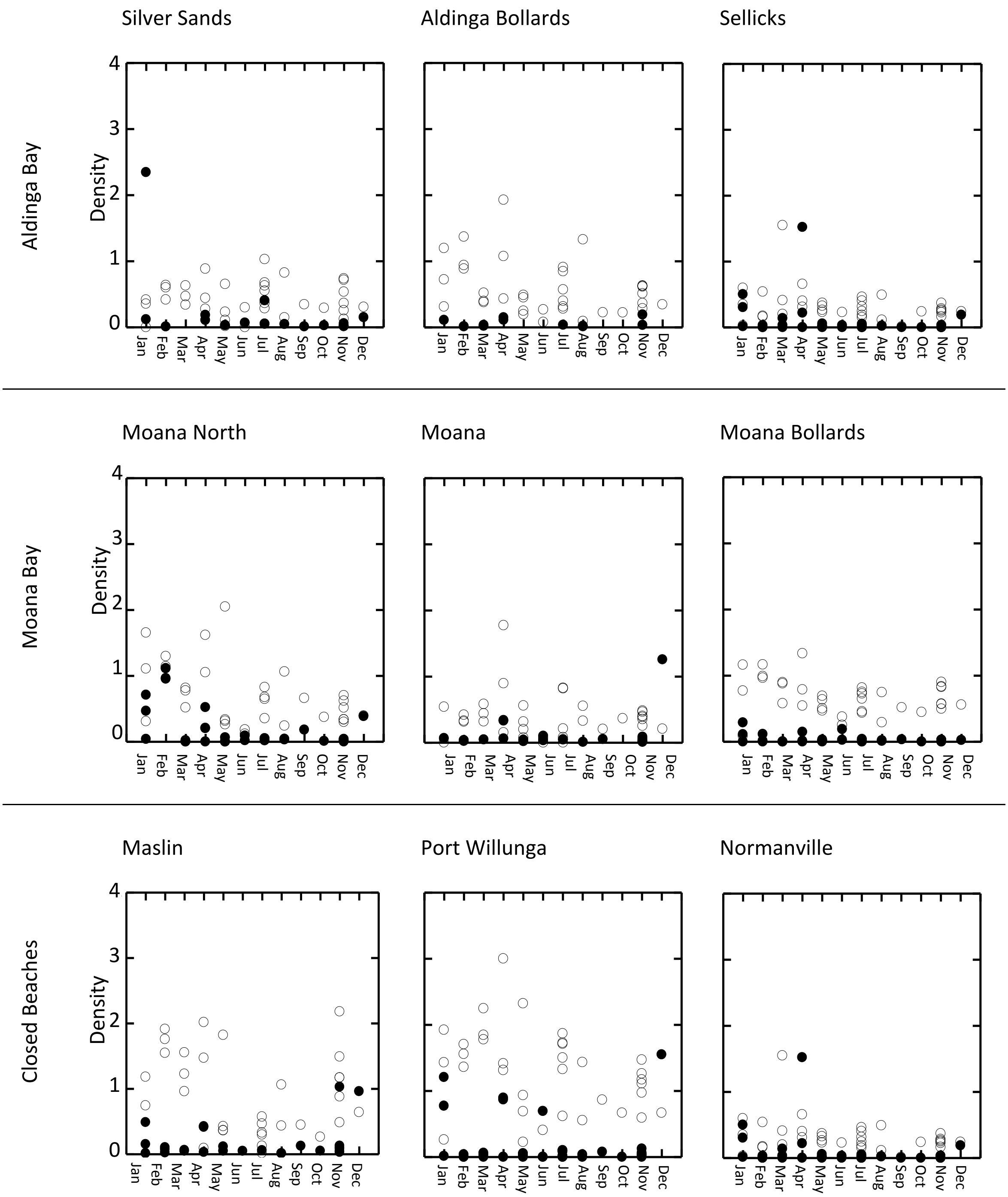


**Figure 2.7:** Pedestrian activity across zones on the nine main study (VOB) beaches. Each bar represents the mean density of either pedestrians counted (per 200m of beach; ±SE; solid-fill bars) or footprints (per linear metre of beach; ±SE; unfilled bars) for each zone across all transects (*n* = 35 transects per zone per beach). The y-axis is consistent across all nine plots.

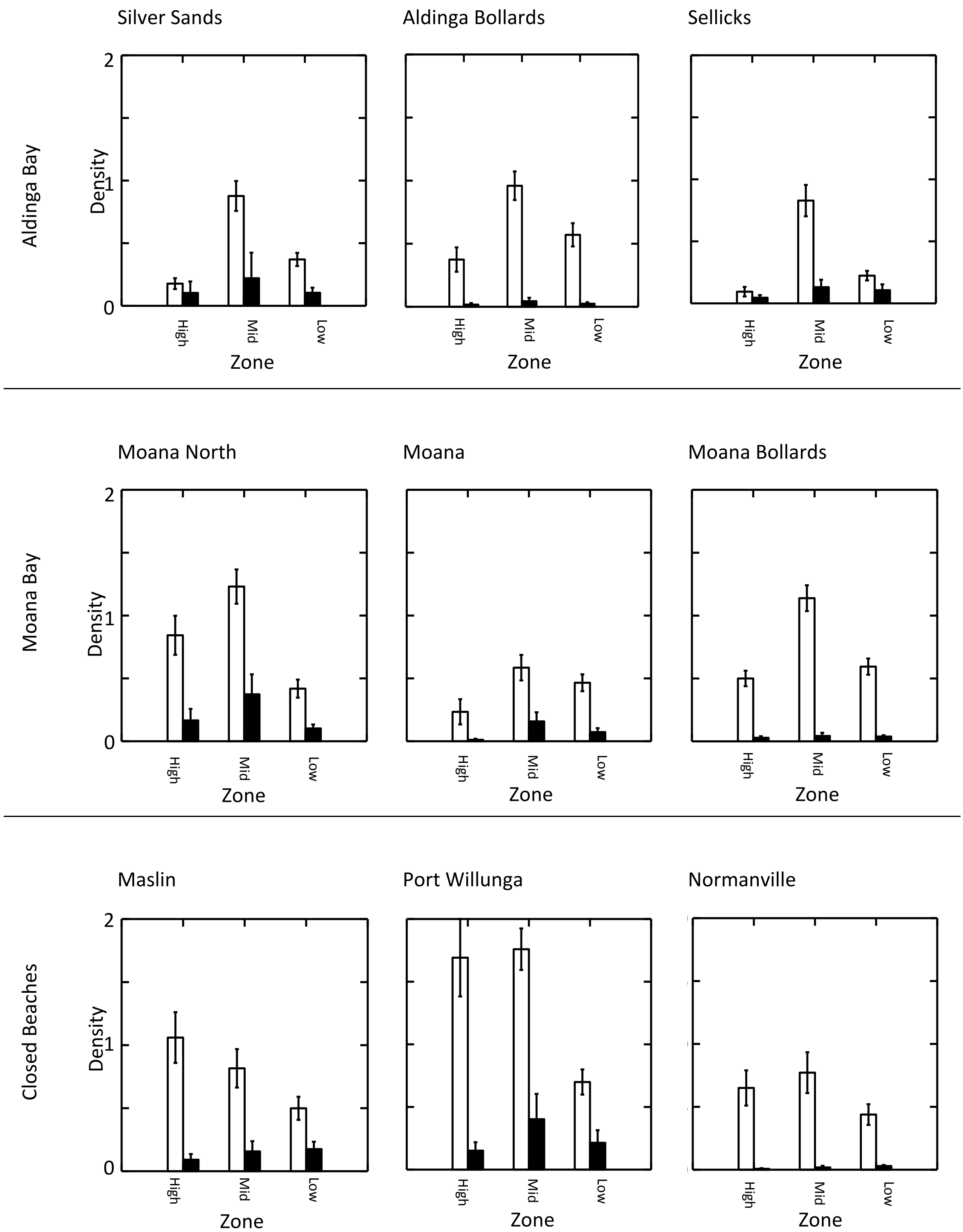


**Figure 2.8:** Pedestrian activity across seasonal sampling occasions (MW: mid-winter; PS: pre-summer; PT: post-summer) on the 9 main study (VOB) beaches. Each bar represents the mean density of either pedestrians counted (per 200m of beach; ±SE; solid-full bars) or footprints (per linear metre of beach; ±SE; unfilled bars) for each zone across all transects (*n* = 9 transects per season per beach). The y-axis is consistent across all nine plots.

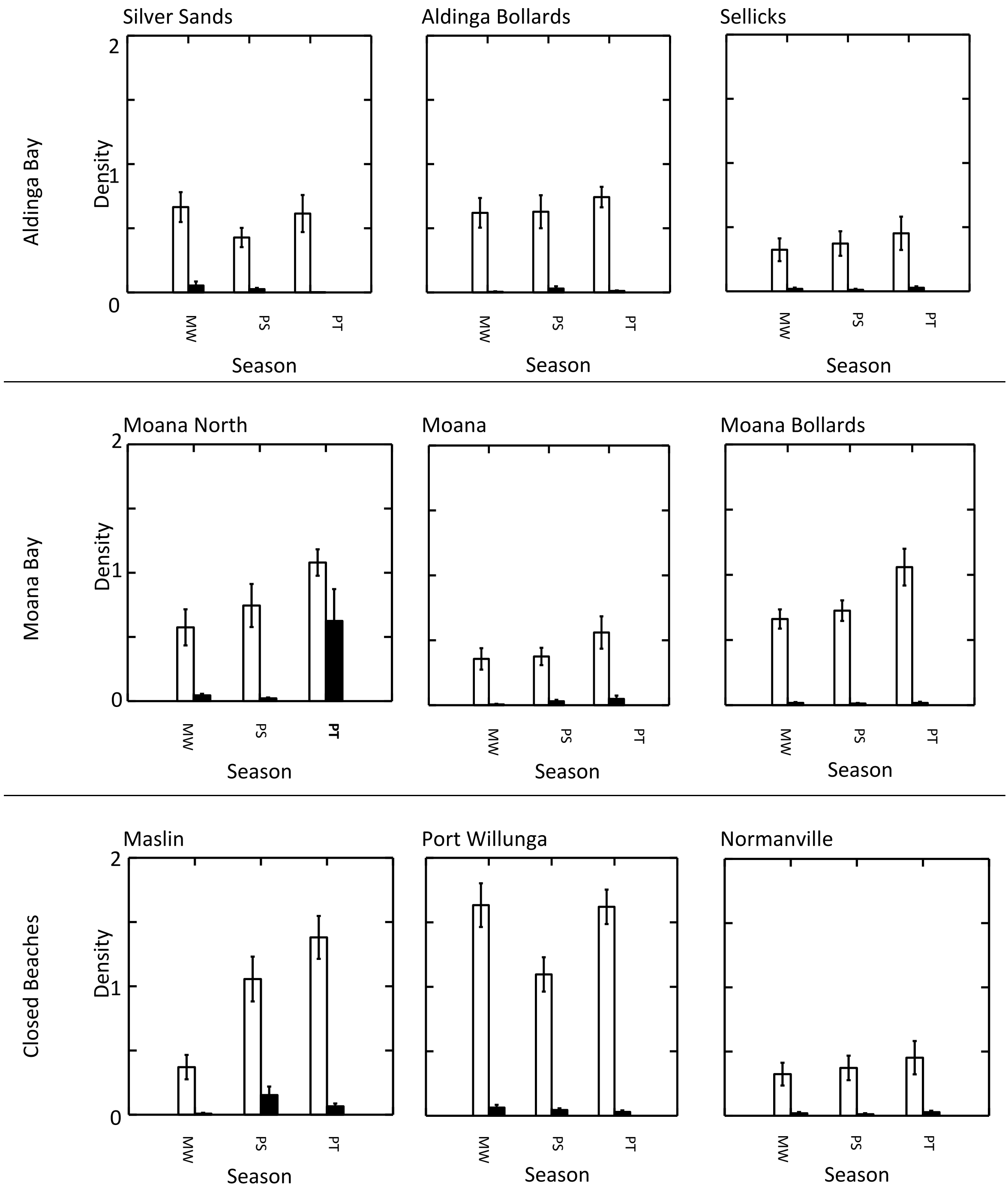


**Table 2.2:** Comparisons of ramp traffic counter and on-beach survey counts of vehicle tracks for Silver Sands and Sellicks Beach sections at Aldinga Bay. For each beach, the first column 'Traffic' lists the average number of vehicle passes over the traffic counter per day over the 7 days for which data was collected during each deployment. The second column, 'Tracks' shows the number of tracks counted across the beach either as a total (for August 2007 & January 2008) or averaged across three replicate transects where possible (i.e. for November 2007). Unfortunately, there were no beach surveys conducted in December 2007 with which to compare ramp counter data.

| Section: | Silver Sands | | Sellicks | |
|---|---|---|---|---|
| Month | Traffic | Tracks | Traffic | Tracks |
| Aug 07 | 228.0 | 31 | 105.9 | 57 |
| Nov 07 | 546.7 | 102.7 | 240.4 | 97.3 |
| Jan 08 | 1258.4 | 59 | 415.4 | 27 |

*Vehicle ramp access at Aldinga Bay*

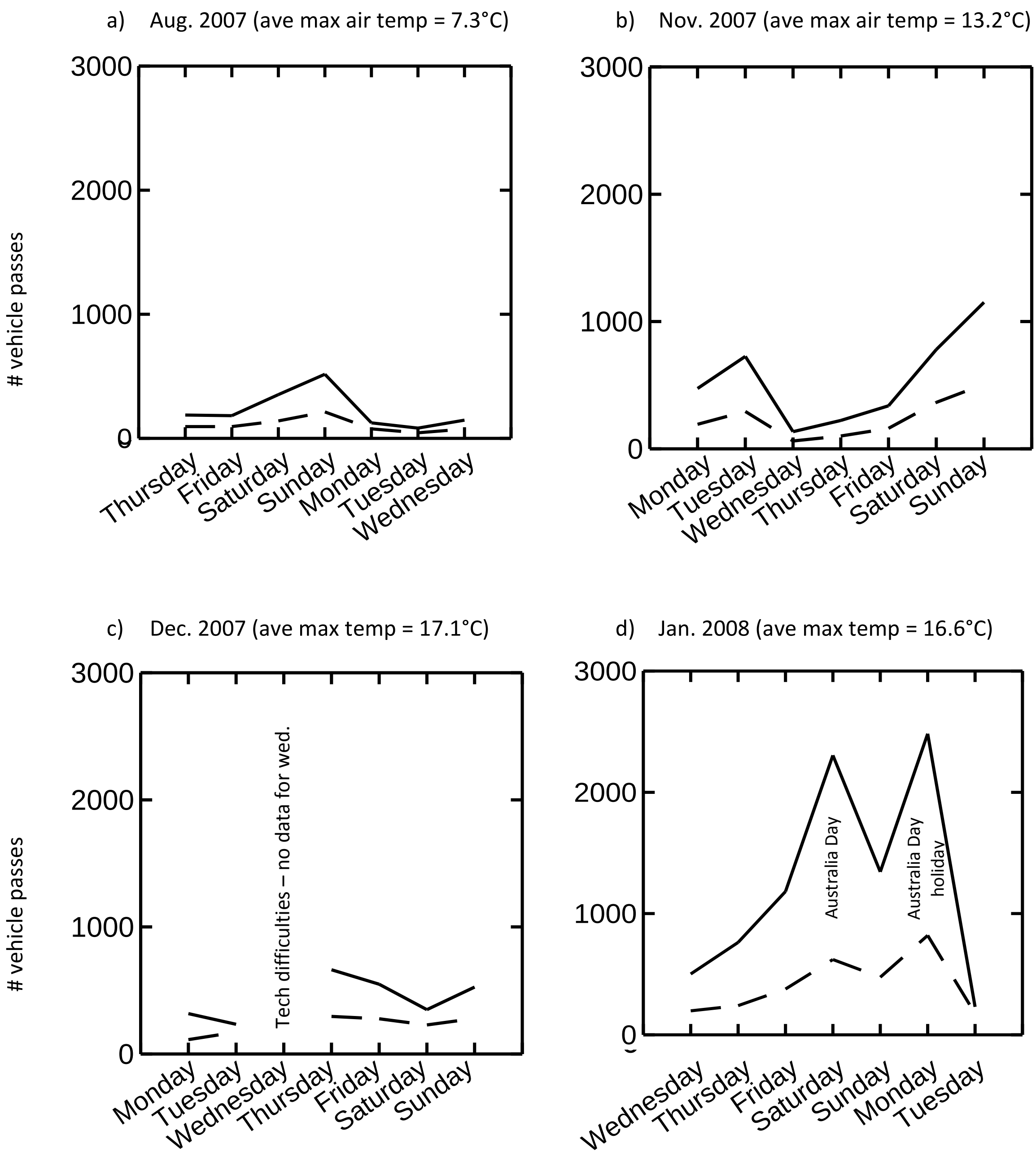
Ramp counts at Silver Sands were always higher than Sellicks North (Figure 2.9), and should reflect the fact that anyone entering the beach at this ramp would also have to leave via it too, because there is no through access to the Sellicks North ramp (Figure 2.2). Anyone driving onto the beach at Sellicks North ramp could either leave via the Sellicks North or South ramps (counters were not placed on the southern ramp at Sellicks). Weekend days (Saturday, Sunday) generally recorded more vehicle usage than weekdays (Monday-Friday), and counts were twice as high in January than November, and four to five times higher in January than December or August (Figure 2.9). The maximum usage of the ramps occurred on the Australia Day long weekend in January (Australia Day was Saturday 26/01/07; observed Monday 28/1/07; Figure 2.9). Vehicle traffic was not noticeably higher during weeks of warmer maximum mean air temps (averaged over the 7 day deployment period; Figure 2.9). Vehicles were recorded using the Silver Sands during the closure period (Figure 2.9); however, it is still permissible to use the ramp and a small section of this beach to launch boats, so not all recorded usage was ‘illegal’.

Data for both monthly track and vehicle counts and ramp counts were only available for three months (no data for December 2007). Vehicle activity recorded by the two different techniques (ramp counters and on-the-beach track counts) did not match well. For example, the highest vehicle activity (# of tracks) in this period was recorded in November 2007 for both beaches, but ramp traffic counters recorded the highest usage in January (Table 2.2). Ramp counter data did show that usage patterns of the two ramps, each accessing two separate sections of Aldinga Bay Beach, was similar (i.e. same months for max and min counts for both ramps), with approximately half as much usage at Sellicks Beach (which has two access ramps, only one of which had a counter) relative to Silver Sands Beach (which has only one ramp).

*Area covered by vehicle tracks on main study beaches*

In total, track width measurements were taken on 26 transects with vehicle tracks across two sampling occasions and at seven of the nine study

**Figure 2.9:** Ramp vehicle-counter daily data for each occasion (average weekly max air temp given in brackets) on which counters were placed on ramps at Aldinga Bay (solid line = Silver Sands; dashed line = Sellicks). Note that the counters were not always placed on the ramps on the same start day of the week (see x-axis) but every occasion covered a full week of deployment of the counter. Data courtesy of the City of Onkaparinga.



beaches. The percentage of the beach covered with vehicle tracks ranged from 0.02% (Aldinga Bollards; width = 86m) to 23.2% (Sellicks Beach; width = 96m). There was a significant, positive linear relationship between track density and the percentage of the beach-face that was covered by tracks that explained a large percentage of the variation in the relationship between track density and percent cover (track % cover (TC) = 17.79*track density (TD) +1.10; $R^2$ = 0.92; $F_{1, 24}$ = 257.3; $p$ = 0.000; Figure 2.10). This relationship was also significant (i.e. at $p$ = 0.000) for data analysed separately for each zone, with a tighter relationship between variables for the low-shore (TC = 17.07*TD + 0.35; $R^2$ = 0.95) than the high- (TC = 28.83*TD + 1.14; $R^2$ = 0.82) or mid-shore (TC = 18.17*TD + 0.77; $R^2$ = 0.81) zone. The slope of this regression was steeper for tracks in the high-shore zone (i.e. greater area of disturbance for a given number of vehicle tracks; Figure 2.10).

*All beaches – vehicle usage across eastern South Australia*

There was vehicle use recoded on most beaches sampled across south-eastern South Australia (i.e. MA, FP and SE regions combined; Figure 2.1). Only vehicle track densities measured on open beaches in the Fleurieu Peninsula region of South Australia (i.e. Morgans and Goolwa Beaches; 0.028 ±0.009 vehicles. $m^{-1}$; 0.786 ±0.640 tracks.$m^{-1}$; $n$ = 2; Table 2.3) were as high as open beaches in the study region (i.e. VOB beaches; 0.070 ±0.021 vehicles.$m^{-1}$; 0.704 ±0.079 tracks.$m^{-1}$; $n$ = 70; Table 2.3).

Beaches in the south-east (SE) of South Australia were more intensively sampled than FP or MA beaches (Tables 2.1 & 2.3); however all beaches sampled in this region were open to vehicles. Vehicle activity was slightly greater in the summer months but otherwise was fairly consistent throughout the year (Figure 2.11a). Mid- and high-shore zones were favoured by drivers (Figure 2.11b). Both track (Mann-Whitney's test: $U$ = 2305.5; $p$ < 0.001) and vehicle ($U$ = 1804.0; $p$ < 0.001) density were significantly greater on open beaches in the VOB region than in the SE (Figure 2.12).

**Figure 2.10:** Relationships between track percentage cover of the beach-face and track density

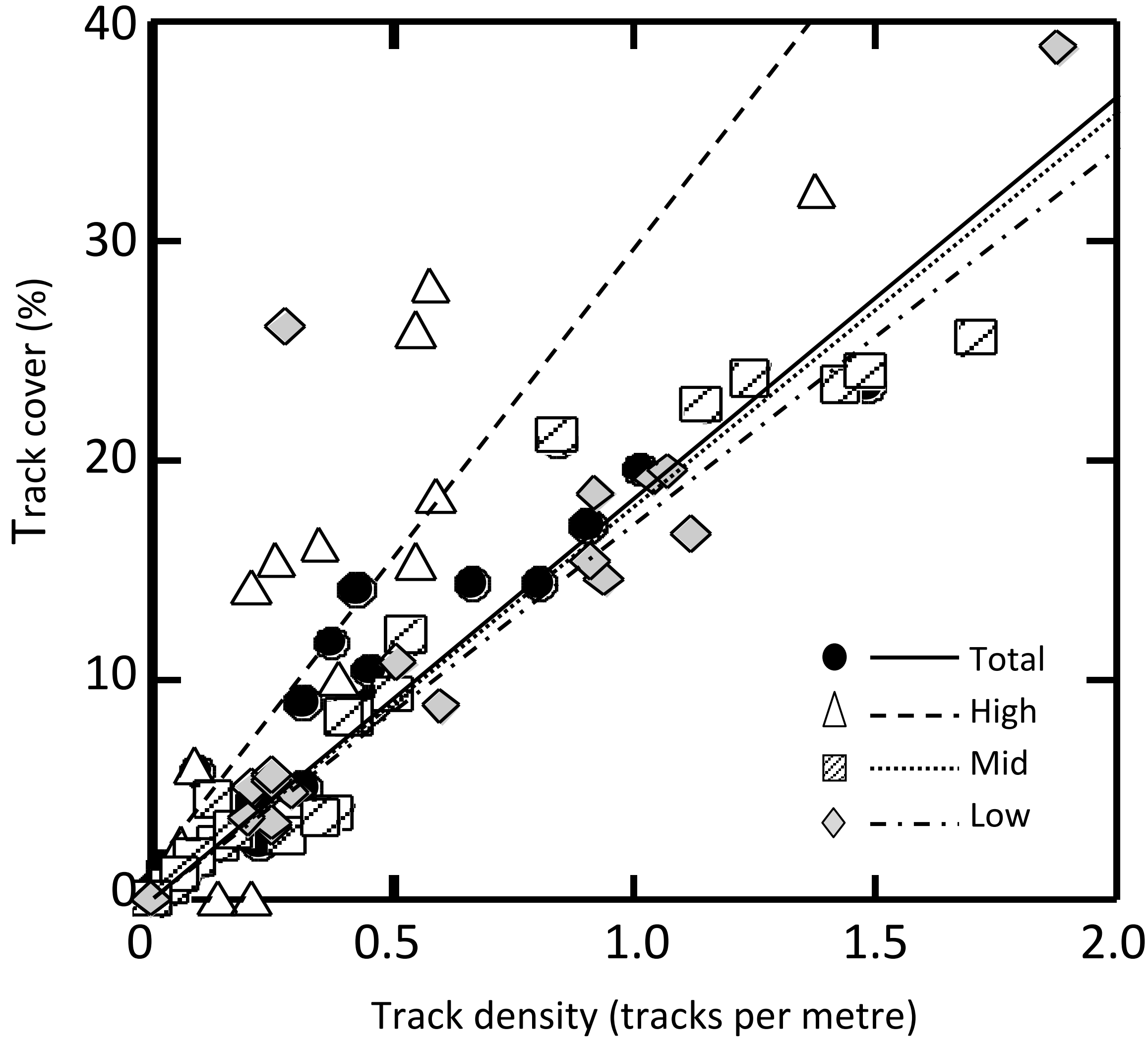
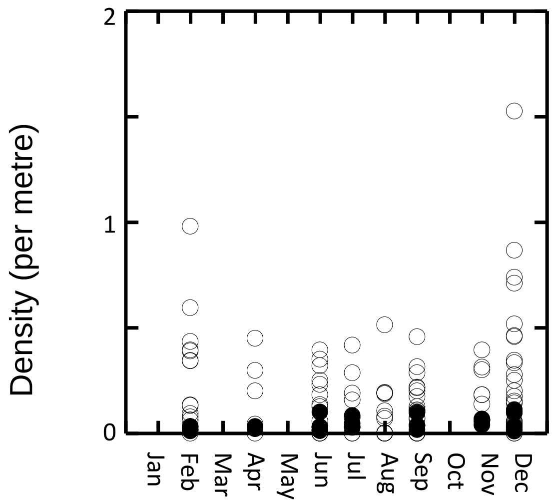


**Table 2.3:** Mean (±SE) for vehicle and track densities for beaches open or closed to vehicles for the VOB (*n* = 4 beaches either open or closed to vehicles), MA (*n* = 3 beaches surveyed), FP (*n* = 6 beaches surveyed) and SE (*n* = 26 beaches surveyed) regions of South Australia. Numbers in brackets are number of transects per vehicle access type per region.

| | | | **Vehicle usage** | |
|---|---|---|---|---|
| **Region** | **Type** | **Beach Width (m)** | **Vehicles.m$^{-1}$** | **Tracks.m$^{-1}$** |
| VOB | Open (*n* = 70) | 70.5 ±3.3 | 0.070 ±0.021 | 0.704 ±0.079 |
| | Closed (*n* = 70) | 64.9 ±2.4 | <0.001 ±0.000 | 0.007 ±0.013 |
| MA | Boat Ramp (*n* = 3) | 53.0 ±9.5 | 0.000 ±0.000 | 0.044 ±0.044 |
| | Closed (*n* = 4) | 87.8 ±11.3 | 0.012 ±0.009 | 0.059 ±0.047 |
| FP | Open (*n* = 2) | 54.5 ±0.5 | 0.028 ±0.009 | 0.786 ±0.640 |
| | Closed (*n* = 6) | 41.8 ±13.3 | 0.000 ±0.000 | 0.000 ±0.000 |
| SE | Open (*n* = 105) | 46.3 ±2.1 | 0.015 ±0.002 | 0.201 ±0.023 |
| | Closed | no closed beaches surveyed in the SE region | | |

**Figure 2.11:** Vehicle activity in the SE region across a) months (each point represents the density of either vehicles (per 200m of beach; solid-fill points) or vehicle tracks (per linear metre of beach; unfilled points) on each beach) and b) zones (each bar represents the mean density of either vehicles (per 200m of beach; ±SE; solid-fill bars) or vehicle tracks (per linear metre of beach; ±SE; unfilled bars) for each zone) across all SE region beach transects combined ($n$ = 105).

a)




b)

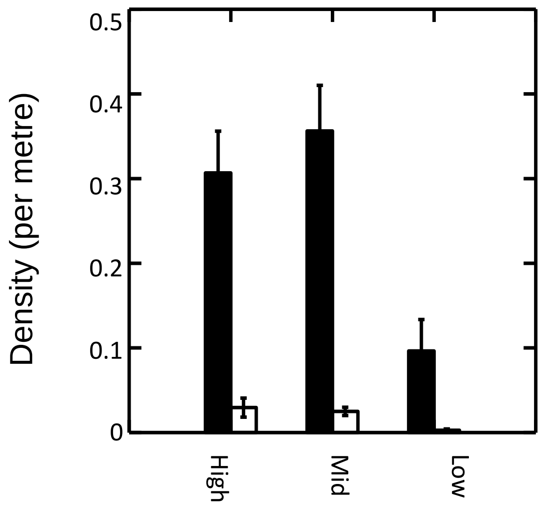
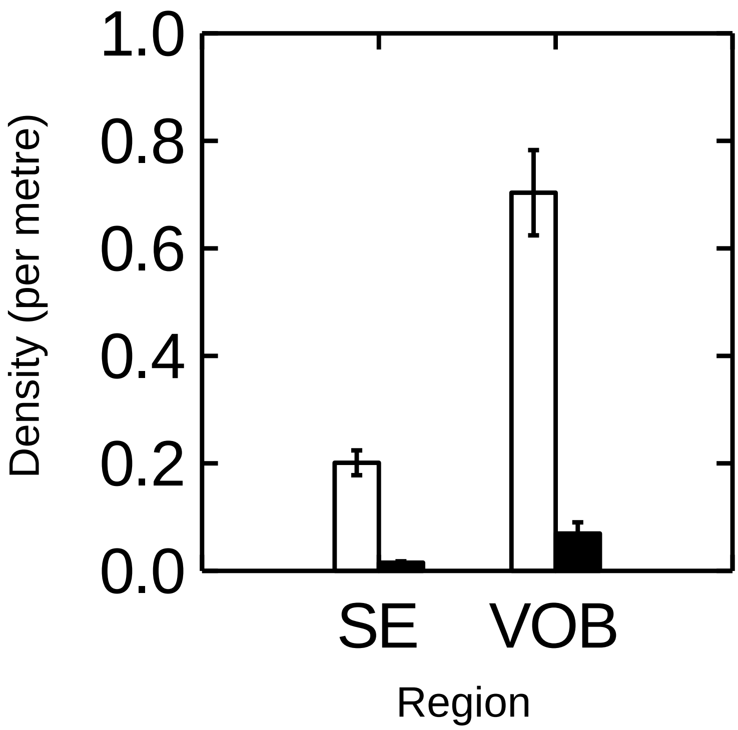


**Figure 2.12:** Comparison of open VOB beaches (*n* = 70 transects) and SE beaches (*n* = 105 transects) for vehicles (per 200m of beach; ±SE; solid-fill bars) and tracks (per linear metre of beach; ±SE; unfilled bars) density.



## 4. Discussion

Vehicle activity was observed on almost every beach on which observations were made (Figure 2.1). This included most beaches that are closed to vehicles by either local policy (e.g. Glenelg Beach) or those where attempts have been made to physically block vehicle access (e.g. Aldinga Bollards). Usage of these closed beaches by drivers did, however, appear to be reduced relative to open beaches. Vehicle and pedestrian usage of the VOB beaches and other South Australian beaches surveyed was recorded throughout the year and across all three beach zones. As expected, vehicle usage, in terms of intensity and driver behaviour, of the two open beaches in the main (VOB) region differed greatly from that observed in the SE. Both track and vehicle densities were greater on VOB beaches relative to SE beaches, and there was a tendency for drivers to use the mid- and low-shore of VOB beaches rather than the mid- and high-shore zones. The SE situation more closely resembles the vehicle usage situation more commonly observed in other Australian states and overseas, and the situation that has been studied and reported previously for research on vehicle impacts on beaches. The situation observed on the VOB region beaches is unique among those beaches surveyed in South Australia, and, based on reports from the literature, unique both nationally and globally.

*VOB beaches: usage throughout the year and patterns of driver behaviour*

Vehicle activity recorded on beaches in the main study region open to vehicles was greatest on public holidays during warm months (i.e. Australia Day, Easter long weekends). Vehicle activity was also high for other summer-time public holidays not surveyed (e.g. Christmas Day Dec. 25$^{th}$; pers. obs.), and days of extreme high temperatures, especially if these occur on a weekend day (i.e. Saturday or Sunday; pers. obs.). These times represent extraordinary peaks in vehicle usage, above that generally observed throughout the remainder of the warmer summer months but have been included here to give an idea of the maximum levels of usage likely on these beaches. Aside from these unusual peaks, vehicle activity on beaches open to vehicles in the VOB region was relatively consistent throughout the year, with only a slight decline in vehicle and track densities on open beaches (including the seasonal closure at Silver Sands) during winter months.

There were some differences in vehicle usage level between the two open beaches in the VOB region; for example, vehicle usage was greater in the high-shore zone at Moana Beach relative to Sellicks Beach (Figure 2.4). There are natural differences in the morphology of these two beaches: although both are LTT in morphotype (Short 2006b), Sellicks Beach displays a more ‘typical’ LTT profile, with a high-shore reflective beach consisting of a cobble bank that is very distinct from the low-shore dissipative sandy beach, while the cobble bank at Moana is buried under wind-blown sand resulting in a slightly more even profile across the beach-face (pers. obs.). It seems that fewer vehicles attempted to traverse the more difficult conditions associated with these steep, loose stones at Sellicks Beach than the soft sands at Moana. However, vehicle usage of the high-shore zone of both beaches was low, relative to the mid- and low-shore zones, where tracks and vehicles were concentrated. This result likely reflects a pattern of driver behaviour on these beaches – drivers appear to traverse the firm low- or mid-shore sands then park either above (in the high-shore) or below (in the low-shore) the mid-shore ‘road-way’ (pers. obs.). This pattern differs to that seen on beaches in the SE region, where vehicle tracks were concentrated in the mid- and high-shore of the beach, likely reflecting drivers who avoid the often dangerously-soft low-shore sands that are too unstable for beach driving (pers. obs.).

*Violations of closed beaches and beach sections in the VOB region*

All beaches in the VOB region recorded some level of vehicle activity, including the two beaches supposedly closed to vehicles, Maslin and Port Willunga. The only vehicles that were observed on Maslin and Port Willunga Beaches were either service vehicles (e.g. collecting rubbish) or businesses granted permission to drive on the beach (e.g. ice-cream vendors; pers. obs.). Tracks observed on these closed beaches were most likely those of the service and business vehicles observed, rather than members of the general public. Access ramps to Maslin and Port Willunga Beaches are chained, requiring that persons wishing to access the beach by vehicle must first obtain a key.

There were frequent violations of closures (both seasonal and permanent) at Aldinga Bay. The seasonal closure at Silver Sands was not well obeyed by the public, with only a slight decrease in vehicle usage during the wintertime closure period observed, and no significant difference in vehicle usage level (measured by track density) of the seasonal closure during the winter months compared to the two open beaches, Sellicks and Moana. These results indicate that Silver Sands is not effectively closed to vehicles during the winter months, and thus cannot be considered a true seasonal closure. Vehicle activity was observed in both the high- and low-shore zones at Aldinga Bollards, despite the installation of wooden posts blocking vehicle access to this section of the beach (see Chapter 1; Figure 1.4b). The bollards at Aldinga have a chained gap near the top of both rows of bollards, to allow access for service vehicles; however, this chain was frequently cut by some members the public to gain access to the bollarded section (pers. obs.). Vehicles were only observed in the high-shore zone at Aldinga Bollards, and all vehicles observed by me were non-service vehicles passing illegally between the gaps in the bollards. Also, when the tide is too low for the bollards to reach the swash, some of the low-shore beach is exposed and unprotected by bollards, thus allowing through traffic in the low-shore zone (pers. obs.).

Unlike Aldinga Bollards at Aldinga Bay, vehicle activity at Moana Bollards was not observed in the low-shore zone. At Moana, bollards extend well into the swash zone and access into the Moana Bollards section is only possible by traversing up, around the top of the line of bollards, through the dunes, then down again across the high-shore (pers. obs.). Tracks were only observed inside the bollarded section at Moana during the winter months, indicating that such violations (i.e. driving around the top of the dunes) were more frequent at Moana Bollards in winter months, a time when beach patrols policing vehicle activity are very infrequent (pers. obs.). Some vehicle activity was recorded in the Moana North closure section. Council vehicles, including earth-moving equipment, were used occasionally on Moana North to repair storm damage to the high-shore zone and backing seawall and cliffs, with work generally done in late spring and early summer, before the peak summer-holidays period (pers. obs.). In addition, at some point prior to the sampling occasion in February 2007 but after the pre-summer sampling occasion in November 2006, the beach at Moana was raked to remove wrack deposited in the high-shore zone, and some tracks were left on the beach by the vehicles and tractors used (pers. obs.).

This was the only occasion over the three year study period when evidence of beach raking was observed on any of the study beaches.

The restrictions to vehicle access imposed by the local council were generally better obeyed by the public at Moana Bay than at Aldinga Bay, with vehicle activity frequently observed within the Aldinga Bollards (e.g. drivers traversing the low-shore, below the bollards) and during the winter closure period at Silver Sands. It is likely that this result reflects both how long closures have been established and the relative community support for closures, both of which differ between the two Bays. Closures at Moana Bay have been established for at least 15 years, following community requests for areas free of vehicles on the northern section of the beach, where there is parking available above the beach, and in the southern section, after the development of the suburb Moana Heights, which included a car park and toilet block to service the southern end of Moana Bay. Community support for the closures at Moana is strong, and the public generally self-polices local policy restricting vehicles to the middle section of the beach (i.e. see Figure 1.4a). Closures at Aldinga Bay are relatively recent, having only been established in 2005. Initially, it is likely that some members of the public were not aware of the restrictions, resulting in unintentional violations, especially during the winter closure at Silver Sands. However, there is strong opposition to the closures at Aldinga Bay within some community groups (Anon. 2008), and it is also likely that some of the closure violations have been deliberate.

*Ramp counter versus beach survey techniques comparison*

Ramp counter and beach transect survey data did not match well. Unfortunately surveys did not coincide exactly with the deployment of traffic counters because I was often not made aware of the deployment of ramp traffic counters until after they had been collected, so it was not possible to operate the two methods for assessing vehicle usage concurrently. These ramp count data highlight the high degree of short-term variability in beach usage at both Aldinga and Sellicks beaches, and also again imply the importance of cultural holidays in drawing people to the beach (i.e. the Australia Day long weekend). These peaks and variability are missed by beach surveys unless the observer happens to be on the beach at that specific time. Both ramp counts and beach surveys have their drawbacks. Ramp counts are not a measure of disturbance on the beach, some drivers may not go all the way onto the beach itself, others may traverse up and down the beach several times before parking or leaving. Alternatively, in addition to missing short-term variability (at least on the time scale of survey sampling days employed in this study), beach surveys are limited by periods between tidal inundations, during which visible tracks are wiped from the beach, especially since tidal inundations differ among zones (i.e. high-shore only wetted by spring high tides and storms; see caveats). Unlike ramp counts, surveys are an estimate of actual impact on the beach itself.

*Vehicle usage of beaches across south-eastern South Australia*

The number of transects taken from other metropolitan Adelaide (MA) and Fleurieu Peninsula (FP) beaches was very low and infrequent (Table 2.1), with few beaches represented, and thus the data obtained most likely do not reflect the true levels more generally of vehicle and pedestrian usage on MA & FP beaches. Generally, beaches along the MA coastline are closed to vehicles, with only a few beaches permitting access onto the beach for the purpose of launching and retrieving boats (e.g. Seacliff; pers. obs.). On these beaches, 2WDs and 4WDs can gain access to the beach. In addition, beach nourishment activities are undertaken on two of the beaches surveyed (Seacliff & Glenelg), and some heavy vehicle activity was recorded on these beaches associated with sand carting operations. FP beaches are generally closed to vehicles as local policy (i.e. Middleton & Victor Harbour) or because vehicle access to the beach is not possible (e.g. Waitpinga). Only two beaches surveyed in the FP region permit vehicle access, Morgans and Goolwa, and both require 4WDs to gain access to the beach. Vehicle activity measured on these beaches was as high as open beaches in the VOB region but, only two transects were ever conducted on Goolwa and Middleton Beaches, and thus these data most likely don't reflect true levels of vehicle usage on these two beaches. Goolwa is a very popular 4WD beach, especially in the summer months (when FP beaches were undersampled; Table 2.1). Although there is no physical barrier to vehicle access (i.e. bollards, rocks, headland etc.) between Goolwa and Middleton Beaches, vehicles rarely use Middleton Beach, which is a very popular pedestrian and surf beach (pers. obs.). Most beaches in the SE region permit vehicle access by 4WD vehicles, and dunes backing beaches are often tracked, especially near headlands or bluffs that block through-traffic between beaches (pers. obs.).

*Tracking of beaches by vehicle tyres*

In this study, up to 23.2% of the intertidal beach-face was found to be disturbed by vehicle tyres (i.e. tracked or rutted), with increased disturbance observed in the high-shore zone where larger ruts were formed in the softer sands. The highest recorded track density was 2.3 tracks.$m^{-1}$, equating to 221 tracks across the beach in total; however, this is likely an underestimate of true vehicle activity, as track density increases there are more overlain tracks (pers. obs.), and so the values here are minimum potential vehicle traffic estimates. In Queensland, two beaches used intensively by vehicles became heavily tracked and rutted, with up to 90% coverage of the intertidal beach-face in vehicle tracks and maximum track densities of 6.35-8.06 tracks.$m^{-1}$ of beach-face (Schlacher & Thompson 2008), indicating a much higher level of vehicle activity than that observed on the VOB study beaches. The level of disturbance (i.e. track coverage) for open beaches in the VOB region was never measured during times of peak vehicle usage of these beaches due to the density of vehicles making it impossible to survey a transect (i.e. see Chapter 1; Figure 1.4a) and the danger to workers from the traffic. However, even the maximum recorded track density (2.3 tracks.$m^{-1}$) would not equate to this level of beach disturbance, using the regression equation relating track density and percent cover of the beach-face with vehicle tracks, with only approximately 40% of the beach estimated to have been covered by tracks (not taking zone differences into account). High levels of disturbance approximating those observed on Queensland beaches by Schlacher and Thompson (2008) were only estimated for the mid-shore zone of open beaches, twice at Sellicks Beach (214% [track density = 12.0 tracks.$m^{-1}$] & 99.9% [track density = 5.0 tracks.$m^{-1}$] for Feb. 2007 & Dec. 2006, respectively) and once at Moana (90.6% [track density = 5.6 tracks.$m^{-1}$] for July 2007). This is the zone favoured by users for driving, with the mid-shore often forming a ‘road-way’ between parked cars (pers. obs.). Estimates of track percent cover greater than 100% likely result from overlapping tracks. Other cases for comparison and tabulation of beach tracks data were sought; however, only Schlacher and Thompson (2008) was found to have comparable data. As an aside, counting tracks is a much less time consuming task than measuring track percent cover, and that there is such a tight relationship between track density and percent cover indicates that counting tracks could be used as a tool for the rapid assessment of vehicle disturbance to an intertidal beach. Obviously, however, there are limitations to using such an equation to estimate percent cover from track counts. Because the y-axis intercept is greater than zero, beaches without tracks will have an estimated track cover that is greater than zero. There is also the potential for estimates of disturbance exceeding 100%, due to overlapping tracks.

There are some results that could be interpreted as pedestrians potentially avoiding sections of beaches open to vehicles in the VOB study region. At Moana, footprint densities were greater in the two closure sections than the open section. At Aldinga, pedestrian traffic within the bollards was higher during the summer months and when vehicle traffic levels were highest on open beaches (i.e. summer months), pedestrian footprint densities decreased. However, these results could also be explained by obscuration of footprints by vehicle tracks. Pedestrians were also often obscured on open beaches by parked cars, and thus pedestrian counts are likely to be affected by vehicle density. In both cases (i.e. pedestrian and footprint counts), counts most likely become less accurate as vehicle or track density increases.

*Caveats*

Levels of vehicle and pedestrian activity in the high-shore zone may be exaggerated because of accumulation of tracks or footprints between spring high-tides. Alternatively, tracks and footprints in the high shore may be underestimated because wind-blown sand can accumulate within tracks, which can happen relatively quickly when winds are strong, making them easy to miss by observers. Water only partially covers the high-shore zone of the beaches surveyed during spring high-tides (these occur approximately every two weeks) and the very top of the beach is only wetted by the tide during king-tide events that occur only during intense storms. Thus, the high-shore of the beaches surveyed accumulates tracks over a greater period than mid- or low-shore, where tracks reflect only very recent activity (i.e. since the previous high-tide).

## 5. Conclusion

Vehicle activity was much higher on open beaches relative to closed beaches and beach sections, although some vehicle usage of closed beaches and beach sections was observed. This result matches the predictions made regarding vehicle usage of the study beaches in Chapter 1 (see Figure 1.5). Likewise, there was also increased vehicle activity observed in the summer months and vehicle activity was found to be concentrated in the mid- and low-shore zones, as was expected (see Figure 1.5).

This chapter has identified differences in vehicle activity levels between beaches open versus those closed to vehicles. In addition, it has been shown that Silver Sands is not adequately closed to vehicles during the winter months and is thus not a true seasonal closure, and this must then be taken into consideration during all data analysis and result interpretation. Likewise, it must also be considered that restrictions in place at Aldinga Bollards were ineffective at keeping vehicles out. It must be noted that, for ease of reference, throughout the remainder of this thesis terminology used to describe these beach sections as ‘closed’ to vehicles has been kept.

Beaches in the VOB study region have been suitably divided into access types, with low levels of violations on closed beaches and beach sections, with the exception of Silver Sands. These violations, now quantified, can be taken into account in the general discussion when interpreting between- and within-beaches comparisons to investigate vehicle impacts (i.e. see Chapter 3, 5-7). Finally, the usage on VOB beaches differs from that on other SA beaches surveyed, and to documented examples of vehicles on beaches in the scientific literature.