

WHITE PAPER

NexTrak R1 Performance Testing

IMOS
Integrated **Marine Observing** System

INNOVASEA

Field Testing the New NexTrak R1 Acoustic Receiver in a High Noise Environment

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1 Introduction

Since its introduction over 45 years ago, acoustic telemetry has become a widely used tool for monitoring aquatic animal movements and behavior worldwide. Over the years, the technology has evolved considerably, from its humble beginning as a small-scale active tracking method to a robust passive and real-time monitoring system capable of simultaneously listening for hundreds of thousands of uniquely identified animals. In parallel with advancements in acoustic transmission techniques enabling higher volume and more reliable data throughput underwater, innovations in battery and sensor technologies have additionally provided researchers with access to smaller transmitter and new sensor data, expanding the breadth and complexity of scientific questions that can be addressed. Since 1969, over 2,400 peer-reviewed articles describing spatial ecology-related insights from acoustic telemetry have been published (Matley et al. 2022, Matley et al. 2024).

Despite its evolution and widespread adoption as a research tool, challenges remain with acoustic telemetry technology, which can impact detection performance in some environments. The most widely used acoustic telemetry systems operate at 69 kHz, a favorable frequency for tracking animals in marine environments over relatively long timeframes and large geographic scales. These systems have a proven track record in ocean and freshwater applications. However, they can face performance challenges in some environments, including those with high levels of background noise. Examples of high noise environments that may impact 69 kHz detection range include hydro dam facilities, energetic coastal areas, areas of high biological noise (for example, coral reefs), and areas with high vessel traffic. Researchers doing work in these environments may find the need to use either higher power transmitters (if this option is available given the study's animal size) or reduced receiver spacing to mitigate the impact of reduced detection range.

While higher-frequency acoustic telemetry systems (for example 180 kHz, 307 kHz) can mitigate some of the challenges related to detection performance in noisy environments, there are tradeoffs that must be considered. For example, high-frequency transmitters are typically smaller and less powerful than 69 kHz transmitters (which can result in reduced detection range), have shorter battery life, and there are few

sensor options available. For some research, the transmitter options available at higher frequencies may not be well-suited to the study species or research question.

The new NexTrak R1, recently developed by Innovasea, is a novel 69 kHz acoustic receiver designed to improve detection performance in high-noise environments. Here, we present the results of a field test conducted in partnership with IMOS (Australia's Integrated Marine Observing System), comparing the detection performance of Innovasea's VR2AR receiver with the new NexTrak R1 in Sydney Harbour, Australia. Sydney Harbour is a large coastal embayment exposed to a range of swell and wind conditions, resulting in a high-noise aquatic environment. Two tests were conducted in Sydney Harbour to compare the detection performance of the VR2AR and the NexTrak R1:

- A 90-day static test to assess the influence of weather conditions on detection range
- A four-hour drift test to replicate tagged animals moving through the receiver array

2 Methods

2.1 Test Site

Testing was conducted at the mouth of Sydney Harbour, Australia, a high-noise environment that often experiences large waves and heavy winds in the winter (Figure 1).

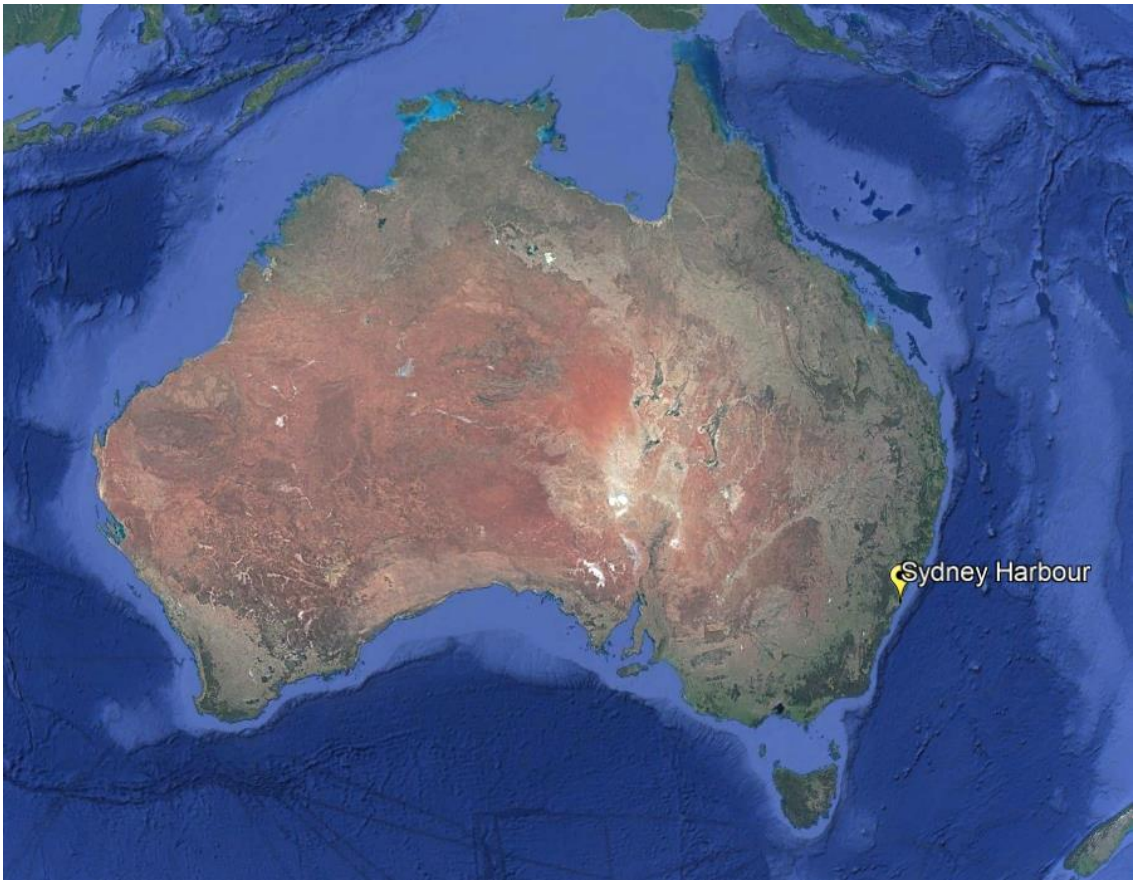


Figure 1

The test site was located between North Head and South Head, an area with a high volume of vessel traffic, including navy ships, cruise liners, and pleasure craft (Figure 1 inset).



Figure 1 (inset). NexTrak R1 testing location

2.2 Mooring design

On each of the three test moorings, a NexTrak R1 receiver was paired with a VR2AR receiver and attached to a line that was connected to a large mooring to pressure-rated flotation. The VR2AR was connected to the mooring with ~2 metres of chain attached to the release lug of the receiver using a load-rated shackle. The NexTrak R1 was placed ~1 metre above the VR2AR receiver and ~2-3 metres below the flotation (Figure 2). The average depth for all moorings in the study was ~24 metres.

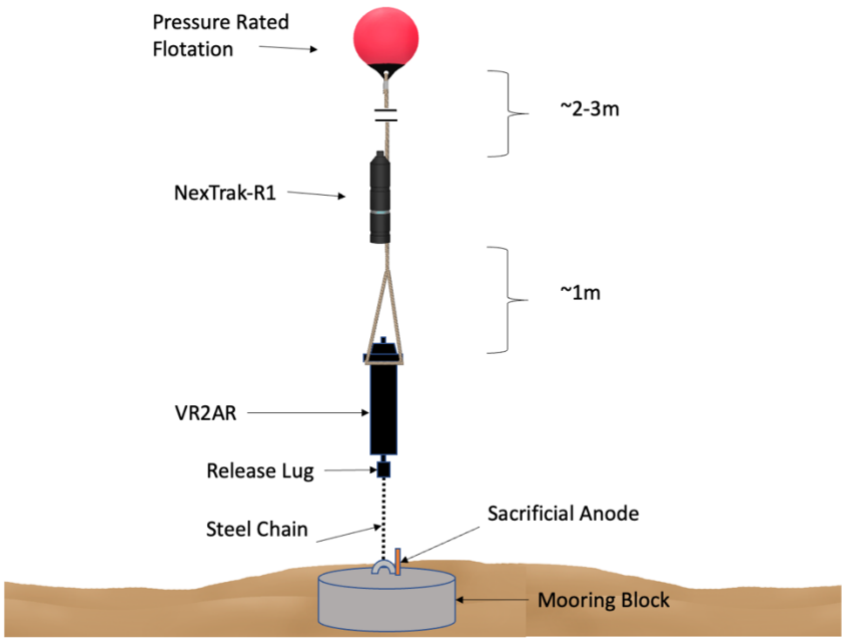


Figure 2. Schematic diagram representing the arrangement of NexTrak R1 and VR2AR receivers on the test moorings.

2.3 Noise Measurements

At the time of this field test, NexTrak R1 noise logging was under development. To ensure NexTrak receivers were tested under high noise conditions, noise data was sampled using the VR2AR receivers deployed at each mooring location.

2.4 Static Range Test

The first and most comprehensive test was a 90-day static range test. The test, conducted from April to July, was centered around four permanent IMOS stations which span the 2km channel between North Head and South Head (Figure 3: SG1, SG2, SG3, and SG4).

The IMOS installations, which have been in place for more than a decade, stretch across the channel in a line running northeast. The test moorings described in section 2.2 above – each consisting of a paired VR2AR and NexTrak R1 - were deployed in a triangular shape (Figure 3: M1, M2, and M3) around the northernmost IMOS mooring (SG4), which experiences the highest noise of the four IMOS sites.

The seven VR2ARs each had a built-in transmitter sending out a 160dB signal every 540 – 660 seconds. The 160dB signal is akin to that of an Innovasea V16 transmitter, a transmitter commonly used by shark researchers.

Each transmitter sent out 144 signals a day (12,960 over the course of the three-month study). One key benefit of this long-term study is that it measured the performance of the NexTrak R1 system in a broad

range of meteorological and tidal conditions. Overall, the study monitored performance at 15 unique distances; the longest distance between transmitter and receiver was 1,500 metres.

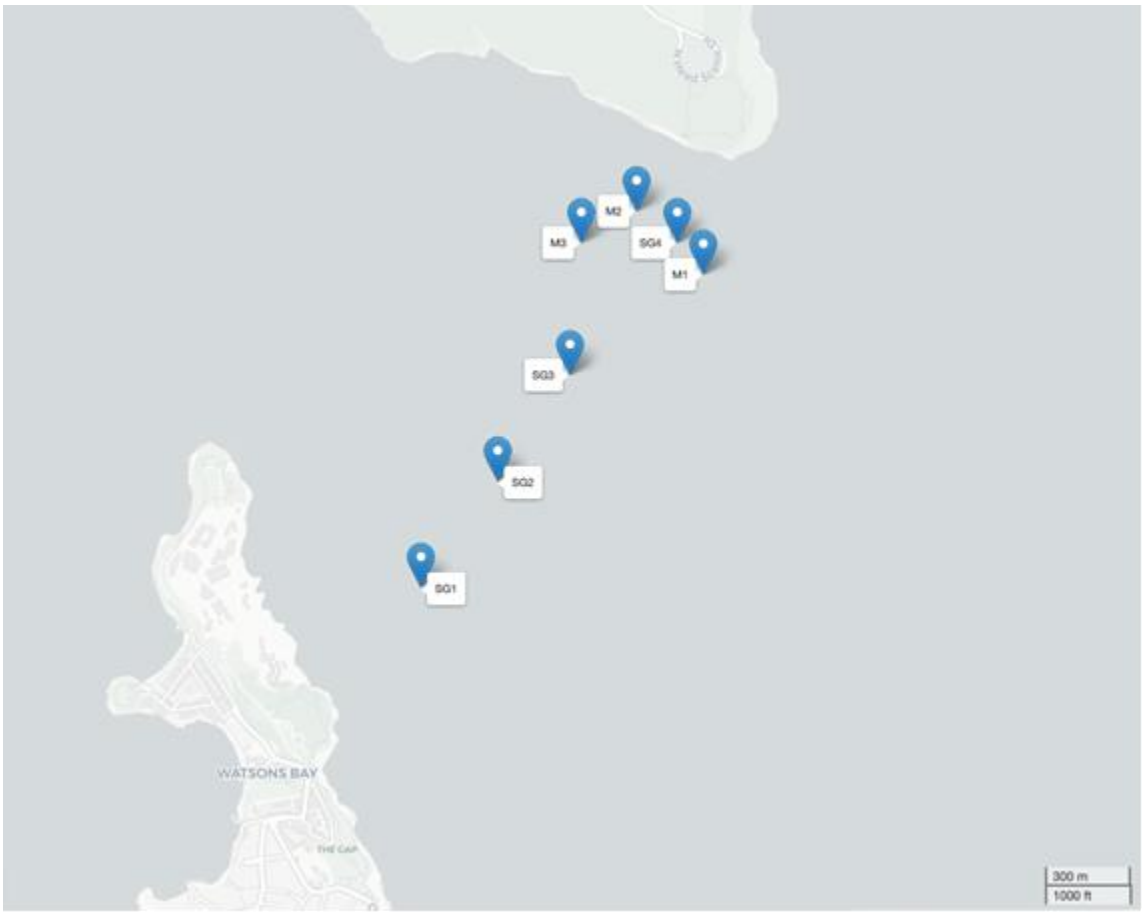


Figure 3. Acoustic receiver array deployed at the entrance to Sydney Harbour, Australia showing existing IMOS moorings containing VR2AR receivers (SG1, SG2, SG3, SG4) and range test moorings with paired NexTrak R1 and VR2AR receivers (M1, M2, M3)

2.5 Drift Range Tests

Drift tests were performed using a VR100-300 manual tracking receiver for GPS logging, a VHTx transponding hydrophone, and two range test transmitters. To test the effective range of the common transmitters used in coastal studies, a single V16-6x and a V9-2x transmitter were attached to the VHTx hydrophone cable, one metre above the hydrophone. Each transmitter was programmed with a fixed 27-second delay interval, alternating between low and high power after a transmission cycle. To avoid misinterpreting the results, power levels were distinguished in the detection data using alternating ID codes.

Individual drifts were undertaken with the hydrophone, and transmitters lowered to a depth of approximately 2 metres to ensure they were below the vessel's hull. The vessel was positioned upwind of the test moorings and passively moved through the test area at a speed of 0.8 metres per second. The

procedure was repeated five times, with each drift covering 1,000-1,200 metres in distance. Each drift lasted 45 to 60 minutes.

2.6 Array Performance Simulation

To assess the differences in receiver technology, a series of simulation models were developed to describe the detectability of tagged fish as they crossed the Sydney Harbour receiver array. Simulations were developed using a modified version of the *receiver_line_det_sim* function of the *GLATOS* R package (v0.8.0) to accommodate both time and temporal variation in receiver performance.

Each model iteration simulated the passage of 1000 tagged fish passing through the array using a restricted random walk model and a constant swim speed of 0.8m/sec. Transmissions along each fish trajectory were defined using a random interval between 40 and 80sec to replicate tagged sharks known to be in the study area. Detection probability fields around each receiver were modelled using data derived from the range tests and detection probability of each transmission calculated using a weighted binomial model. Model simulations were run 1000 times to produce detection efficiency values of 1,000,000 fish passing through the array.

2.7 Data Analysis

Receiver log files were downloaded from the VR2AR receivers using Fathom Mobile and from NexTrak R1 receivers using Fathom Connect, with all .VDAT files transferred to Fathom Central. Log files were exported from Fathom Central in CSV format and imported into R-Studio (v2023.09.0) for manipulation, analysis and visualization using the R software environment (v4.3.1).

Detection data from the static range test were binned into 10-minute time intervals for each transmission distance for the duration of the study. Time bins were either scored as a success if they contained a detection, or a failure for the absence of a detection. A logistic classifier model was used to classify each outcome as a function of distance and the data was fitted with a response curve. The effective detection range of the receiver-transmitter pair was determined by calculating the intersection of the response curve and a horizontal plane with a y-intercept equal to 0.5 (i.e. the distance at which 50 percent detection probability was observed).

Array performance simulations were performed using a modified version of the *receiver_line_det_sim* function of the *GLATOS* R package (v0.8.0). To accommodate both time and temporal variation in receiver performance, the base function was modified to accept a user-defined list of detection performance parameters.

3 Results

3.1 Static Range Test

Results from the static tests identified clear differences in the detection performance of the NexTrak R1 compared to the VR2AR acoustic receivers at each of the three test locations. The NexTrak R1 achieved a

~38 percent increase in range compared to the collocated VR2AR receivers at mooring 1 (M1) and mooring 2 (M2), and a ~24 percent increase at mooring 3 (M3) (Figure 4).

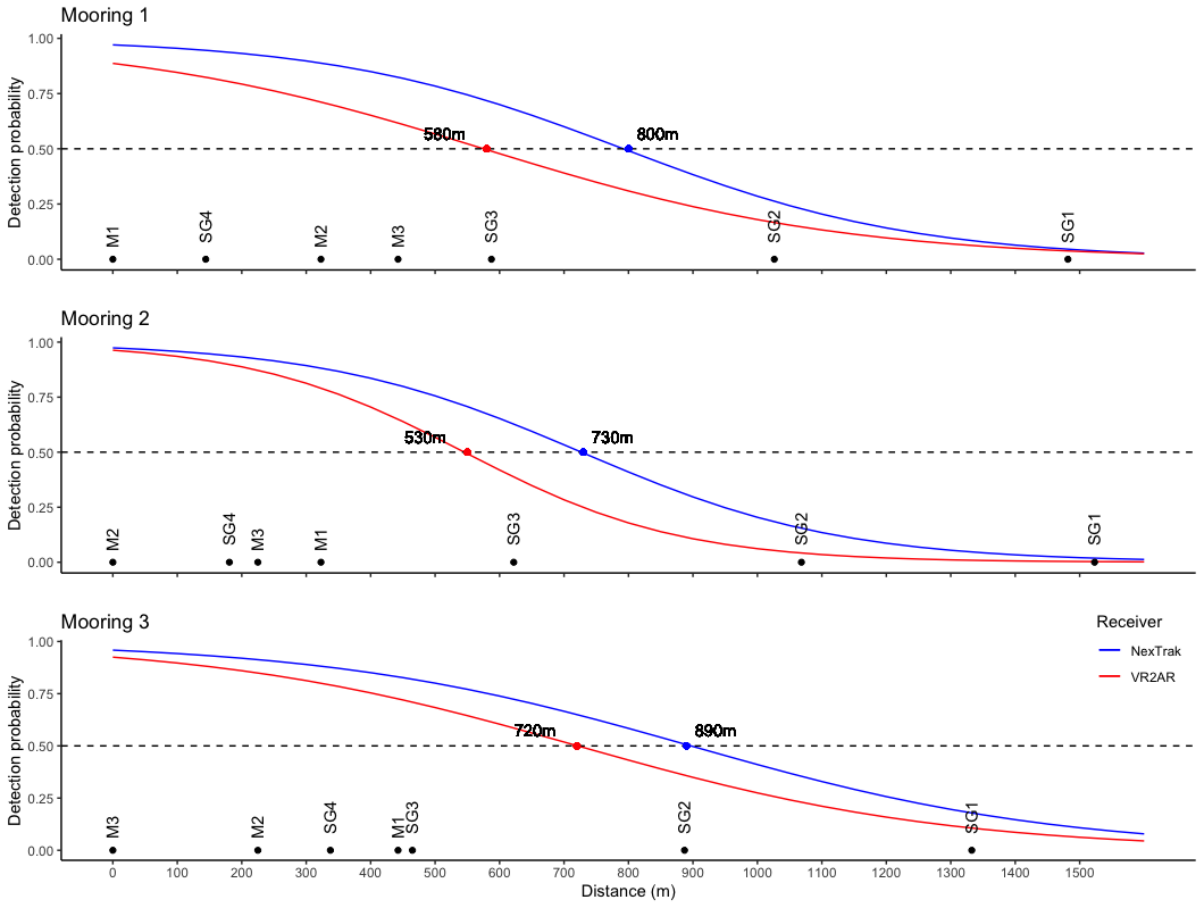


Figure 4. Detection range curves for collocated NexTrak (blue) and VR2AR (red) receivers over an 89-day period, using a 160dB transmission source, at three locations in Sydney Harbour. Dashed lines represent effective detection range (50% detection probability) and black points the distance between transmission sources and the test mooring.

3.2 Drift Range Tests

Like the static tests, results from the drift tests show a substantially increased detection range of the NexTrak R1 compared to collocated VR2AR receivers at mooring site M2. When towing a V16-6x transmitter, the effective range of the NexTrak R1 was ~1.9 times greater than the VR2AR for a 158 dB signal (V16-6H) and ~2.7 times greater for a 152 dB signal (V16-6L) (Figure 5).

When using a V9-2x transmitter for the drift test, the NexTrak R1 had an effective range ~2.28 times that of the VR2AR using a 151 dB signal (V9-2H), and 3.1 times using a 146 dB signal (V9-2L) (Figure 6).

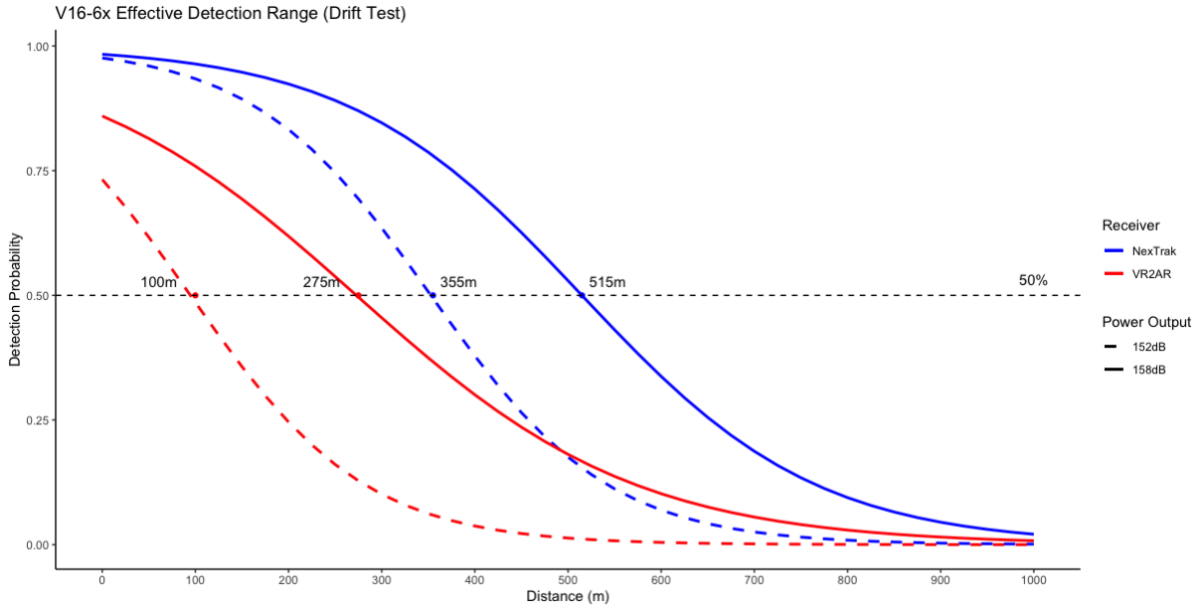


Figure 5. Detection probability curves constructed from data collected at mooring site M2 from five consecutive drifts using a V16-6x with alternating 158 dB (high power) and 152 dB (low power) transmissions.

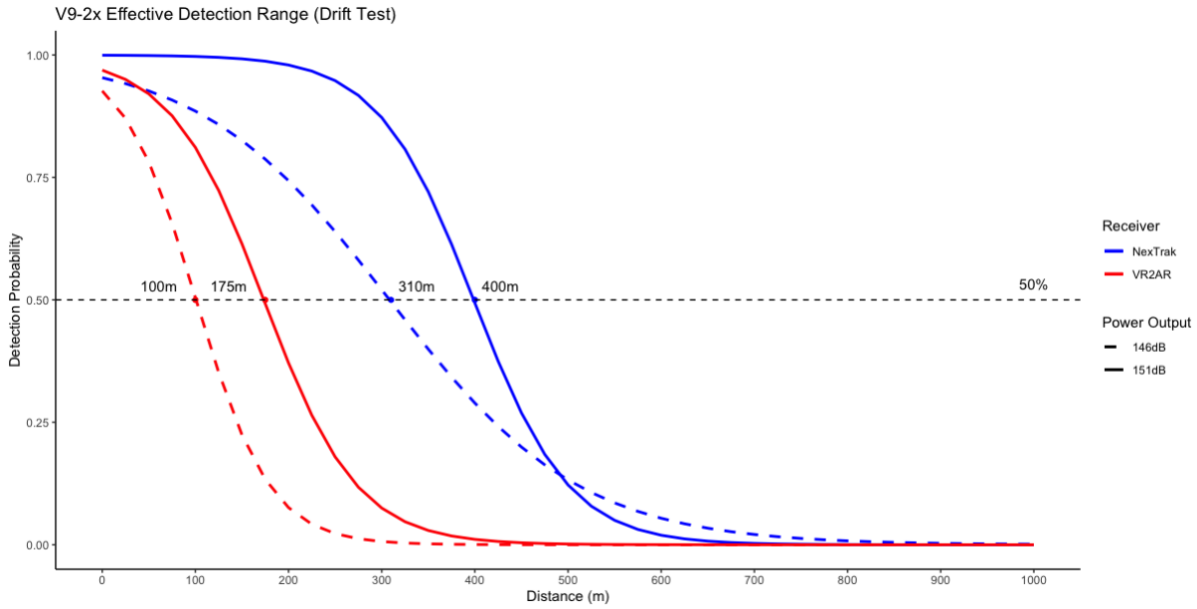


Figure 6. Detection probability curves constructed from data collected at mooring site M2 from five consecutive drifts using a V9-2x with alternating 151 dB (high power) and 146 dB (low power) transmissions.

3.3 Noise Measurements

To assist with interpreting the static test results, receiver diagnostic data were collected using the VR2AR receivers deployed on the M1, M2 and M3 moorings. The data suggests the M2 mooring was exposed to the highest level of in-band (69 kHz) noise. The peak in the noise profiles coincided with an elevated sea state, with the site experiencing approximately a 12-metre swell (Figure 7).

The diagnostic data show that noise levels throughout the test period were consistently within the 300 – 650 mV range considered "moderate to challenging" for 69 kHz detection performance ("Receiver Noise Measurements," https://go.innovasea.com/receiver_noise.pdf), and at times reached > 750 mV, the noise threshold above which detection performance is expected to be significantly impacted.

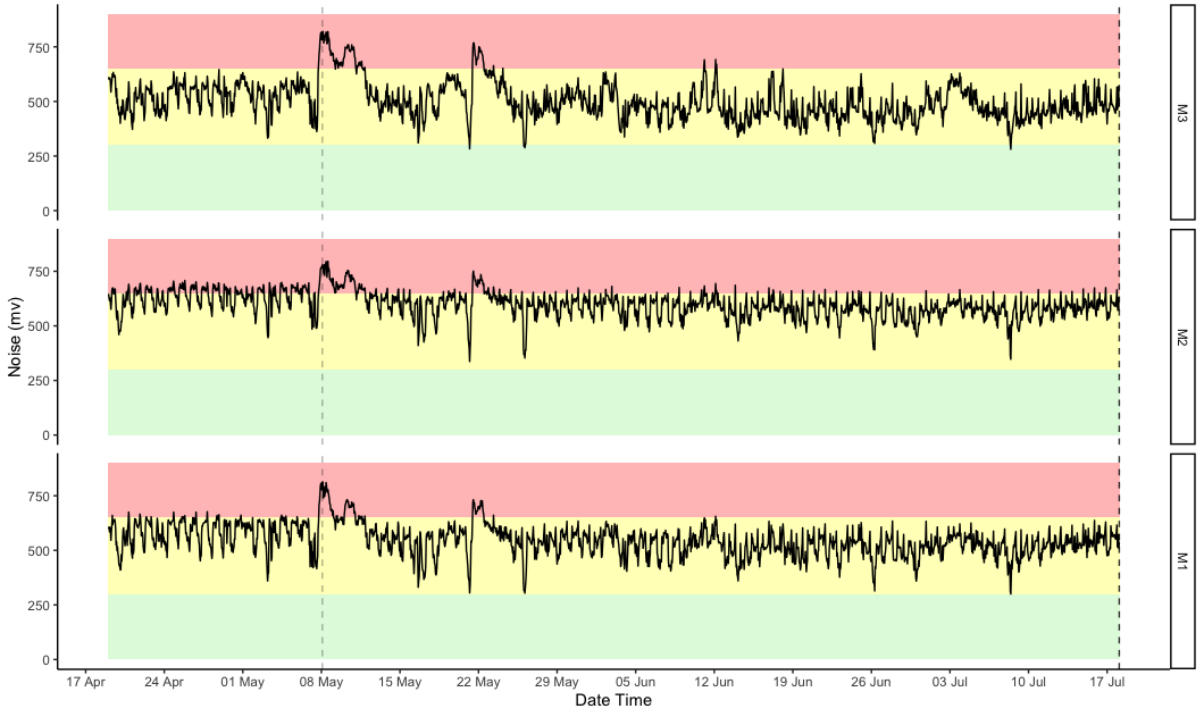


Figure 7. In-band noise profiles from VR2AR receivers deployed on the M1, M2 and M3 moorings between April 19 and July 17. Dashed line (grey) indicates the peak in noise profiles coinciding with heavy sea states (~12-metre swell). Drift tests were conducted on July 17 (black dashed line).

3.4 Tagged Animal Detections

One of the benefits of conducting the testing within Sydney Harbour was the potential to detect animals fitted with Innovasea acoustic transmitters. Since 2012, the New South Wales (NSW) Department of Primary Industries has tagged more than 2,000 sharks at various locations along the NSW coastline that are regularly detected by IMOS receiver arrays. During the static testing, 25 unique IDs registering more than a single detection were detected by the collocated receivers. While the NexTrak R1 receivers were able to detect all 25 IDs, the VR2AR receivers detected 20 of the IDs, or 80 percent (Table 1).

In addition to detecting five more unique IDs than the VR2AR receivers, the NexTrak R1 successfully decoded more transmissions from the A69-9002 and A69-9004 code spaces, yielding between 2.5 and 3.7 times the amount of animal-borne sensor data (temperature and acceleration).

Table 1. Summary of detection counts by NexTrak and VR2AR receivers on test moorings during the 90-day static test

Code space	Unique IDs NexTrak-R1	Unique IDs VR2AR	Detections NexTrak-R1	Detections VR2AR
A69-9001	11	10	316	130
A69-9002	4	4	78	31
A69-9004	10	6	74	20

3.5 Array Performance Simulations

Simulation modelling demonstrated the receiver array at the entrance to Sydney Harbour, comprised of VR2AR receivers, would have an average detection efficiency of ~21% for fish carrying V9-2L transmitters (Fig.8).

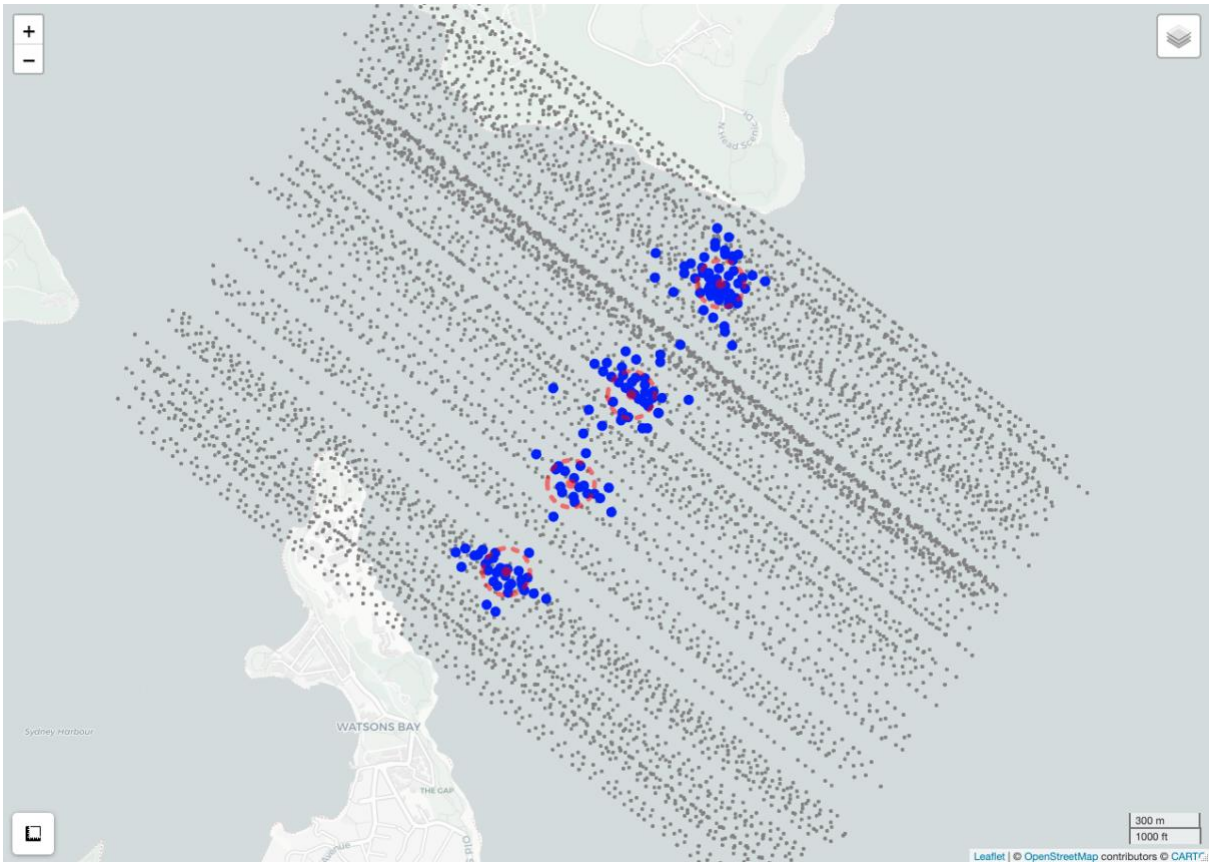


Figure 8. Simulated fish trajectories passing through the IMOS receiver line comprised of VR2AR receivers (red dots) at the entrance to Sydney Harbour. Transmissions (grey) were placed along each trajectory using a random delay of 40-80sec and swim speed of 0.83m.sec^{-1} with detections (blue dots) modelled using a binomial distribution weighted by the detection probability field of each receiver.

When the four VR2AR receivers were replaced by the NexTrak R1, the simulations indicated the average detection efficiency would increase by ~70% with over 90% of fish tagged with V9-2L being detected at least once by one receiver (Fig. 9).

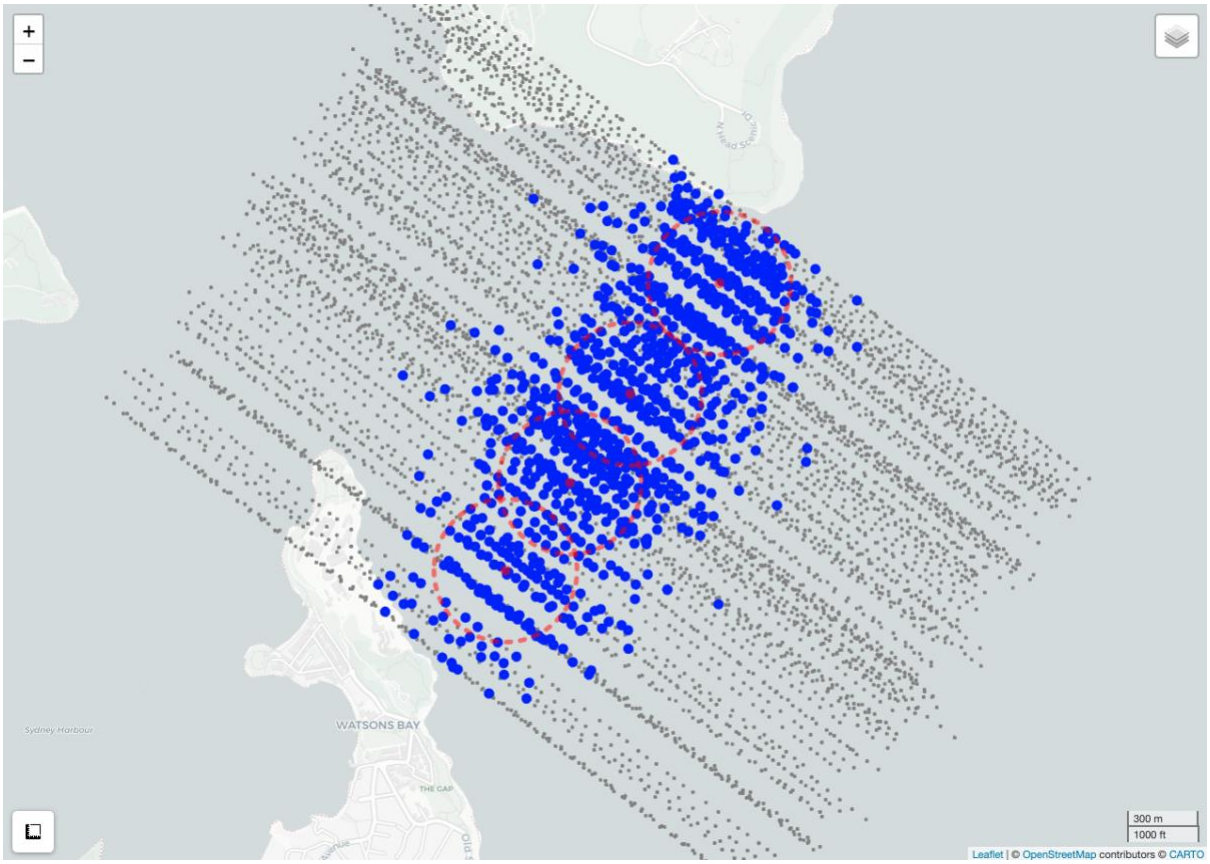


Figure 9. Simulated fish trajectories passing through the IMOS receiver line comprised of NexTrak R1 receivers (red dots) at the entrance to Sydney Harbour. Transmissions (grey) were placed along each trajectory using a random delay of 40-80sec and swim speed of 0.83m.sec^{-1} with detections (blue dots) modelled using a binomial distribution weighted by the detection probability field of each receiver.

To assess the impact of using a combination of receiver models on array performance, the simulation models were adjusted with one VR2AR receiver substituted for a NexTrak R1. To accommodate the greater effective range of the NexTrak R1, the remaining three VR2AR receivers were spread out along the axis of the array. Simulation models of the mixed array indicated the average detection efficiency of the array increased from ~21% to ~80% for fish tagged with V9-2L transmitters (Fig. 10).

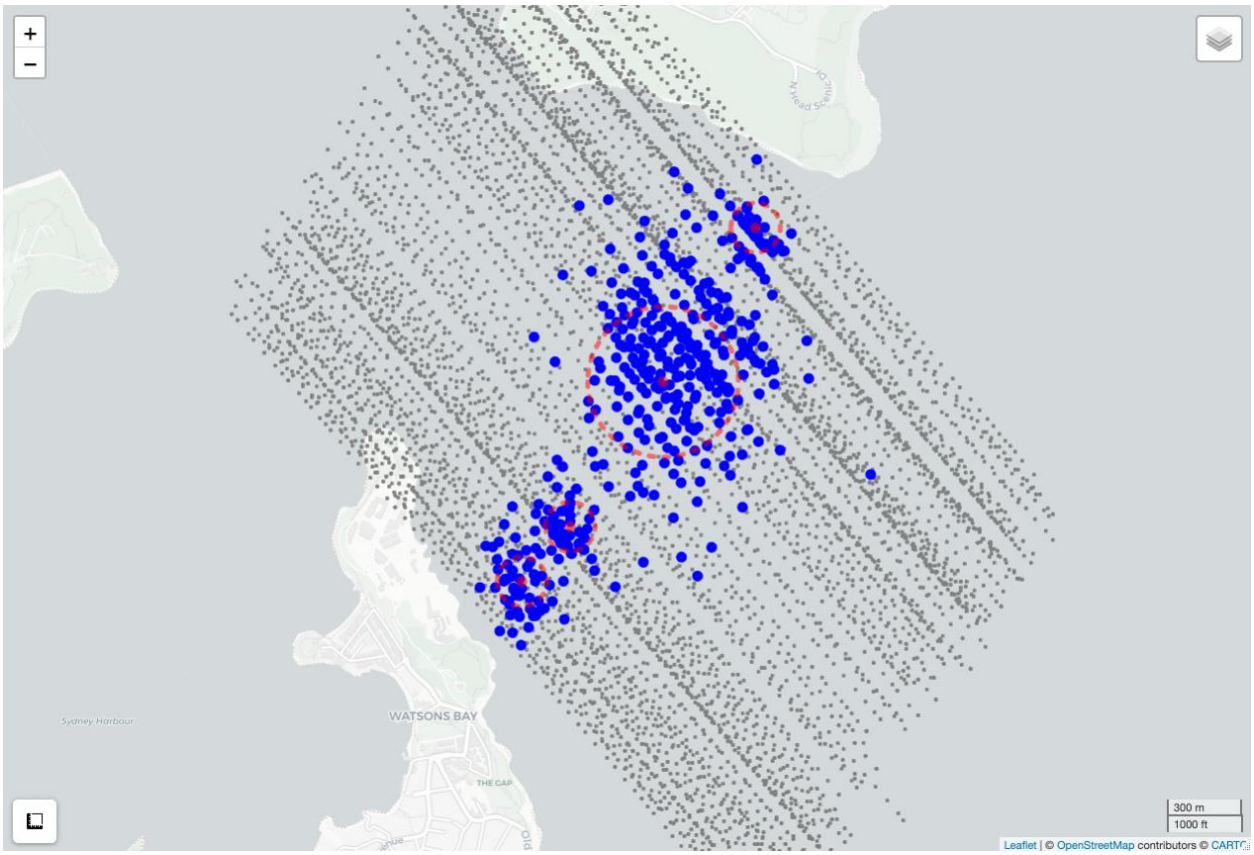


Figure 10. Simulated fish trajectories passing through the IMOS receiver line comprised of three VR2AR receivers and one NexTrak R1 (red dots) receiver at the entrance to Sydney Harbour. Transmissions (grey) were placed along each trajectory using a random delay of 40-80sec and swim speed of 0.83m.sec^{-1} with detections (blue dots) modelled using a binomial distribution weighted by the detection probability field of each receiver.

4 Summary

In both range tests performed during this study, the NexTrak R1 outperformed the VR2AR by a significant margin.

In the static test, the effective range of the VR2AR was 530-720 metres, compared to 730-890 metres for the NexTrak R1. Compared to the VR2AR devices, two of the NexTrak receivers had a 38 percent greater range, and the third had a 24 percent greater range. Overall, the NexTrak R1 recorded 158 percent more detections than the VR2AR devices.

The drift range tests showed that the NexTrak R1 had 2-3 times the effective range as the VR2AR. With the V9-2x signal, the range for the VR2AR was 115-200 metres compared to 320-390 metres for the NexTrak R1. With the V16-6x transmitter, the VR2AR range was 120-260 metres compared to 360-510 metres for the R1.

In addition to the range tests, we examined detection data from tagged sharks traveling into and out of Sydney Harbour during the three-month deployment period. Once again, the NexTrak R1 outperformed the VR2ARs, recording 468 detections compared to 181.

Results from simulation modelling indicated that substantial increases in detection efficiency (70% increase) could be achieved by substituting all existing VR2AR receivers in the test array with NexTrak R1. Substituting a single VR2AR in the array provided a ~60% increase in detection efficiency, indicating that the NexTrak R1 can contribute significantly to improved performance when integrated into existing arrays.

5 Conclusion

The results of this test reveal comparatively strong detection performance of the 69 kHz NexTrak R1 receiver in high-noise conditions that would typically be considered challenging for 69 kHz technology, in particular where study animal size may require the use of smaller (≤ V9) transmitters. This performance improvement presents new possibilities for more efficient array designs that can result in improved detection performance and significant savings in infrastructure costs.

6 References

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