A shot in the dark:

monitoring immediate disturbance and short-term impacts from fireworks on shorebirds

Moreton Bay Marine Park | Queensland

#32229 | 0321

Queensland Government

Prepared by Lewis Lawrence, Queensland Parks and Wildlife Service for the Department of Environment and Science

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1. Executive summary

The report was produced to inform discussion between environmental managers, local government, private firework event organisers and industry stakeholders. A publicly available online resource outlining areas of Moreton Bay Marine Park where fireworks can be conducted as a lower impact activity or where a permit will be required will be developed as a result of this report and discussion with stakeholders.

A firework test event was held in Manly, Queensland, for the purpose of studying disturbance effects on shorebirds over distance and time. More detailed and location specific data was required for area managers to assess firework event impacts on protected shorebirds found in Moreton Bay Marine Park and Ramsar Wetland. A before-after non-experimental design was used to compare shorebird abundances at adjacent foraging and roost site areas. Thermal image footage and sound recordings were taken at five monitoring stations at increasing distance intervals during the test to determine flight initiation distance (FID) and monitor changes in shorebird behaviour.

Thermal image recordings showed a high proportion (approximately 60%) of birds of varying species took flight up to 2km from the test location. Additional independent observations reported disturbance at 2.7km and 3.67km distances with suspected flight initiation up to approximately 4km due to sound reflecting qualities of the surrounding water. The test was conducted at mid/low tide to reduce impacts to roosting shorebirds, it is predicted a firework display at high tide would have a greater short-term impact. No significant reduction of shorebird abundance was recorded at the adjacent high tide roost site during the week following the test. Results from foraging bird surveys before and after the test were inconclusive due to a small data set and significant naturally occurring fluctuations. Varying disturbance responses by firework type, species and individual were recorded at a 2km distance. Fireworks with greater sound producing characteristics elicited disturbance at a greater range.

2. Why conduct a firework test?

Queensland Parks and Wildlife Service (QPWS) is regularly required to assess the impact of proposed firework events against a range of criteria in various locations within and along the marine park boundary. Moreton Bay is a locally, nationally and internationally significant wetland home to over 50,000 waterbirds, including 33,000 migrating shorebirds (Moreton Bay Ramsar Information Sheet, 2018). The effect of a proposed use of a marine park zone 'on shorebirds[1], particularly international migratory species of shorebirds' (*Marine Parks (Moreton Bay) Zoning Plan 2019*) must be considered by the chief executive when considering any permission for firework displays within Moreton Bay Marine Park. A range of data is available documenting firework event impacts on birds from Europe and North America (Appendix 1). However, insufficient data was available directly relevant to the range of bird species found in Moreton Bay with the same exposure to local background disturbance levels (such as from road and vessel traffic or water-based recreational activities). The information collected from the test is intended to inform discussion between environmental managers, local government, private firework event organisers and industry stakeholders. The process is planned to culminate in a standard firework display evaluation framework for Moreton Bay which can provide clarity and consistency to stakeholders while minimising impacts to shorebirds susceptible to disturbance. Although a single test event cannot provide indisputable data, it will provide the most location specific and detailed information available for firework event management in Moreton Bay.

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[1] Shorebirds are defined in the *Marine Parks (Moreton Bay) Zoning Plan 2019* as a duck, seabird, swan or wading bird therefore responsibilities of the Department of Environment and Science under legislation are linked to this definition. However, within this report shorebird refers to wading shorebirds and excludes ducks, seabirds and swans unless otherwise specified.

3. Objectives

The primary objective of the firework test was to evaluate the distance from the event location over which shorebirds take flight. Although other changes in behaviour, such as a cessation in foraging can indicate a lower level of disturbance, the flight initiation distance (FID) metric is critical for QPWS assessments. The *Marine Parks (Moreton Bay) Zoning Plan 2019, Section 108* gives as an 'example of conduct that may cause unreasonable disturbance - doing or omitting to do a thing that causes a shorebird to take flight'.

A secondary focus was to evaluate the short-term impact on roosting and feeding populations within the FID of the test. Specifically, whether the number of shorebirds recorded on the adjacent foraging areas or roosting at the Manly Harbour Roost Site would show significant reductions in the 12-48h period following the test.

A final focus of the test was to investigate whether fireworks with different noise and light producing qualities, and detonation heights would generate different disturbance effects on shorebirds. Further, whether the disturbance would vary over distance from event location. The driver for analysing this variation was the potential for results to guide the firework industry in the design of lower impact displays.

Research Questions

- At what distance do firework events cause shorebirds to take flight in Moreton Bay?
- What are the short-term impacts on roosting and foraging shorebird abundance following a firework event?
- Do different types of firework elicit varying responses in shorebirds, and does this response change over distance?

4. Method

The monitoring of firework disturbance involved collection of data prior to the test event and a comparison with data after the activity. This corresponds to a before-after non-experimental design. Monitoring methods specific to recording immediate disturbance and short-term impacts are explained in sections 4.1 and 4.2.

An initial pilot survey of foraging areas was made on 16 July 2020 from Wynnum to Lota on a 1.5m to 1.15m ebb tide[2] (Map 1). Although the firework test was planned to take place after dark, the pilot survey was conducted in daylight hours as accurate counts and species identification was unattainable using night-vision or thermal imaging equipment. Due to wading shorebirds following a tidal pattern of roosting and feeding (Milton and Harding, 2007), day time shorebird counts at a given tide are thought to be a good indicator of night-time counts at the same tide. However, without an accurate method for counting at night, this is difficult to confirm. The purpose of the pilot survey was to ensure sufficient shorebirds would likely be present at various distances from the event location to record FID from a test event. An ebb tide height of 1.2m was selected for the test event based on a combination of the pilot survey results, observations of the Manly Harbour Roost Site and the effective range of thermal monitoring equipment available.

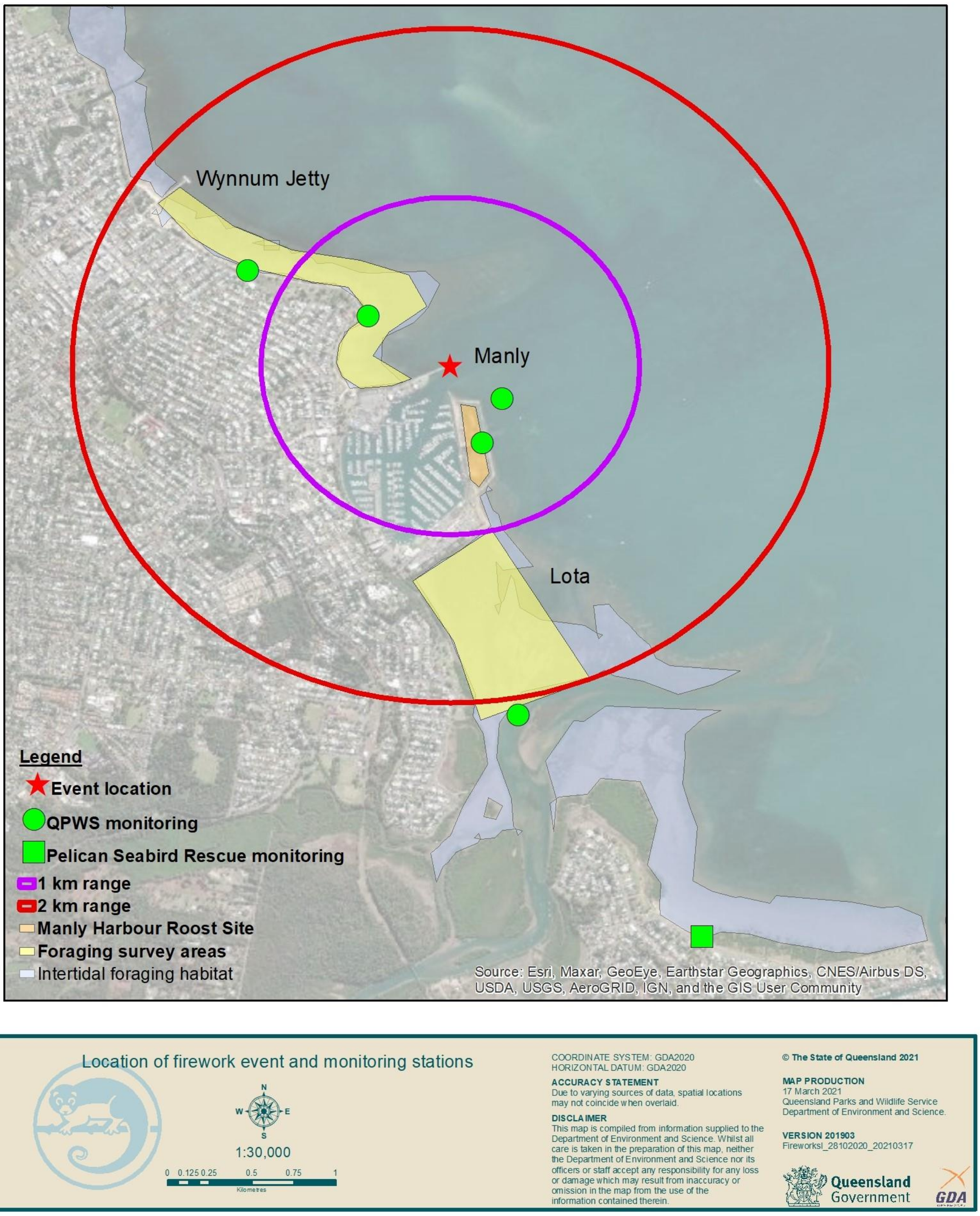
QPWS immediate disturbance monitoring positions (Map 1) were selected based on the likely location of foraging shorebirds on a 1.2m ebb tide that could provide suitable distance intervals to record birds taking flight up to an expected FID of ~2km. Monitoring positions were planned at 500m, 1230m and 2100m. Additional monitoring was conducted at the roost site (470m) and from a support vessel (230m). The test date was moved from 27 July 2020 to 25 August 2020 due to administrative delays. The final date and time was chosen for a 1.2m ebb tide occurring just after dark and out of non-

[2] All tide heights and times are based on the Tides Qld + App for iPhone using the Manly location.

breeding season (to reduce impacts on migrating birds). However, early migratory shorebird arrivals were noted in some foraging and roost site surveys in late August which complicated data analysis, this is addressed in section 7.2 and why a July test was considered preferable.

4.1 Immediate disturbance monitoring (0-30 minutes from test start)

Monitoring was conducted at five locations (Map 1) from approximately 30 minutes before to 30 minutes after the test. Each QPWS monitoring station aimed to record bird behaviour through thermal imaging cameras before, during and after the test event. A second recording device was used to record the timing of the fireworks by sound and/or light flashes. In addition, a vessel-based radar (able to detect birds in flight) was trialled and a decibel meter recorded sound levels at the Manly Harbour Roost Site. Immediate disturbance monitoring was arranged to address research questions 1 and 3.



Map 1. Manly firework test event location, intertidal foraging area, monitoring positions, Manly Harbour Roost Site and anticipated disturbance range.

4.2 Short-term impact foraging and roosting shorebird counts (12-48 hours after the test)

The design for measuring short-term impacts was based on evidence that wading shorebirds follow a tidal-based pattern of roosting and foraging (Milton and Harding, 2007), rather than time of day or night (Figure 1).

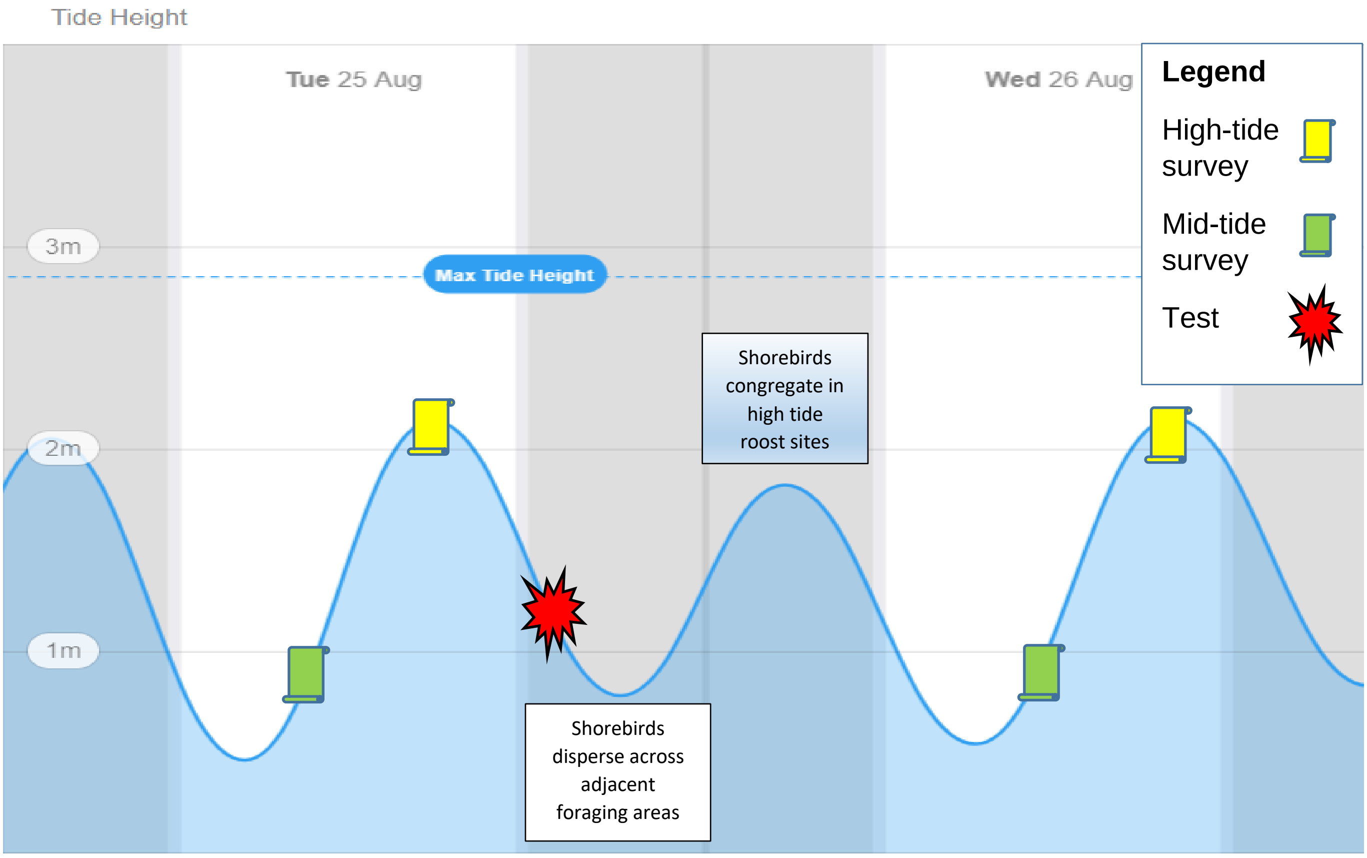


Figure 1 Tide times and heights Manly, 25-26 August 2020 (WillyWeather, 2020). High tide surveys conducted at Manly Harbour Roost Site. Mid-tide surveys conducted across Wynnum to Manly foraging areas (Map 1).

A direct comparison of shorebird numbers before and after the test at a 1.2m ebb tide (tidal state at test), across adjacent foraging areas, was impractical due to the sunrise/sunset times in August combined with the need to conduct the firework test after dark (Fig. 1). The capacity of the thermal cameras available did not extend to conducting accurate bird species counts at night. A 1.2m flood tide was considered for comparison as the same position of the water line was expected to attract similar species and abundance of birds. However, initial observations before the test seemed to show slightly lower abundances compared to a 1.2m ebb tide. Therefore, a 0.75m-1.0m flood tide height was selected to conduct foraging area surveys to provide a consistent tide height for comparison before and after the test with birds present that were likely affected by test disturbance on the earlier ebb tide.

Foraging area surveys were conducted daily between the test event location and Wynnum Jetty from three days before to two days after the test. Foraging areas between Manly and Lota were not surveyed after the initial pilot survey, as they fell within the same distance range as Manly-Wynnum and would have added further monitoring costs. Foraging area surveys were conducted using binoculars and an SLR camera with optical zoom. The Wynnum to Manly foreshore was traversed in a consistent pattern with photos captured of all birds spotted. A desktop review and count followed each survey. The extent of the survey area was chosen based on the anticipated impact range of the fireworks test (2km). The distance was based on literature of previous disturbance monitoring consulted when designing the method.

Shorebird surveys were also conducted in the Manly Harbour Roost Site weekly in the month before the test (initially the test date was expected to be earlier in August) increasing to daily in the two days before the test to provide baseline data. Due to the difficulty of counting large mixed flocks at the roost site, two QPWS staff were used. A QPWS ranger trained in shorebird ID was present at all counts shown in the results, two telescopes were used to identify the birds at the site from various vantage points. Surveys continued daily after the test for two days to monitor impacts. A member of Queensland Wader Study Group (QWSG), a special interest group of the Queensland Ornithological Society, also conducted surveys of Manly Harbour Roost Site from 24 to 31 August 2020 for other purposes. The QWSG counts were shared with QPWS over this time and were used instead of QPWS counts on dates available due to the experience of the counter, increasing the accuracy of counts. Although the roost site was predicted to be largely empty at the time of the firework test, the high-tide roost site surveys were conducted as a proxy measurement of general shorebird abundance in the Wynnum – Manly – Lota area. Many of the shorebirds which regularly use the roost at high tide are likely to forage in intertidal areas adjacent to the roost site (Coleman and Milton, 2012) and a high proportion were expected to be subjected to disturbance at the time of the test.

4.3 Location selection

The Manly Harbour rock wall (Map 1) was selected as the test location due to a combination of factors:

1. Popular firework event location with previously regular annual events.
2. Proximity to a nationally significant[3] shorebird roost site that regularly supports[4] seven migratory threatened species (two species in nationally significant numbers), Table 1, and an additional three migratory species in nationally significant numbers. With summer averages of over 2000 shorebirds including 20 different species of resident and migratory shorebird.
3. Sufficient wintering population to measure FID and short-term impacts thus reducing the number of migrating birds negatively affected by the test.
4. Proximity to both roosting and feeding areas.
5. Monitoring positions available at various distance intervals from test location.
6. Proximity to Manly marine parks office, reducing monitoring costs and facilitating logistics.

EPBC Act threatened species	
Critically Endangered	curlew sandpiper*, eastern curlew*, great knot*
Endangered	Australian painted snipe, lesser sand plover*, red knot*
Vulnerable	greater sand plover*, Western Alaskan bar-tailed godwit*
NCA threatened species	
Critically Endangered	curlew sandpiper*, great knot*
Endangered	eastern curlew*, lesser sand plover*, red knot*
Vulnerable	Australian painted snipe, greater sand plover*, Western Alaskan bar-tailed godwit*, beach stone-curlew

*Table 1. Threatened shorebird species listed under Environment Protection and Biodiversity Conservation Act 1999 and Nature Conservation Act 1992. * Regularly recorded at Manly Harbour Roost Site.*

[3] Nationally significant means at least 0.1% of the East-Asian-Australia-Flyway population (Hansen et al., 2016).
[4] Based on average counts over the October to March period, 2010-2020 data provided by QWSG.

5. Firework test event details

The firework test event took place on Manly Harbour rock wall on 25 August 2020 at 6:41pm, with a 0-5 knots easterly wind and no cloud cover. Skylighter Fireworks offered to design the event profile and provided bio-degradable fireworks. The event profile built gradually from 'very low impact' level items used in the first minute (e.g., 30mm Comet Effects, Table 2) through to 'low impact' level items from 2-5 minutes (e.g., 75mm Aerial Shells). Note, impact rating provided by Skylighter Fireworks based on light and sound producing characteristics. Fireworks described as medium and high impact (Table 2) were not included in the display to try to reduce disturbance while still providing a display viable for a commercial event. A simulation of the 5-minute test event can be found at https://youtu.be/Y4-iVLHLp2k.

Impact Level	Item / Effect	Description / Notes	Type	Calibre	
Very Low Impact	Comet Effects	Shooting star effect. No secondary burst.	Multi-shot	20 to 30mm	1st min
Very Low Impact	Fish Effects	Shoot star to secondary soft break effect.	Multi-shot	30mm	
Very Low Impact	Crossette Effects	Shooting star effect, rising to secondary soft break.	Multi-shot	20 to 30mm	
Very Low Impact	75mm (Soft Break) Aerial Shells	Soft breaking shell effects, such as Fish, Falling Leaves, Waterfalls and Horse Tails	Aerial Shell	75mm	2-5 mins
Low Impact	Hard break Multi-shot Effects	Hard break multishot effect. Rising star to secondary burst.	Multi-shot	30mm	
Low Impact	65mm (Colour Star) Aerial Shell	Colour Star Shell	Aerial Shell	65mm	
Low Impact	75mm (Colour Star) Aerial Shell	Colour Star Shell	Aerial Shell	75mm	
Low Impact	100mm (Soft Break) Aerial Shells	Soft breaking shell effects, such as Fish, Falling Leaves, Waterfalls and Horse Tails	Aerial Shell	100mm	Not used
Medium Impact	Whistle Effects	Rising projectile that emits loud howling / screeching effect.	Multi-shot	20 to 30mm	
Medium Impact	100mm (Colour Star) Aerial Shell	Colour Star Shell	Aerial Shell	100mm	
Medium Impact	Multi-shot Salute Effects	Effect design to create loud noise / report. Minimial visual effect.	Multi-Shot	30mm	
High Impact	150mm (Colour Star) Aerial Shell	Colour Star Shell	Aerial Shell	150mm	
High Impact	75mm (Salute / Report) Aerial Shells	Effect design to create loud noise / report. Minimial visual effect.	Aerial Shell	75mm	

Table 2. Skylighter Fireworks - Pyrotechnic Effects & Associated Noise Characteristics.

6. Results

6.1 Immediate disturbance (0-30 minutes)

Distance

Time

Monitoring station	MV Spoonbill II, adjacent to Manly roost.	Manly Harbour Roost Site	Darling Point, Manly	Wynnum, Penfold Parade	MV Caretta, Tingalpa Creek	Queens Esplanade, Thorneside
Distance from event location (metres)	230	470	500	1230	2100	3670
Birds captured on thermal camera	✓	✗	✓	✓	✓	✗
Bird call intensity increase recorded at start of test.	✓	✓	✓	✓	✓	✓
Birds recorded taking flight 0 – 5 minutes	✓	Birds recorded taking flight from roost area from MV Spoonbill	✓	✓	✓	Audio recording indicates birds took flight.
Behaviour observed 6 - 30 minutes	No birds observed or heard*	No birds observed or heard*	Birds observed arriving and feeding.	Birds observed arriving and feeding.	Birds observed arriving and feeding	No monitoring conducted.

Table 3. Summary of recorded observations during the Manly firework test (time measured from time of first firework launched). Weather conditions at time of launch; 0-5 knots easterly wind, no cloud cover.

* Due to the position and direction of the tide no birds were expected to return to the roost site during this period.

6.2 Short term disturbance (12-48 hours)

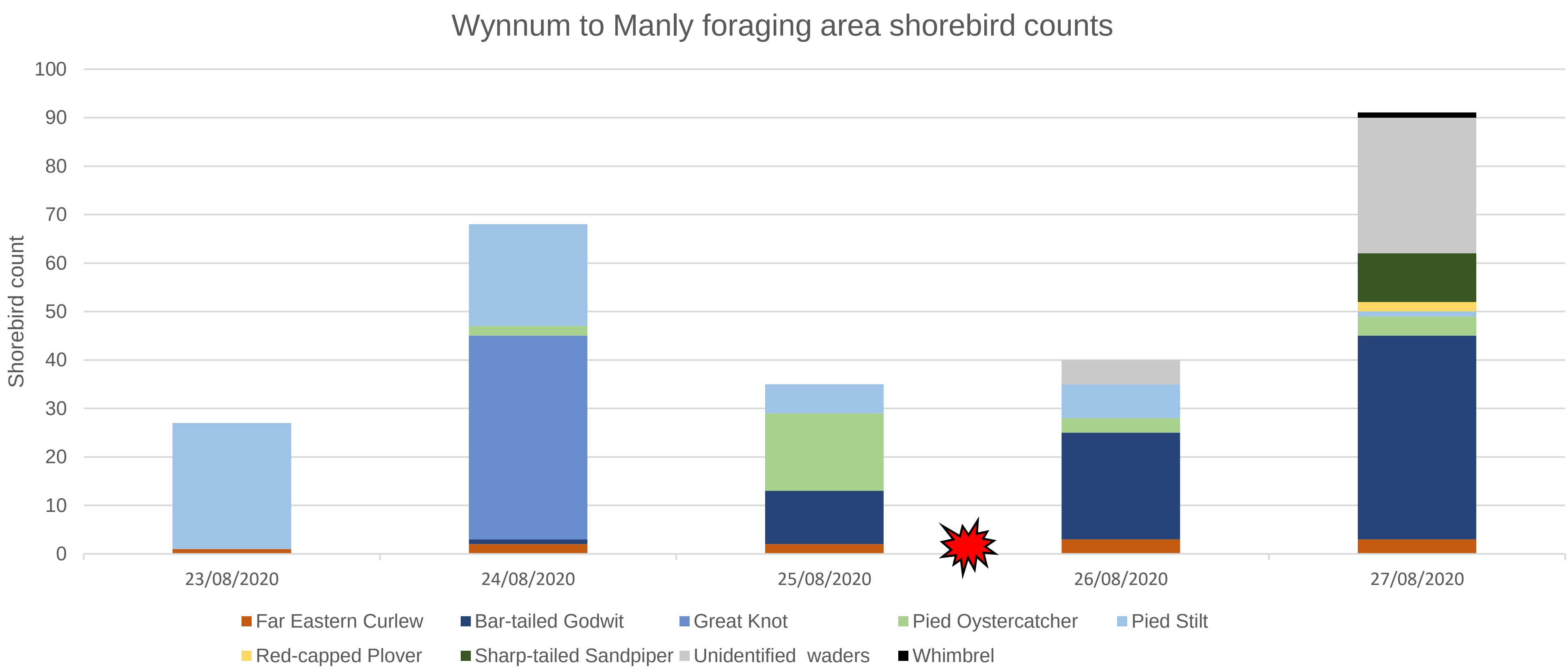


Figure 2. Chart displaying shorebird sub-set counts 3 days before to 2 days after the firework test (full results in Appendix 2).

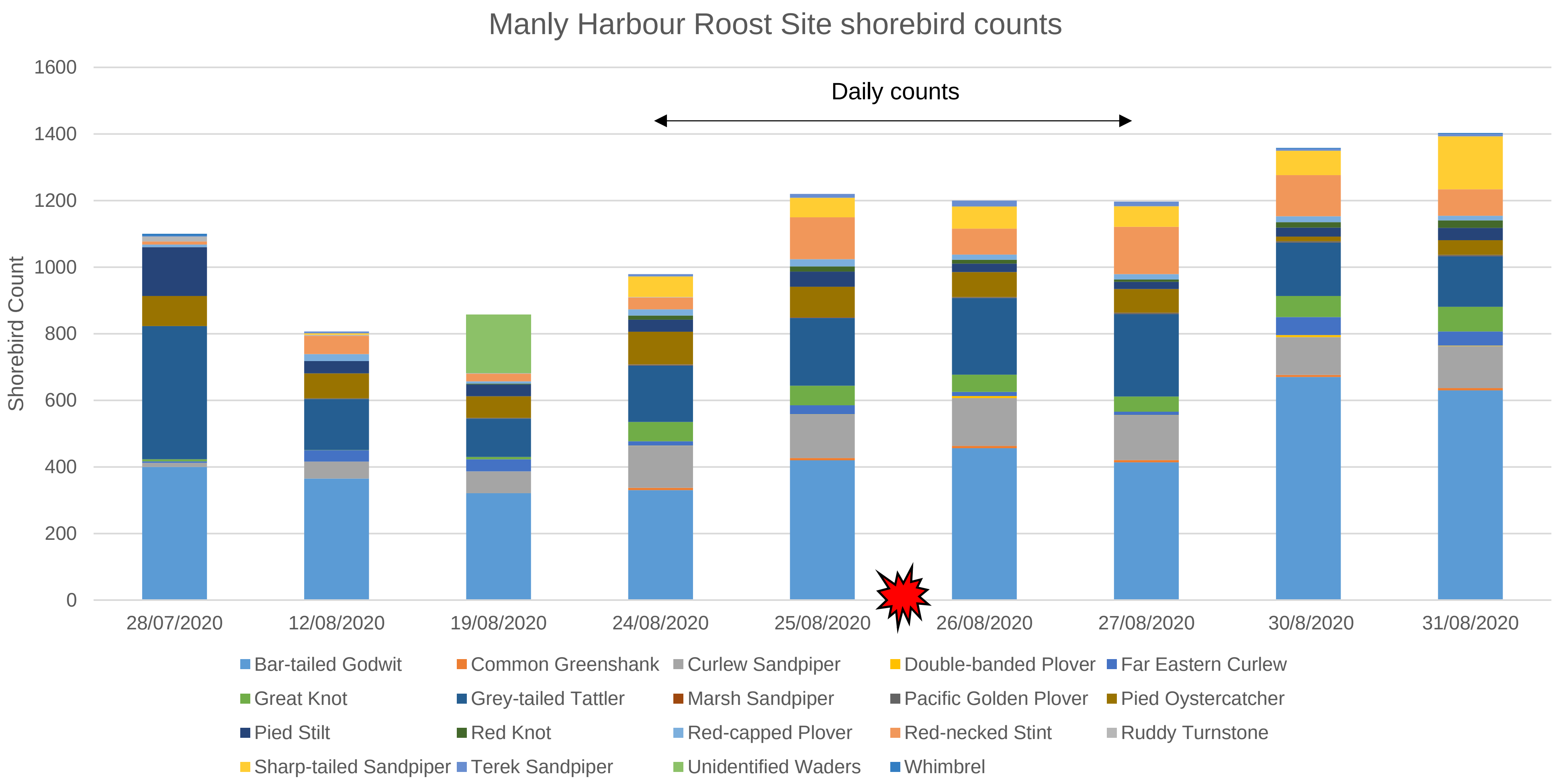


Figure 3. Chart displaying shorebird sub-set counts 4 weeks before to 1 week after the test. Species shown in listed order from Bar-tailed Godwit at the base of column. QPWS data shown 28/7/20-19/8/20. QWSG data shown 24/8/20-31/8/20. Note: QPWS counts were on average 57 lower than QWSG counts taken at the same time and location (full results in Appendix 2).

6.3 Varying response from firework type

Monitoring station	MV Spoonbill II, adjacent to Manly roost.	Manly Harbour Roost Site	Darling Point, Manly	Wynnum, Penfold Parade	MV Caretta, Tingalpa Creek	Queens Esplanade, Thorneside (no thermal camera)
Distance (metres)	230	470	500	1230	2100	3670
Observed reaction to mainly light disturbance, noise from firework launch only (0-0:59 secs).	Immediate response. Birds recorded leaving roost site area, flying away from test.	Bird calls at first launch (pied oystercatcher & masked lapwing), continuing calls through 1st minute. Decibel recording: 60 - 69.	Immediate response. Pelicans take off as a group on initial firework launch, continue to fly away from fireworks along the coast until out of sight. Other small groups of birds seen flying away from event site. Bird calls recorded.	Increase in tone of bird calls, changing to constant. Birds on ground seen running, some birds flying away. Flock of birds flying past, away from event, 40 seconds after start.	Within 5 seconds of test start bird calls increase (grey-tailed tattlers, far eastern curlew, whimbrel, pied oystercatcher, masked lapwing & silver gull). Continue at increased pitch. Very few birds take flight. Further behaviour change at display time 40 secs (change from comet to strobe willow fireworks). At 40 secs birds seen running (grey-tailed tattler), some take flight. A few fly short distance and settle. Calls seem to peak and maybe even decline towards 1 minute mark.	Bird calls start directly after first launch (far eastern curlew, masked lapwing & whimbrel). Build in intensity, then start to fade in volume.
Observed reaction to a combination light and secondary detonation, aerial shells. (1-5 mins)	Some sporadic bird calls.	Some sporadic bird calls (same species as above). No bird calls recorded final 2 minutes. Decibel recording: 65 – 89.	Bird flying away from event location. Another bird flying around, rather than away from event.	Increase again of bird calls. Bird calls die away 2 min 20 secs after test start. 3 birds come into land near structure, immediately take off again. 3 birds fly away high in view, 2 birds fly away low down. 3 birds seen on flats, possibly feeding (unidentified plover sp. & masked lapwing).	Dramatic increase in birds taking to wing, flying away from event at first aerial shell. Various bird calls after 1st aerial shell (masked lapwing and silver gull), calls reduce after first 2 mins of test. Some birds observed flying around rather than away from event location. A proportion of some bird groups in foreground remain throughout test (grey-tailed tattler). Majority take to the wing.	Bird calls continue to fade up to 1 min 45 secs past test start. Faint sporadic calls continue (far eastern curlew).

Table 4. Observed response from varying firework type. Species given in brackets is an opinion given by a QWSG member with experience of species regularly seen and heard in the Wynnum – Manly – Lota area.

7. Discussion

The recordings from each of the five QPWS monitoring stations from 30 minutes before to 30 minutes after the test varied in quality of picture and utility due to the following factors:

1 Two types of thermal camera set ups being used. The first camera model with a better picture quality and time stamp was used with a tripod for a steady image. Video from the thermal camera was displayed on a tablet and filmed by a fixed Go Pro camera (with accompanying sound). The second camera model type was hand-held with only a body cam attached to the user recording standard video and sound.
2 Distance of the monitoring station to birds.
3 Temperature contrast between birds and substrate.
4 Overall abundance of birds in the vicinity of the monitoring station at time of test start.

Recordings were analysed by the author through watching each video and noting the time of the recording for each change in behaviour, e.g., bird calls increase, birds in foreground take flight, birds flying away from event location. The recorded changes in behaviour were then compared with the timing of the start of the test, changes in type of firework during the test and the end of the test. Recordings at each location were then viewed with the individual who made the recording to ensure no details had been missed and to gather any additional information not evident in the recording. Species identification from thermal image and sound recordings was sought from representatives of the University of Queensland (UQ), QWSG and QPWS.

7.1 Immediate disturbance

** Species identification from bird calls and examination of thermal images provided by a QWSG member with experience of species regularly seen and heard in the Wynnum – Manly – Lota area.*

The thermal image recordings from the Manly Harbour Roost Site (~ 400 metres), Darling Point (~500 metres) and Tingalpa Creek (~2100 metres, screen shots on Appendix 3) show strong evidence that birds took flight at these locations as a result of the firework test (Table 3). The recording from Wynnum (~1230 metres) was less conclusive due to a combination of the above factors (section 7) but still captured evidence of bird disturbance. Although it could be argued that the birds recorded taking flight were changing location for other reasons, the timing of flight in relation to the test, simultaneous response at multiple locations and lack of other disturbance factors suggests flight was initiated as a result of firework disturbance in all locations where thermal imagery was available. Vessel based radar set to detect bird flocks did manage to detect a group of 13 Pelicans flying from the roost site to Darling Point before the firework test start and picked out the same group leaving Darling Point within 10 seconds after test start. However, flocks of smaller sized birds were not detected. Abundances may have been too low and dispersed across a wide area for detection or the radar may not have been sensitive enough to detect small sized birds.

The bird calls heard in the recordings from Tingalpa Creek and Thorneside (independent monitoring[5] with non-thermal camera at ~3670 metres) show a similar pattern, increasing sharply at the start of the test continuing through the first minute and receding after the first aerial shell. This suggests birds at Thorneside (whimbrel, masked lapwing and far eastern curlew*) also took flight as a result of the test. It is unlikely bird calls would reduce as disturbance increased, unless the birds had left the monitoring area. An experienced shorebird counter's opinion suggested that the tone and pattern of the calls at Thorneside was indicative of whimbrel and far eastern curlew taking flight. Interestingly, faint far eastern curlew calls could be heard at Thorneside up to 5 minutes after the test start. As the calls are faint and intermittent, this may mean the birds are circling in flight or have landed a short distance away and are calling intermittently. A further eyewitness account[6] was submitted by a

[5] Pelican and Seabird Rescue Inc.
[6] Cameron Macpherson, Wynnum resident.

resident on the Wynnum North Esplanade (~2700 metres), who describes birds taking flight from foraging mudflats in front of floodlit football fields during the firework test. However, there was no recording made at this location.

In addition to the data collected from the test on 25 August 2020, QPWS has conducted monitoring to a lesser extent on two previous commercial firework displays. The first being at Darling Point ~500 metres from the same Manly test location, at a NYE firework display 2018/19. This thermal camera footage shows a reaction similar to that seen from the test monitoring at Darling Point, with a rapid and urgent evacuation of the area by all birds captured by the thermal camera. The second monitoring recording was captured at the Kakadu Beach roost site ~3160 metres from an event location at Sandstone Point Hotel on 7 July 2019. On this occasion birds captured by the thermal camera (estimated to be pied oyster catcher) did not take flight but stopped moving throughout the display indicating a low level of disturbance but not enough to initiate flight.

Differences in weather conditions, species recorded and area topography between the Manly test event and the Sandstone Point Hotel event could explain the different FIDs recorded. The possibility should not be excluded that birds took flight at a ~3670m range from the Manly test. For example, weather at the time of Kakadu monitoring was raining with 20 knot south-easterly wind compared to clear skies and 0-5 knots easterly wind at the 2020 firework test. Sound wave behaviour under different weather conditions has been widely studied. However, little has been considered regarding the combined sound and light (summation) disturbance range on shorebirds under different weather conditions.

The FID recorded over the three monitoring events within Moreton Bay, described above, aligns closely with data collected overseas. Stickroth (2015) provides a comprehensive overview on 133 observations of fireworks (~80% of cases from Europe and ~20% from the USA), key points from the extended abstract available in English can be found in Appendix 1. The overview claims disturbance range will vary by firework type (e.g., detonation height and size of explosive charge), and provides a recommended minimum distance of 2km between fireworks and birds sensitive to disturbance. Stickroth (2015) adds, if sound carrying surfaces such as water are situated between the event location and bird resting areas, the minimum distance should be doubled to 4km. This recommendation aligns with data from the test and suggests that disturbance is feasible up to 4 km across Moreton Bay from water adjacent firework event locations.

Species identification of recorded birds through size comparison, behaviour and bird call was conducted by an experienced counter from QWSG. Individual species were more easily identified from bird calls than through thermal image recordings due to distinctive differences between species. However, thermal images provided clearer evidence of flight initiation and general bird behaviour at a site. Species identification was not possible for all birds captured by thermal imaging. Presence/absence and behaviour (feeding, flying, running, etc.) was generally apparent. A full list of species noted during daytime foraging and roosting surveys can be found in Appendix 4, this list offers the most likely range of species recorded in the thermal images.

Finally, birds were recorded landing and foraging at Wynnum, Darling Point and Tingalpa Creek within 25 minutes after the test (Table 3). Due to the ebbing tide, a lack of birds recorded at the roost directly following the event was not unexpected due to the tidal pattern of roosting and foraging and should not be attributed to the firework event (Fig. 1). It is unclear whether a proportion or all birds arriving during this 25-minute period are returning birds disturbed by the test, or birds flying in from other surrounding areas after test completion. The recording of a recommencement of foraging within 25 minutes is perhaps a positive indication that short-term impacts were not as severe as expected. Further analysis is found in the next section.

7.2 Short-term disturbance

The data presented in this section of the report concentrates on a sub-set of shorebirds (species list found in Appendix 5), consisting of wading shorebirds regularly found at the Manly Harbour Roost Site. The reasons being that wading shorebirds are more vulnerable to disturbance and for data comparison to independent QWSG data sets.

Examples in the literature consulted before the test suggested significant reductions in bird abundances were possible following a firework event. Weggler (2015) (Appendix 1) recorded a delay of three to ten days for numbers of swans, ducks and other waterbirds to return to pre-firework event levels on lake Zurich after NYE fireworks in 2013/14 and 2014/15, with reductions of abundance up to 35%. However, foraging area counts at the Wynnum to Manly foraging survey site show an increase from before to after the test (Fig. 2). The fluctuation in shorebird abundance on Wynnum to Manly foraging areas before and increase after could indicate that other meteorological and tidal factors were having a greater effect on abundances in these areas throughout the 5-day survey period than the firework test itself. A longer time series with more data points is needed to make any conclusions from foraging area data.

Caution must be taken when interpreting the high-tide roost counts before and after the test at the Manly Harbour Roost Site, as the firework disturbance did not occur at high tide. The Manly Harbour Roost Site presented only a 1.6% drop between the high tide counts before and after the test. A change of 1.6% is not considered significant. On initial consideration, the short-term impact results at the roost were suspected to have been skewed by arriving shorebirds replacing those displaced by test disturbance. The test was initially planned for July 2020, when winter populations are fairly stable. Unfortunately, due to administrative delays, the test occurred at a time when the first migratory shorebirds were starting to arrive in Moreton Bay from their northern breeding grounds. However, after comparing data through August over the last 5 years (Fig. 4), the abundance and trend of shorebird fluctuations before and after the test in 2020 is within the variation seen since 2016. As firework displays in Manly are not routinely held in August, variation displayed from years 2016-2019 inclusive is a result of natural fluctuations combined with other unknown human impacts.

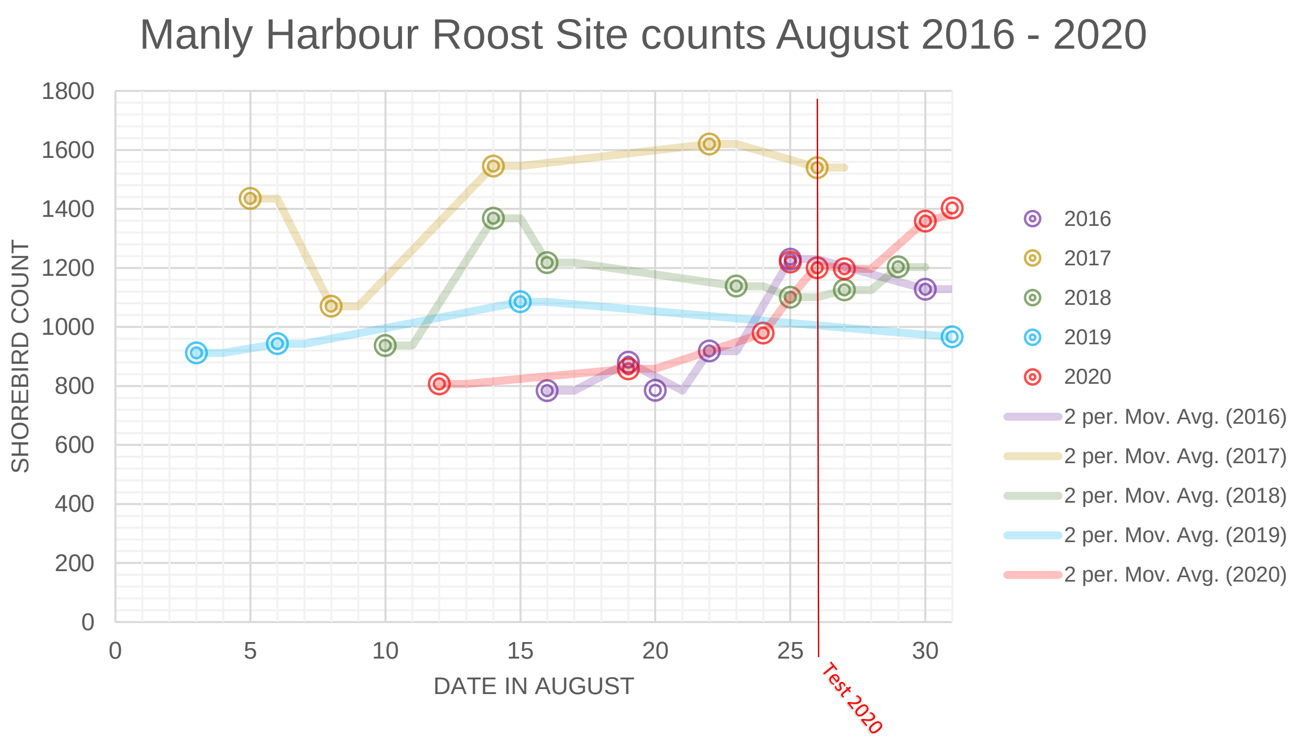


Figure 4. Manly Harbour Roost Site counts in August, 2016 – 2020. Data from 2016 to 2019 provided by QWSG. Data from 2020 is a combination of QPWS (12-19 August) and QWSG counts (24-31 August). Only migratory and resident shorebird species data shown.

The high-tide roost counts should not be taken out of context as an indication of short-term impact effects of future firework events at different points of the tidal curve (Fig 1). The test was deliberately designed for practical and ethical reasons to reduce disturbance to shorebird roosting and feeding patterns as far as possible while still maintaining a sufficient number of birds at monitoring locations to record FID. Shorebirds which took flight during the test and flew in a direction away from the event had a range of intertidal foraging areas on which to land and forage through a low tide period before returning to their preferred roost (Map 1). If the test had been conducted at high tide, displaced shorebirds would have had to relocate to a suitable high tide roost site outside of the disturbance range, potentially resulting in a longer flight and a greater energy loss.

As touched on in the method (Fig. 1), a direct comparison of shorebird abundances directly before and after at the tide height at test (1.2m ebb tide) was not possible due to daylight hours in August. Therefore, it is unknown how abundances were affected in foraging areas through the low tide (8:46 pm, 25/8/20) and roost site at the following high tide (2:42 am, 26/8/20). The recording of birds landing and foraging at Darling Point, Wynnum and Tingalpa Creek within 25 minutes of test completion may suggest a faster than expected normalisation of feeding patterns.

It should be noted that cannon netting was conducted at the Manly Harbour Roost Site by an independent researcher on the weekend of 1 August 2020 for the purpose of banding birds for shorebird monitoring. Survey results from 05/08/20 were not included in Fig. 3 (data included in Appendix 2) as they were considered anomalous. Total abundance of shorebirds was reduced from 1100 on 28/07/20 to 770 on 05/08/20, a 30% decrease. A pre-netting abundance of 1100 was not reached again until 25/08/20 (Fig. 3). It is unclear as to whether this slow recovery in abundance was due to the netting activity or natural fluctuations as are evident in Fig. 4. Previous cannon netting and banding by the researcher at high tide had caused recorded reductions in site abundance for up to 10 days. Although netting and banding of birds presents a different type of disturbance to a firework display, the cannon netting example shows the potential for greater short-term impacts at roost sites from disturbance during a high tide.

7.3 Varying response from firework type

As all recorded birds (by thermal image) at the roost site (~400m) and Darling Point (~500m) took to flight as an immediate response to the first type of firework (designed as the lowest impact), no further reactions were visually recorded for other firework types (Table 4). Bird calls recorded at the roost site (pied oyster catcher and masked lapwing*) did continue through the first minute, which suggests these resident species remained within sound recording range of the roost site until larger calibre shells were introduced at 1 minute+. Bird calls were recorded sporadically after this point with none heard in the last 2 minutes of the test. The decibel recording at the roost site (~470m) increased from 60-65dB over the first minute to 65-89dB over the following 4 minutes. Various online comparisons are available to other noise sources at this decibel level, for example power mower and loud traffic. Analysing the disturbance response of birds to different types of sound at the same decibel level is beyond the scope of this report and decibel levels were recorded for use in further assessments.

As the hand-held thermal camera at Wynnum was mainly employed panning across the foraging area throughout the test it is difficult to ascertain the effect of different firework types on a particular set of birds at this location (~1230m). Although a number of small groups of birds are filmed flying across the area in a direction away from the event it is not practical to estimate which type of firework caused them to take flight.

The thermal and Go Pro recordings made at Tingalpa Creek (~2100m) show the clearest evidence of varying disturbance response from firework type (Table 4). At this distance, the initial lowest impact fireworks (0-40 secs) elicit alarm calls but only a very small proportion (estimated from birds in view approximately <2%) of birds were recorded taking flight. A change in firework type from 40 secs to 1 minute provoked a marginally greater disturbance (estimated approximately 2-5%) response with more birds taking flight as well as others beginning to run along the substrate. A significant behaviour change is recorded at 1 minute with the introduction of the first 65mm calibre aerial shell (Table 2), a high proportion of birds remaining in view (up to approximately 60%) take to flight although one small species of bird seems less disturbed than all others recorded. Various small groups of what appear to be the same species, based on behaviour and size (grey-tailed tattler*), remain at the edge of the waterline throughout the test. Portions of these hardy groups are seen to leave progressively after the one-minute mark, suggesting that individuals within a species group also have varying tolerances to firework disturbance. Various types of bird calls were heard through the first minute (whimbrel, far eastern curlew, pied oyster catcher, silver gull, masked lapwing and grey-tailed tattler*), calls fade after 1 minute 45 seconds, with only a few sporadic calls heard after (masked lapwing*). No further behaviour change was discernible at the first 75 mm shell. Comparing thermal images panning the foraging area directly before and immediately after the firework test, it is estimated a 60-70% reduction in birds occurred within range of the thermal imaging camera at Tingalpa Creek.

8. Conclusions

1. At what distance do firework events cause shorebirds to take flight in Moreton Bay?

In the test scenario birds taking flight were recorded by thermal imaging up to 2 km from the test site. Audio recordings suggest flight was initiated at 3.67 km. Based on available literature, eyewitness accounts, thermal imaging and sound recordings flight initiation can occur up to approximately 4 km from a firework event location depending on type of firework, surrounding sound reflecting surfaces, topography, weather conditions and species present.

2. What are the short-term impacts on roosting and foraging shorebird abundance following a firework event?

In the test scenario there was no attributable reduction in roosting or foraging shorebird abundance 12-48 hours after the test. Firework events conducted within flight initiation distance of significant high-tide roost sites, at tides when roosts are occupied, are predicted to have the highest potential short-term impact as a greater number of birds would be put to flight and a reduced selection of nearby suitable landing sites would be available. Foraging bird abundance was not a reliable indication of short-term impacts for the test due to fluctuations dependant on other naturally occurring factors.

3. Do different types of firework elicit varying responses in shorebirds, and does this response change over distance?

Fireworks producing different types and levels of sound (Table 2) elicit varying responses in shorebirds. Disturbance thresholds vary between species and individuals. Disturbance thresholds are more easily exceeded at a shorter range, meaning a wider variety of species take flight at shorter distances. At greater range, varying responses between, species and individuals by firework type are more easily discernible. From the firework types used in the test scenario, response can be divided into two firework types:

(a) Fireworks producing light flashes with no loud secondary bursts/aerial shells.

Unreasonable disturbance as defined by the *Marine Parks (Moreton Bay) Zoning Plan 2019*, specifically causing shorebirds to take flight was recorded up to 2km. Bird alarm calls indicating a lesser disturbance response were recorded at 3.67km.

(b) Fireworks producing light flashes and sharp, explosive noise from secondary bursts/aerial shells.

Unreasonable disturbance (as defined above) was recorded up to 3.67km, with suspected flight initiation up to approximately 4km depending on surrounding sound reflecting surfaces, topography, weather conditions and species present.

9. Acknowledgements

QPWS would like to thank Skylighter Fireworks for designing the display, providing and organising the launch of the fireworks and for working with QPWS to reduce impacts on protected shorebirds in Moreton Bay. QPWS would also like to thank Queensland Wader Study Group for their ongoing dedication to data collection at the highest standard and commitment to the conservation of shorebirds, as well as Pelican and Seabird Rescue for providing additional recordings and Cameron Macpherson for providing an eyewitness statement.

10. Ethics approval

Approval granted by the Department of Agriculture and Fisheries on 14 July 2020. AEC Application Reference Number: SA 2020/07/748.

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Weggler, M. (2015) ‘Effect of new year’s eve fireworks on wintering waterbirds on lake Zurich [Effekt von silvesterfeuerwerk auf überwinternde wasservögel im unteren zürichsee-becken]’, Ornithologische Beobachter, 112(3), pp. 211–218.

WillyWeather (2020) Manly Tide Times and Heights. Available at: https://tides.willyweather.com.au/qld/brisbane/manly.html (Accessed: 25 August 2020).

Appendix 1. Literature summary

Bibliography	Study details and disturbance observed	Summary of findings/ recommendations
Shamoun-Baranes, J., Dokter, A.M., Van Gasteren, H., Van Loon, E.E., Leijnse, H., Bouten, W. (2011), 'Birds flee en mass from New Year's Eve fireworks', *Behavioral Ecology*, 22 (6), pp. 1173-1177.	• Thousands of birds took flight shortly after midnight, with high aerial movements lasting at least 45 min and peak densities measured at 500 m altitude. The highest densities were observed over grasslands and wetlands, including nature conservation sites, where thousands of waterfowl rest and feed. • The spatiotemporal patterns indicate that individual birds flew several kilometers before settling again and may even remain in the air for more than 30 min. • Fireworks were discharged in urban areas <5km from natural areas.	• The spatial and temporal extent of disturbance is substantial. • Although we do not expect fireworks to be directly lethal to birds, confounding factors, such as disorientation, or flying in inclement weather normally avoided could potentially result in mortality.
Stickroth, H. (2015) 'Auswirkungen von Feuerwerken auf Vögel – ein Überblick', *Berichte zum Vogelschutz*, 52(October 2016), pp. 115–149. Extended abstract in English added in 2019.	• Critical overview of 133 observations. • Observations of 88 taxa including waterbirds, cormorants, geese, Lari families, big wading birds, birds of prey, owls, gamebirds, oscine families and woodpeckers, crows and pigeons. • Birds react to both visual and acoustic stimuli. • Visual stimulus caused disturbance up to panic at short distances. Surprise effect different from meteorological storms that are expected due to air pressure change and slow approach. • Disturbance categorised into trepidation, flight and panic (flight). • Repeated disturbances often led to; increased evasion, complete abandonment of the area and individual and species count reduction. • High proportion of flocking birds react with panic flight which showed return abundance lower than normal flight and with a longer absence. • Nesting birds negatively affected, with some adults giving up the nest or returning too late. • No habituation to firework disturbance recorded.	• Majority of disturbance cases attributed to acoustic disturbance. Response varied between species and time of year (hunting season). • An increase in the rate of similar disturbance events led to 'stronger disturbance effects'. • Shielding structures between event and site of disturbance reduce reaction. • Reflective or sound carrying surfaces increase reaction (e.g. water, buildings, hills, dunes). • In various ways fireworks increase the risk of mortality for individual birds. • 'For populations with an unstable conservation status, negative trend or small population size as well as for sensitive species types (birds that flock or breed in colonies), the conservation status can worsen.' • For sensitive species a recommended minimum distance in 2km doubling to 4km if water or reflective surfaces are involved. • A time interval of 4 weeks should be taken between successive fireworks at the same location. • Distance between 2 displays on the same day should be >10km.

Weggler, M.(2015) ‘Effect of new year’s eve fireworks on wintering waterbirds on lake Zurich’ [Effekt von silvesterfeuerwerk auf überwinternde wasservögel im unteren zürichsee-becken], *Ornithologische Beobachter*, 112 (3), pp. 211-218.	• Overnight, the number of swans, ducks and other species of waterbirds dropped by 26 % and 35 %, respectively. The figures recovered quickly. After three (2013/14) to ten days (2014/15) • 2 counts before and 2 counts after each display • Grebe, cormorant, mallard and gulls	• Apart from the Mallard, all recorded species showed significantly lower numbers immediately after the fireworks.
Weigand, J.F. & McChesney, G.J. (2008) *Seabird and marine mammal monitoring and response to a fireworks display at Gualala Point Island, California, Sonoma County, May to August 2007*. Unpublished report, USDI Bureau of Land Management, California State Office, Sacramento, CA; and USDI Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, CA. 38 pp	• Gualala Point Island, Sonoma County, California. Breeding colony of Brandt’s Cormorant Pelagic Cormorants, Western Gulls and Black Oystercatchers • Observations documented a visible response by nesting seabirds on Gualala Point Island. Digiscoped and infra-red photography during the 6 July fireworks display showed that Brandt’s Cormorants quickly changed from resting to erect postures at the first fireworks, followed by birds moving about or departing from the island • Western Gulls also flushed, circled and called during the fireworks display. • There was higher than normal abandonment of Brants Cormorant nests. • Pelagic Cormorants abandoned both of the two monitored nests on Gualala Point Island between 10 and 16 July for unknown reasons. For one day after the fireworks display, counts of adult Western Gulls on the island declined significantly, but no Western Gull nesting failures were known to have occurred during the count period.	• Disturbance to water birds was observed 1.8km away from firework location. • Potential to increase nest abandonment, more data needed.
Werner, S. (2015) ‘Strong disturbance of waterbirds caused by fireworks’ [Feuerwerk verursacht starke Störung von Wasservögeln], *Ornithologische Beobachter*, 112 (4), pp. 237-249.	• Severe flight reactions of 95% of birds • Reacted to first light flashes • 4000 water birds disappeared within minutes • Effects were strongest in the breeding and molting seasons • Numbers of birds were less 2 days after display • Water birds (Cootes, Grebes, Swans) were counted before, during and after fireworks displays using night vision goggles. • Fireworks went to 150m high • Monitoring was undertaken 1000m from discharge location	• The disturbance of water birds caused by fireworks is considerable and is not compatible with the conservation aims of an EU Special Protection Area.

Appendix 2. Survey results

Wynnum Jetty to Manly Rock Wall bird counts.

Organisation	QPWS&P	QPWS&P	QPWS&P	QPWS&P	QPWS&P
Date	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug
Tide (m)	0.95-1.14	0.87-0.93	0.9-0.97	0.86-0.95	0.9-0.98
Common name					
far eastern curlew	1	2	2	3	3
bar-tailed godwit	0	1	11	22	42
great knot	0	42	0	0	0
pied oystercatcher	0	2	16	3	4
pied stilt	26	21	6	7	1
red-capped plover	0	0	0	0	2
sharp-tailed sandpiper	0	0	0	0	10
unidentified waders	0	0	0	5	28
whimbrel	0	0	0	0	1
Sub-total	27	68	35	40	91
caspian tern	0	0	0	2	1
gull-billed tern	6	6	9	8	5
greater crested tern	3	1	1	1	1
great egret	0	1	0	1	1
ibis	0	1	3	0	1
lapwing	1	5	2	4	5
little egret	0	0	1	1	0
silver gull	21	47	36	13	16
white faced heron	0	1	1	0	1
white bellied sea eagle	0	0	0	1	0
Sub-total	31	62	53	31	31
Total	58	130	88	71	122

Manly Harbour Roost Site bird counts

Organisation	QPWS&P	QPWS&P*	QPWS&P	QPWS&P	QPWS&P	QWSG	QPWS&P	QWSG	QPWS&P	QWSG	QWSG	QWSG	QWSG
Date	28-Jul	5-Aug	12-Aug	19-Aug	24-Aug	24-Aug	25-Aug	25-Aug	26-Aug	26-Aug	27-Aug	30-Aug	31-Aug
Common name													
bar-tailed godwit	400	395	365	321	270	330	420	420	456	456	414	670	630
common greenshank	0	4	0	0	4	7	7	7	6	7	7	6	7
curlew sandpiper	12	9	51	66	105	126	102	130	141	144	134	114	126
double-banded plover	0	0	0	0	0	1	0	1	6	6	1	6	1
far eastern curlew	5	0	34	36	9	13	29	27	12	12	10	54	43
great knot	6	21	1	7	58	58	59	59	52	52	45	63	74
grey-tailed tattler	400	210	153	115	140	170	232	204	230	230	248	161	152
marsh sandpiper	0	0	0	0	1	1	1	1	0	1	1	1	1
pacific golden plover	0	2	2	2	2	2	0		2	2	3	3	3
pied oystercatcher	90	41	75	65	93	98	62	92	69	75	71	14	44
pied stilt	147	71	37	36	44	36	39	46	30	26	22	27	37
red knot	0	5	0	2	13	13	17	15	11	11	7	16	22
red-capped plover	8	5	21	7	6	18	6	22	16	16	16	18	14
red-necked stint	9	0	55	23	20	36	105	126	5	78	142	123	80
ruddy turnstone	15	0	3	2	0	1	0		0			0	0
sharp-tailed sandpiper	0	0	4	0	50	62	18	58	67	66	62	74	159
terek Sandpiper	1	7	6	0	0	7	0	12	14	18	14	6	8
unidentified waders	0	0	0	176	126		73		2			0	0
whimbrel	7	0	0	0	0		0		0			2	2
Total	1100	770	807	858	941	979	1170	1220	1119	1200	1197	1358	1403

All counts conducted within 1h of high tide. (*Note: week following cannon netting not shown on Figure 3.)

Appendix 3. Before and after extracts from thermal camera at Tingalpa Creek

Note: time stamp on video at start of test 18:45, end of test 18:50. Due to the camera panning from side to side, the clearest still images have been extracted here at the times closest to the start and end of test available from video recordings. Very little disturbance was seen at 2 km within the first minute of the test. Figures 5 to 8 represent views before and after aerial shells were detonated from 1-5 minutes of the test.

Figure 5. View 1 from Tingalpa Creek vessel monitoring station towards Manly Harbour, 44 secs after start of test

Figure 6. View 1 from Tingalpa Creek vessel monitoring station towards Manly Harbour, 30 secs after end of test.

Figure 7. View 2 from Tingalpa Creek vessel monitoring station towards Lota Camping Reserve, 28 seconds after start of test.

Figure 8. View 2 from Tingalpa Creek vessel monitoring station towards Lota Camping Reserve 10 seconds after end of test.

Appendix 4. All birds recorded during surveys (possible to see in thermal images)

Common name	Scientific name
chestnut teal	*Anas castanea*
great egret	*Ardea alba*
ruddy turnstone	*Arenaria interpres*
sharp-tailed sandpiper	*Calidris acuminata*
red knot	*Calidris canutus*
curlew sandpiper	*Calidris ferruginea*
red-necked stint	*Calidris ruficollis*
great knot	*Calidris tenuirostris*
double-banded plover	*Charadrius bicinctus*
red-capped plover	*Charadrius ruficapillus*
silver gull	*Chroicocephalus novaehollandiae*
little egret	*Egretta garzetta*
gull-billed tern	*Gelochelidon nilotica*
pied oystercatcher	*Haematopus longirostris*
pied stilt	*Himantopus leucocephalus*
Caspian tern	*Hydroprogne caspia*
bar-tailed godwit	*Limosa lapponica*
little pied cormorant	*Microcarbo melanoleucos*
unidentified waders	*N/A*
unidentified terns	*N/A*
far eastern curlew	*Numenius madagascariensis*
whimbrel	*Numenius phaeopus*
Australian pelican	*Pelecanus conspicillatus*
little black cormorant	*Phalacrocorax sulcirostris*
Pacific golden plover	*Pluvialis fulva*
lesser crested tern	*Thalasseus bengalensis*
greater crested tern	*Thalasseus bergii*
Australian white ibis	*Threskiornis molucca*
grey-tailed tattler	*Tringa brevipes*
common greenshank	*Tringa nebularia*
marsh sandpiper	*Tringa stagnatilis*
masked lapwing	*Vanellus miles*
terek sandpiper	*Xenus cinereus*

Appendix 5. List of shorebird subset species

Common name	Scientific name
ruddy turnstone	*Arenaria interpres*
sharp-tailed sandpiper	*Calidris acuminata*
red knot	*Calidris canutus*
curlew sandpiper	*Calidris ferruginea*
red-necked stint	*Calidris ruficollis*
great knot	*Calidris tenuirostris*
double-banded plover	*Charadrius bicinctus*
red-capped plover	*Charadrius ruficapillus*
pied oystercatcher	*Haematopus longirostris*
pied stilt	*Himantopus leucocephalus*
bar-tailed godwit	*Limosa lapponica*
unidentified waders	*N/A*
far eastern curlew	*Numenius madagascariensis*
whimbrel	*Numenius phaeopus*
Pacific golden plover	*Pluvialis fulva*
grey-tailed tattler	*Tringa brevipes*
common greenshank	*Tringa nebularia*
marsh sandpiper	*Tringa stagnatilis*
terek sandpiper	*Xenus cinereus*