

# A comparative study of diving behaviour among Procellaria petrel species

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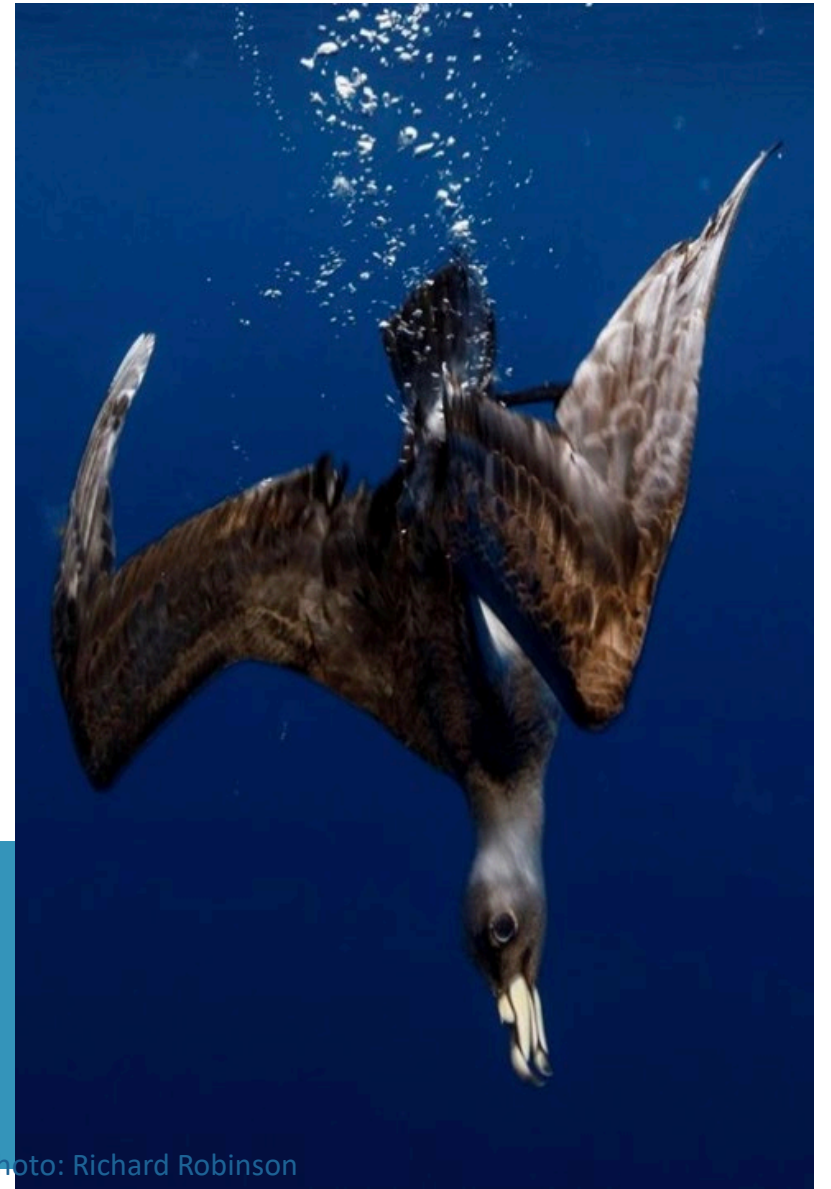


Photo: Richard Robinson

# BACKGROUND

- Seabird mortality in longline fisheries (*Phillips et al., 2016*)
- Diving behaviour necessary to inform bycatch mitigation methods (*Frankish et al., 2021*)
- Proficient divers put less apt divers at risk by retrieving baited hooks (*Jiménez et al., 2012*)
- Time depth recorders (TDRs) to study diving behaviour



# STUDY SPECIES PROCELLARIA PETRELS



Photo: Martin Sanders, BirdsNZ online

**Black petrel**  
*Procellaria parkinsoni*



**Westland petrel**  
*Procellaria westlandica*

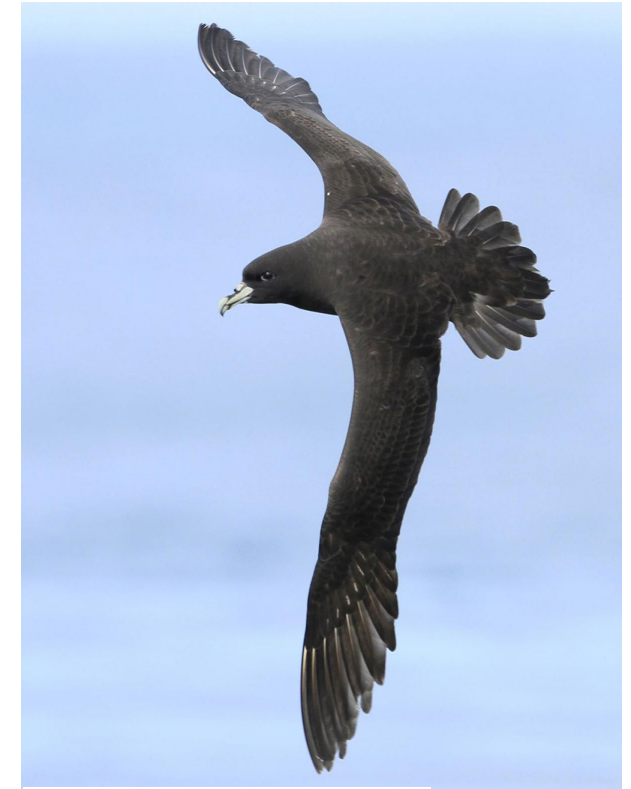
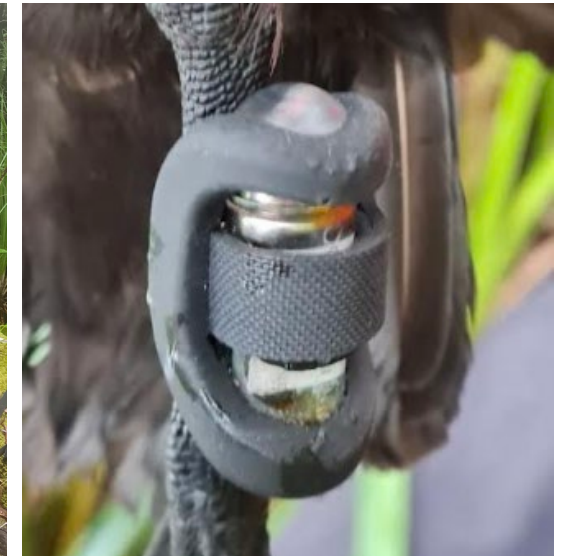


Photo: Phil Battley, BirdsNZ online

**White-chinned petrel**  
*Procellaria aequinoctialis*

# METHODS: Deployment of Time-depth recorders (TDRs)

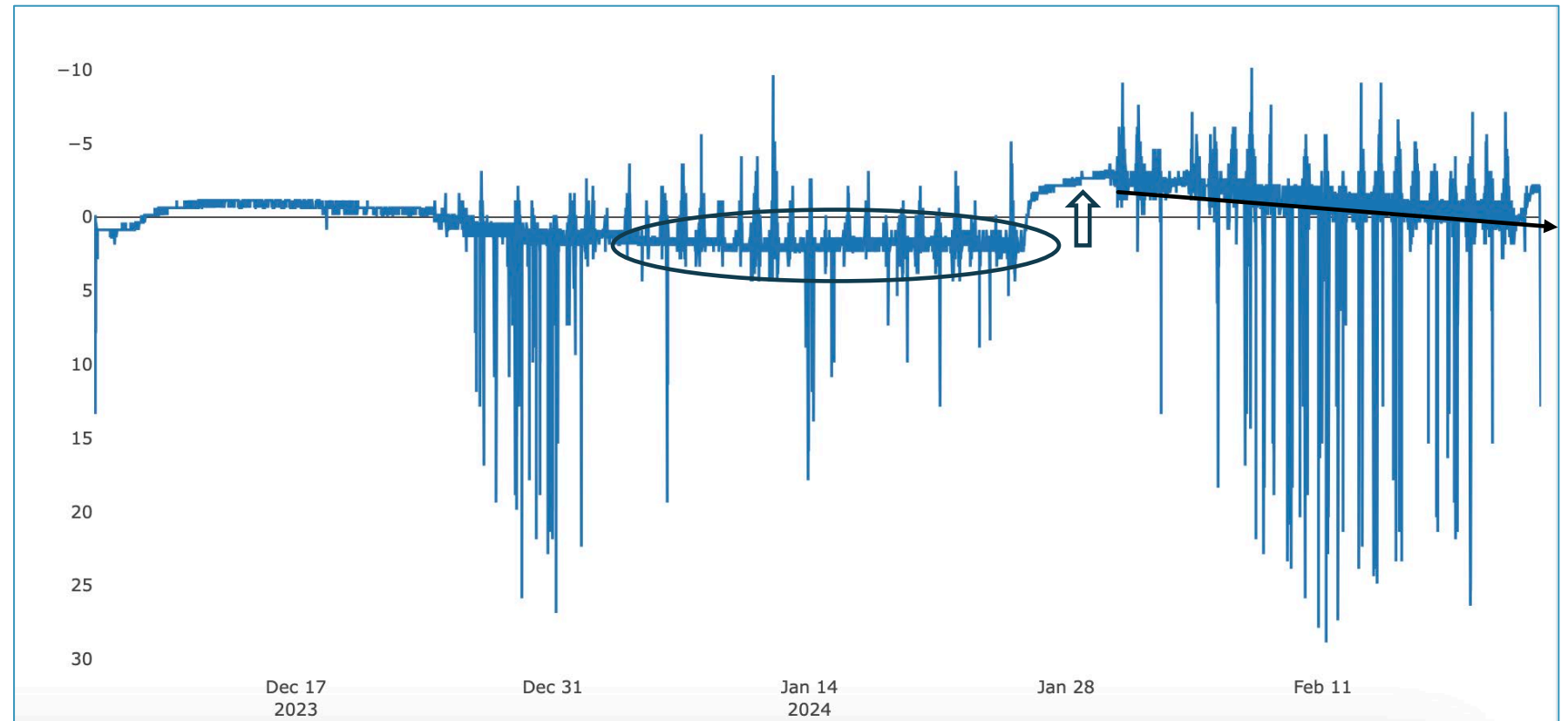
| Species              | Location   | No. deployments | Years       | No. deployed | No. retrieved | No. with data |
|----------------------|------------|-----------------|-------------|--------------|---------------|---------------|
| White-chinned Petrel | Antipodes  | 2               | 2022 / 2023 | 24           | 19            | 13            |
| Black Petrel         | Aotea      | 3               | 2023 / 2024 | 21           | 15            | 10            |
| Westland Petrel      | West coast | 3               | 2022 / 2023 | 45           | 39            | 32            |



# METHODS: Zero-offset

The problem: recorded depth deviates from actual depth over time at unpredictable rates

- Surface noise
- Drift
- Level shifts



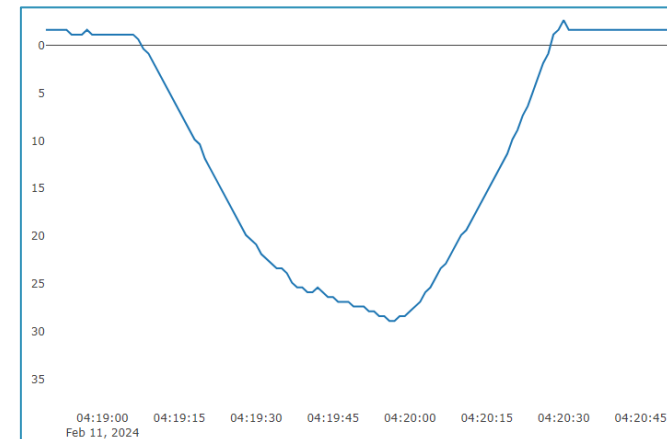
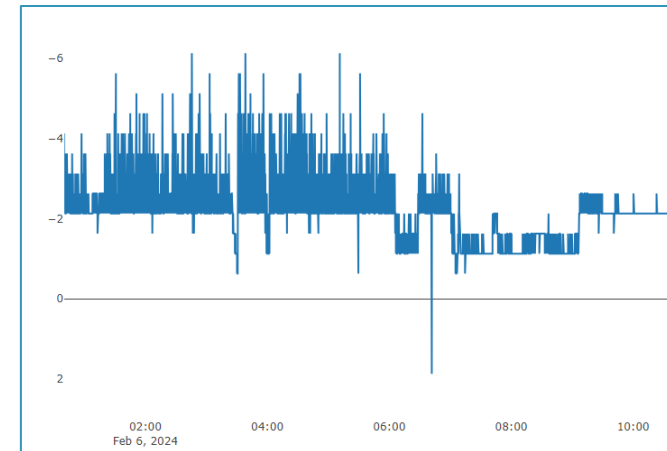
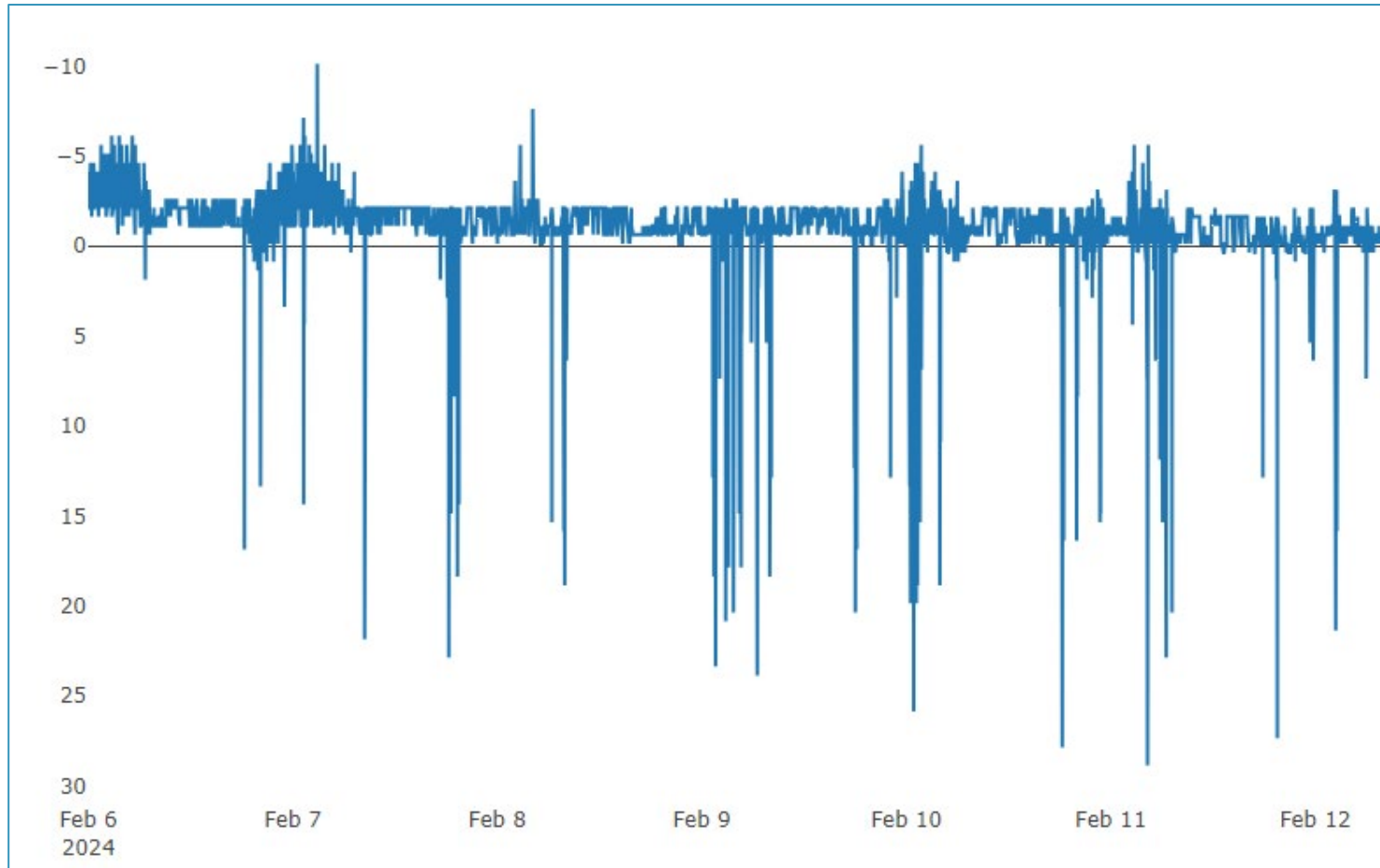
# METHODS: Zero-offset in diveMove

Filtering mechanism using moving windows that calculate specified quantiles

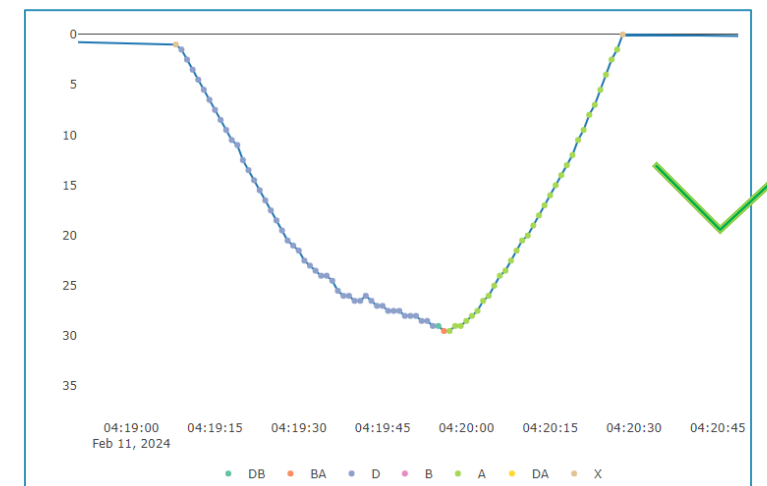
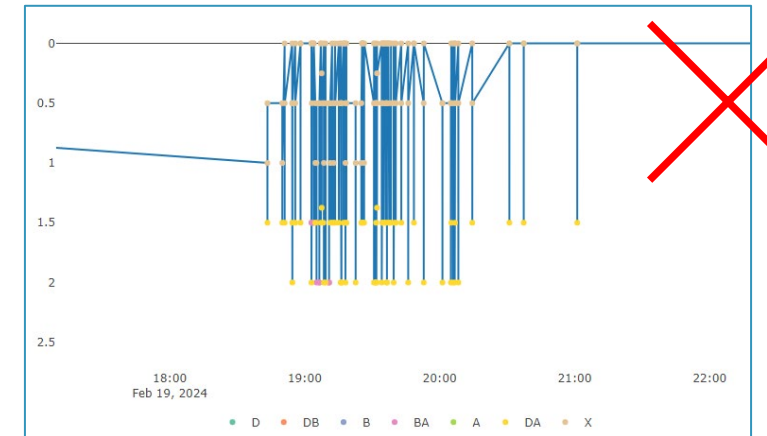
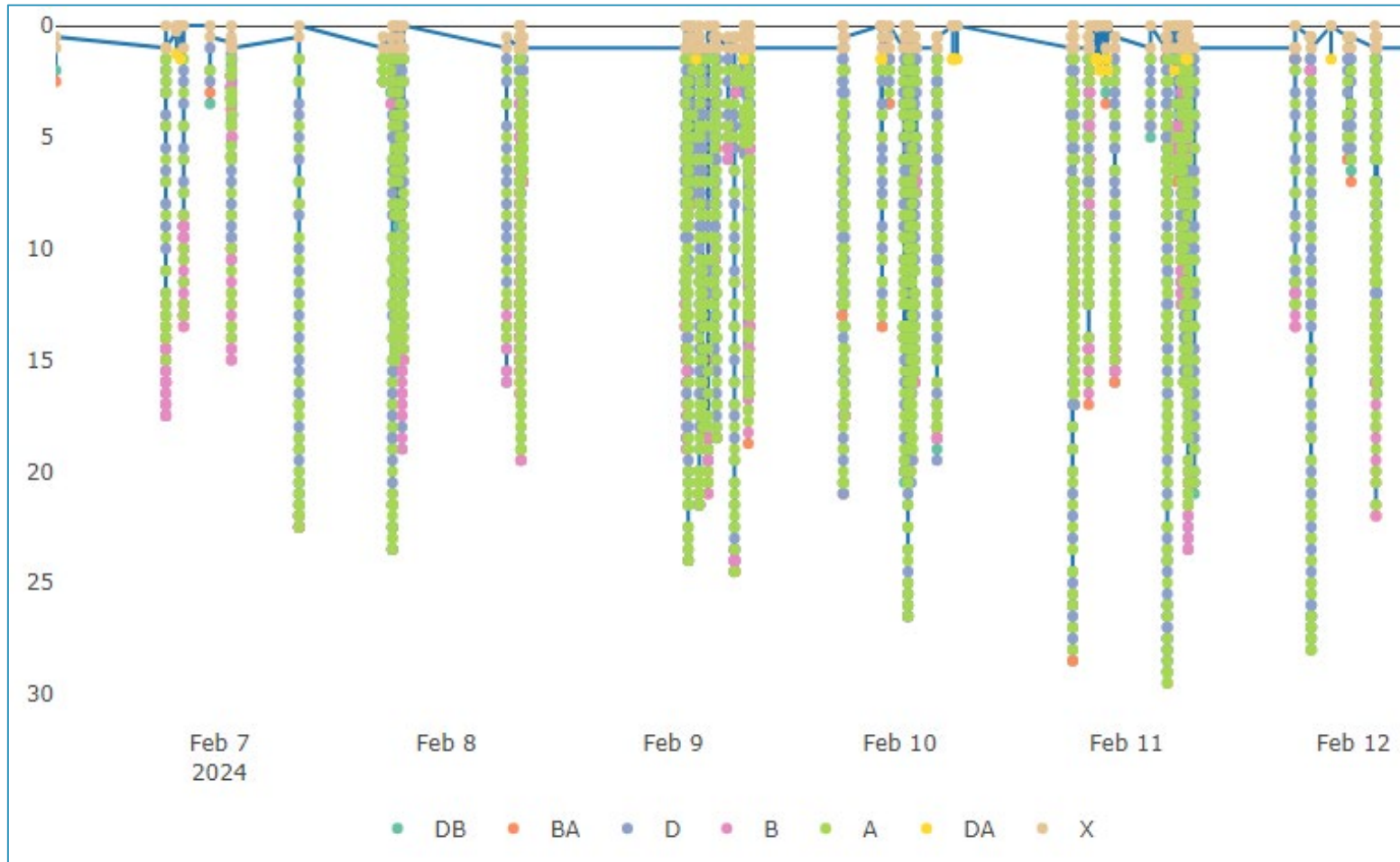


- Step 1:
  - The aim: reduce surface noise
  - Moving window: Slide a fixed-size window across the time series and calculate the median (quantile = 0.5)
- Step 2:
  - The aim: detect surface level.
  - Applied to output of step 1
  - Moving window: Slide a fixed-size window across the time series and calculate a small quantile (e.g. 0.05)
- Step 3:
  - Subtract the detected surface level (output of step 2) from the original depth readings (output from step 1)

# METHODS: Before filtering



# METHODS: After filtering



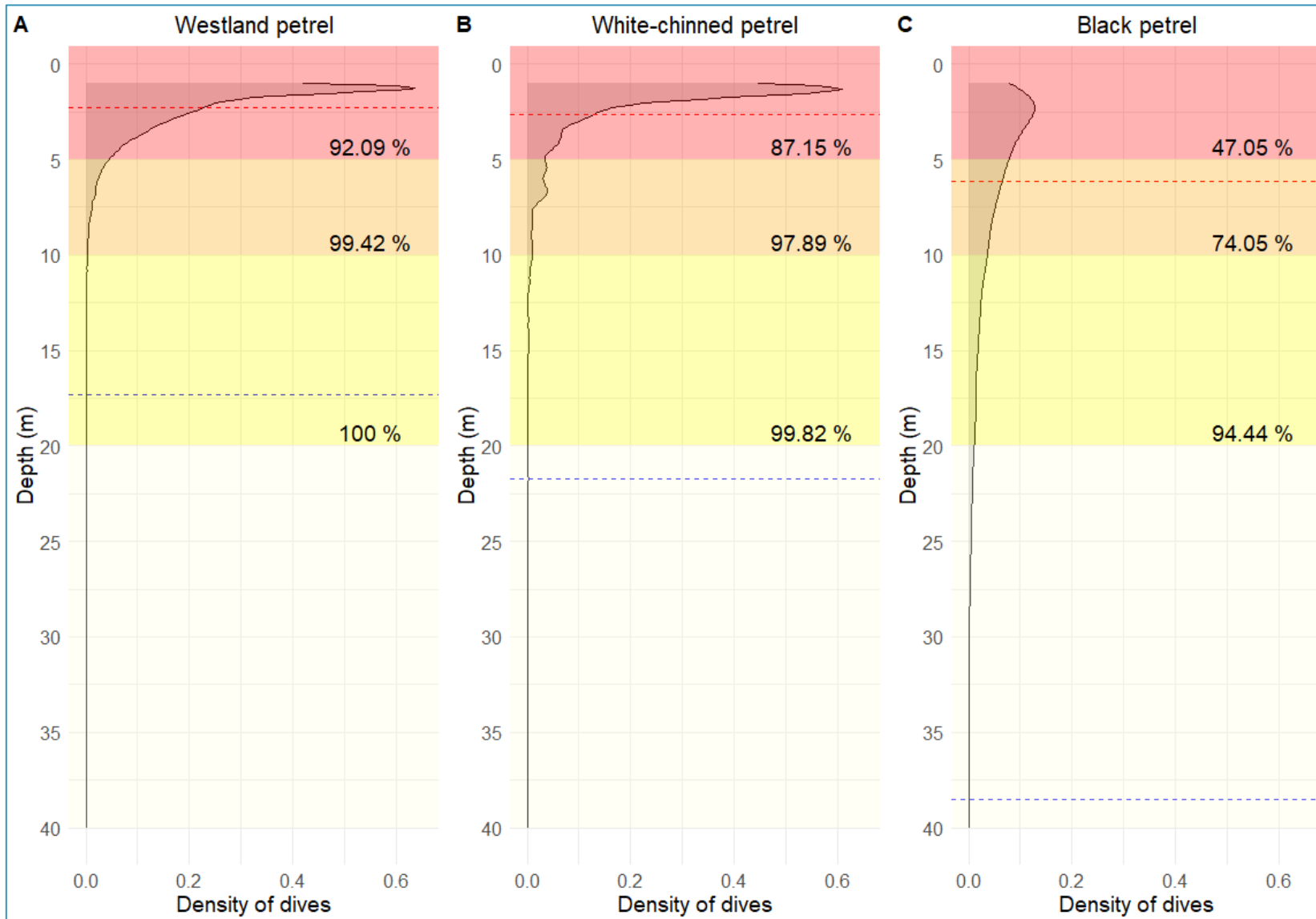


# METHODS: Statistical analysis

- Dive filtering
  - Dives with descent rates  $> 3$  m/s (*Rollinson et al., 2014*)
  - Dives longer than 5 minutes
  - Dive threshold 1 m (*Rollinson et al. 2014; Frankish et al., 2021*)
- Summary statistics
  - Descent rate overall
  - Descent rate excluding dives  $< 5$  m (*Rollinson, 2014*)
- Statistical analysis
  - General Linear Mixed Models (GLMM)



# DIVE DEPTHS



### Mean dive depth

|               | Mean        | Max   |
|---------------|-------------|-------|
| Black         | 6.16 ± 0.88 | 38.5  |
| Westland      | 2.31 ± 0.10 | 17.31 |
| White-chinned | 2.63 ± 0.57 | 21.72 |

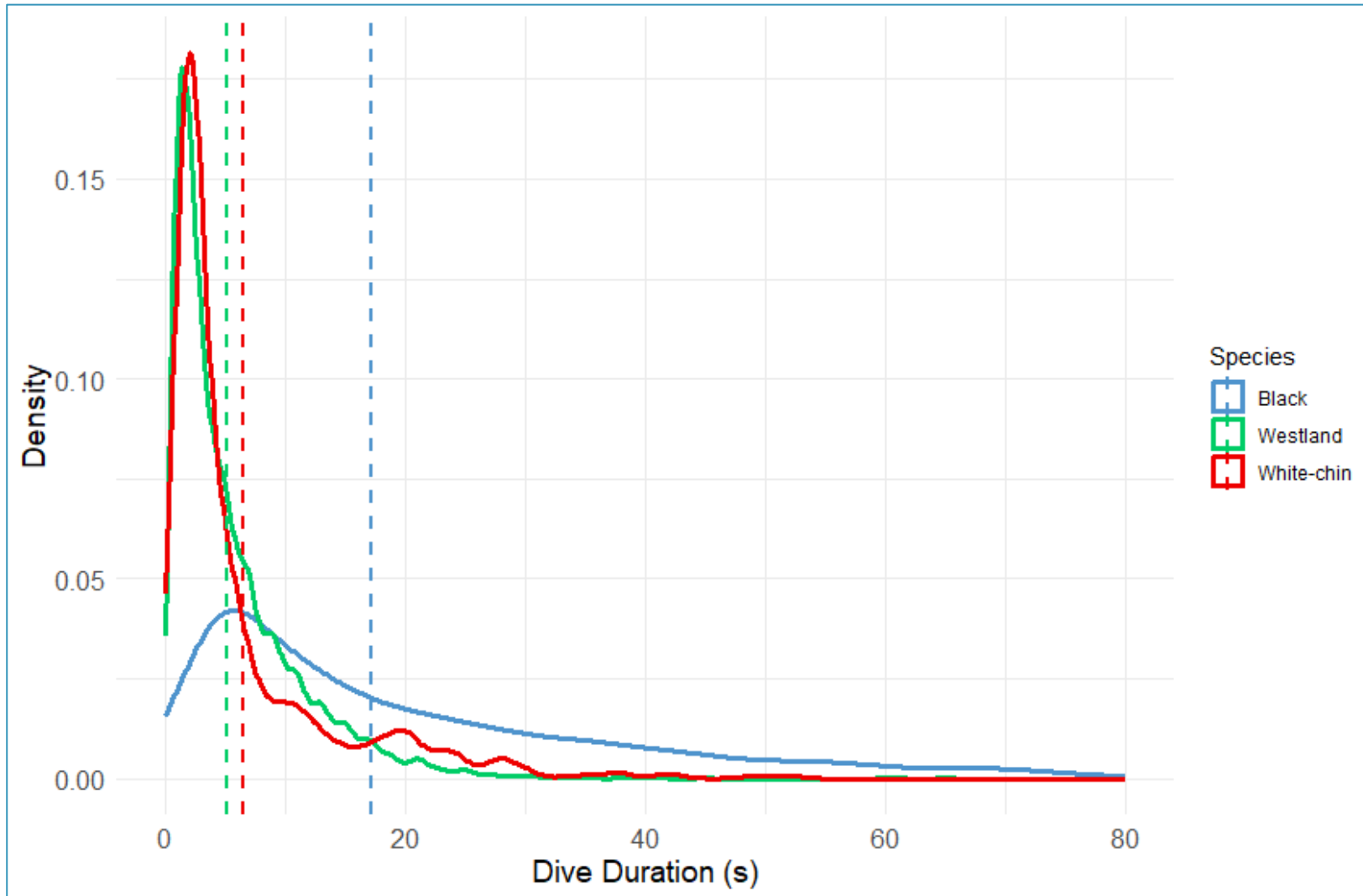
### GLMM

Black Petrels dive significantly deeper than both Westland Petrels ( $\beta = 0.4, p < 0.001$ ) and white-chinned petrels ( $\beta = 0.42, p < 0.001$ ).

### Sample sizes

|               | Bands | Dives |
|---------------|-------|-------|
| Black         | 10    | 3707  |
| Westland      | 32    | 7720  |
| White-chinned | 13    | 568   |

# DIVE DURATIONS



## Mean dive duration

|               |             |
|---------------|-------------|
| Black         | 16.44 ± 2.9 |
| Westland      | 4.99 ± 0.69 |
| White-chinned | 6.59 ± 0.9  |

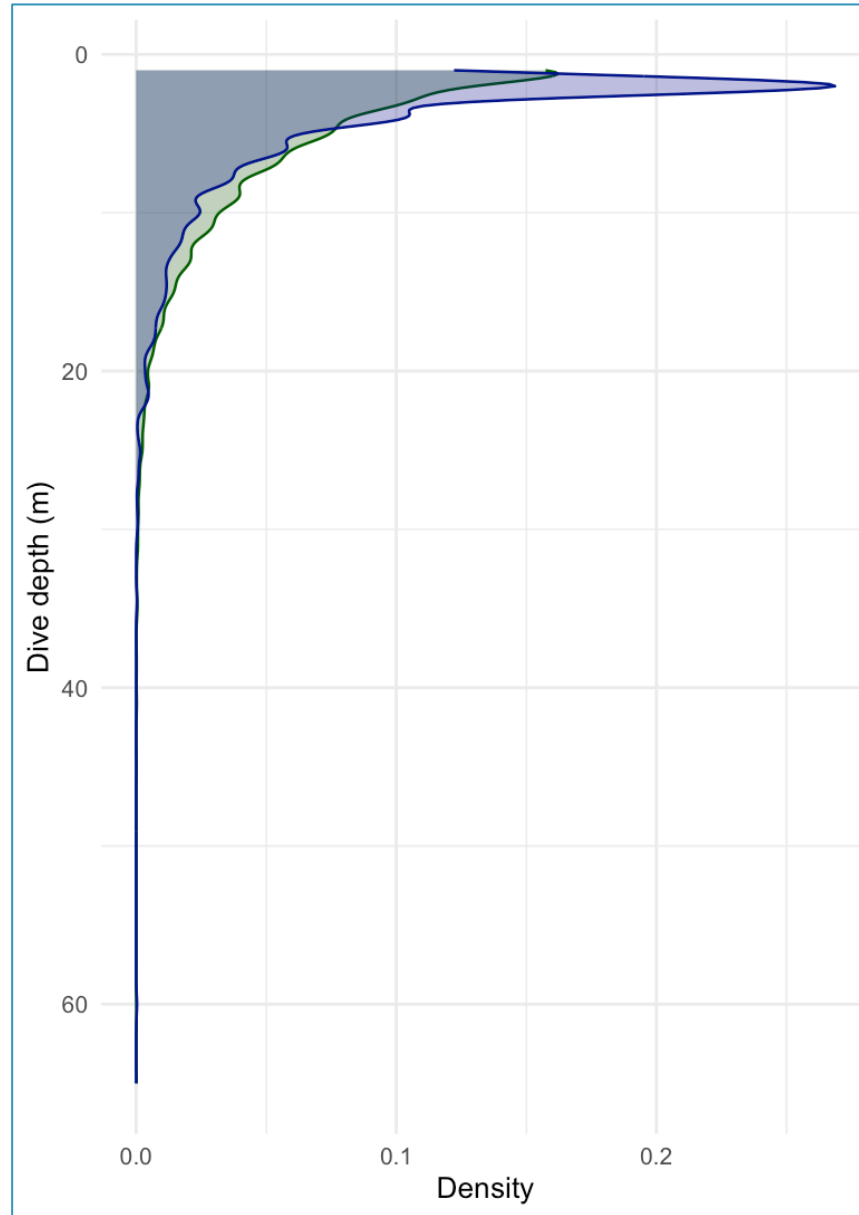
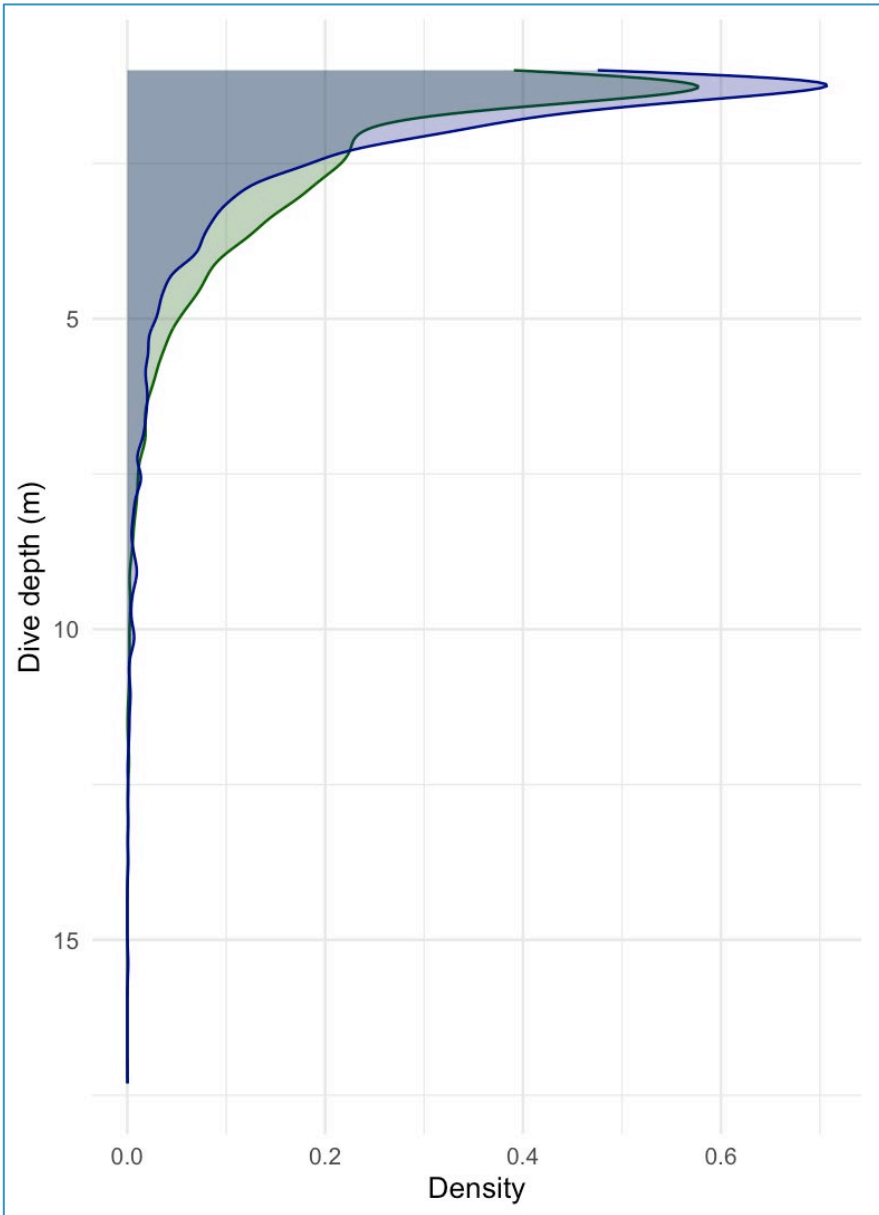
## GLMM

Black Petrels have significantly longer dive durations than Westland Petrels ( $\beta = 0.32, p < 0.001$ ) and white-chinned petrels ( $\beta = 0.4, p < 0.001$ ).

## Sample sizes

|               | Bands | Dives |
|---------------|-------|-------|
| Black         | 10    | 3707  |
| Westland      | 32    | 7720  |
| White-chinned | 13    | 568   |

# DIVE DEPTHS – Westland Petrel Phenology



| Sample sizes  |       |       |
|---------------|-------|-------|
|               | Bands | Dives |
| Chick-rearing | 14    | 5344  |
| Incubation    | 18    | 2376  |

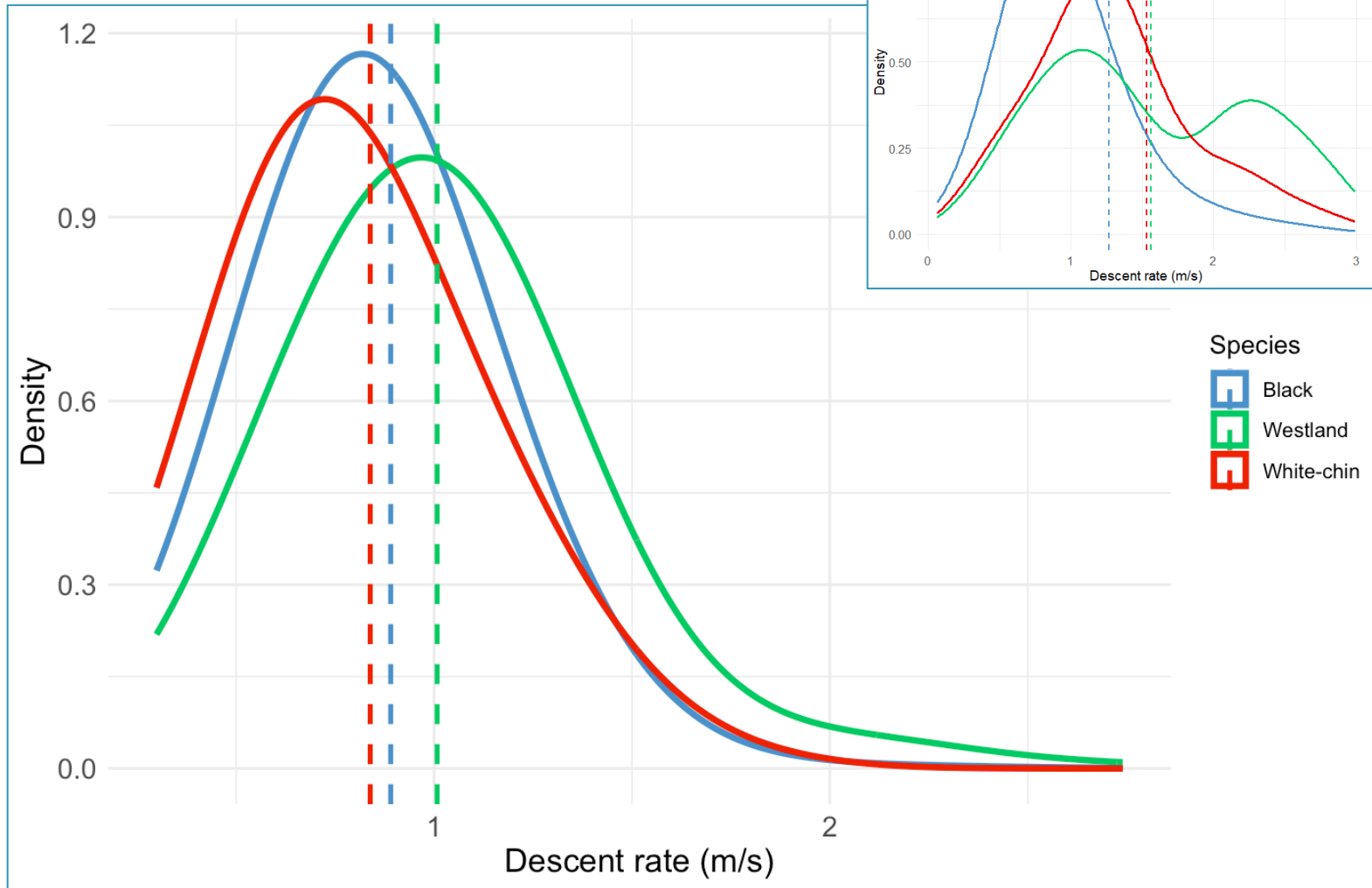
Phenology  
■ Chick-rearing  
■ Incubation

**GLMM**

Dives during **incubation** were significantly longer ( $p = 0.002$ ) and deeper ( $p = 0.004$ ) than dives during **chick-rearing**

# DESCENT RATES

Excl. dives < 5m



**Mean descent rate**

|               |             |
|---------------|-------------|
| Black         | 0.90 ± 0.04 |
| Westland      | 1.01 ± 0.03 |
| White-chinned | 0.84 ± 0.04 |

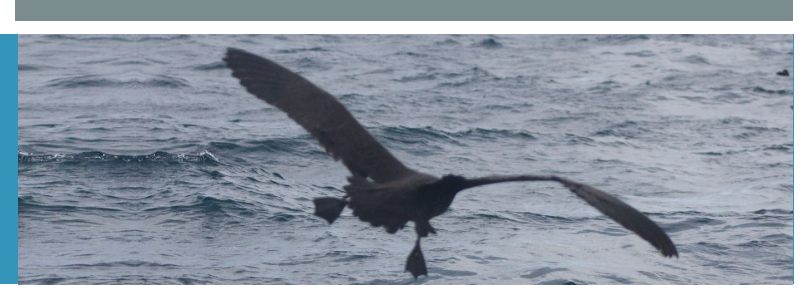
**GLMM**

Westland Petrels have faster descent rates than both Black Petrels ( $\beta = 1.16, p < 0.001$ ) and White-chinned Petrels ( $\beta = 0.89, p < 0.001$ ).

**Sample sizes**

|               | Bands | Dives |
|---------------|-------|-------|
| Black         | 9     | 1848  |
| Westland      | 30    | 598   |
| White-chinned | 11    | 73    |

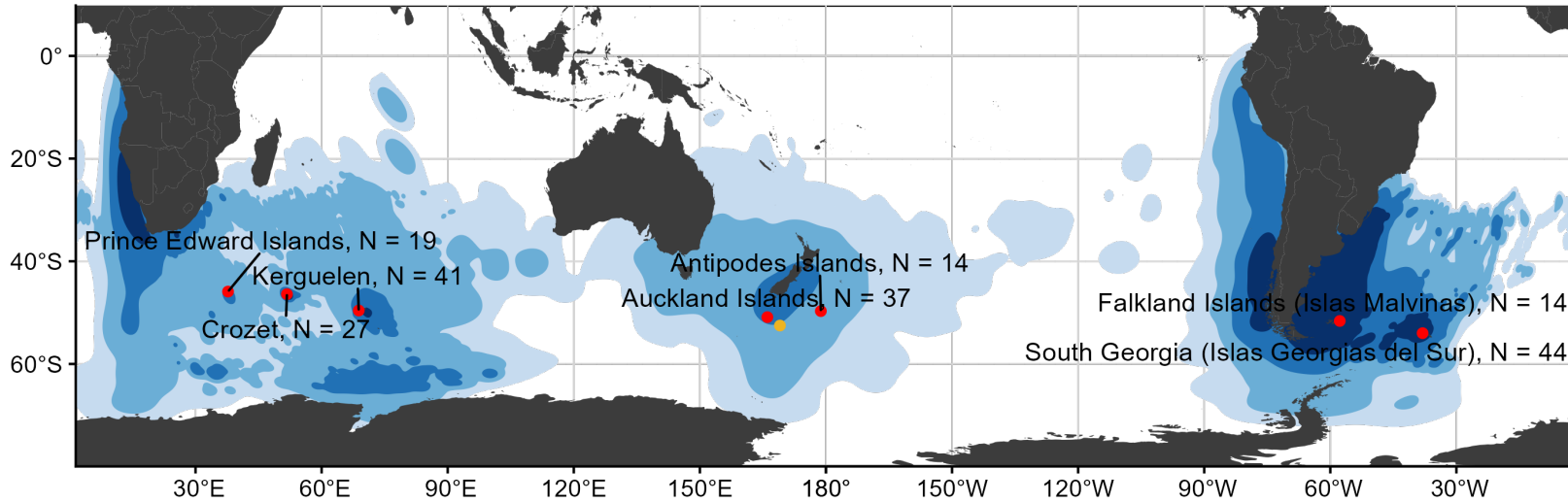
# CONTEXT



- Black petrel
  - Deepest recorded dive of 38.5 m – *previous record was 34.3 m (Bell, 2016)*
  - Deeper mean depth of 6.16 – *previous was 2.6 m (Bell, 2016)*
- Westland petrel
  - Deepest recorded dive of 17.6 – *previous record with capillary tubes was 7.6 m (Freeman and Nicholls, 1997)*
  - Novel diving behaviour data with modern loggers
- White-chinned petrel
  - Novel diving data from the Pacific basin
  - Deepest recorded dive of 21.7
  - *Previous record dive for Indian Ocean was 16.1 m (Rollinson et al. 2014)*
  - *Previous record dive for Atlantic Ocean was 14.5 m (Frankish et al. 2021)*
- Grey petrel (*Procellaria cinerea*)
  - Deepest recorded dive of 22 m (Rollinson et al., 2016)



### White-chinned Petrel

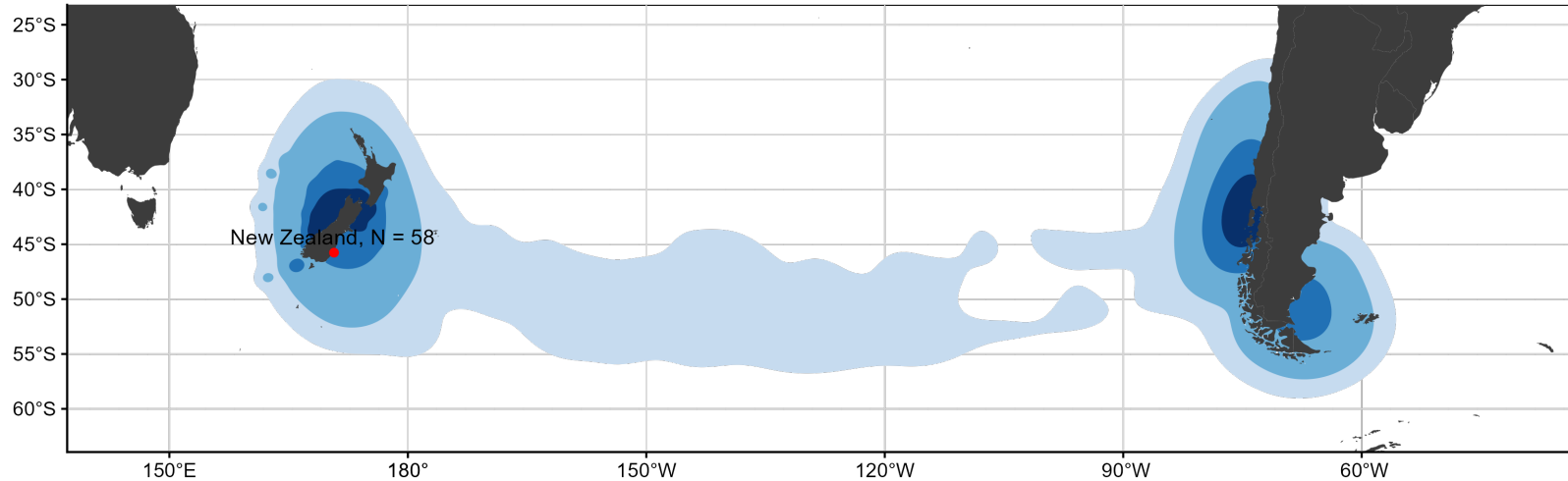


### White-chinned petrel

- 97.9% dives < 10 m
- Diving capability 21.72 m

Minimum depth of **10 m** for unprotected hooks

### Westland Petrel



### Westland petrel

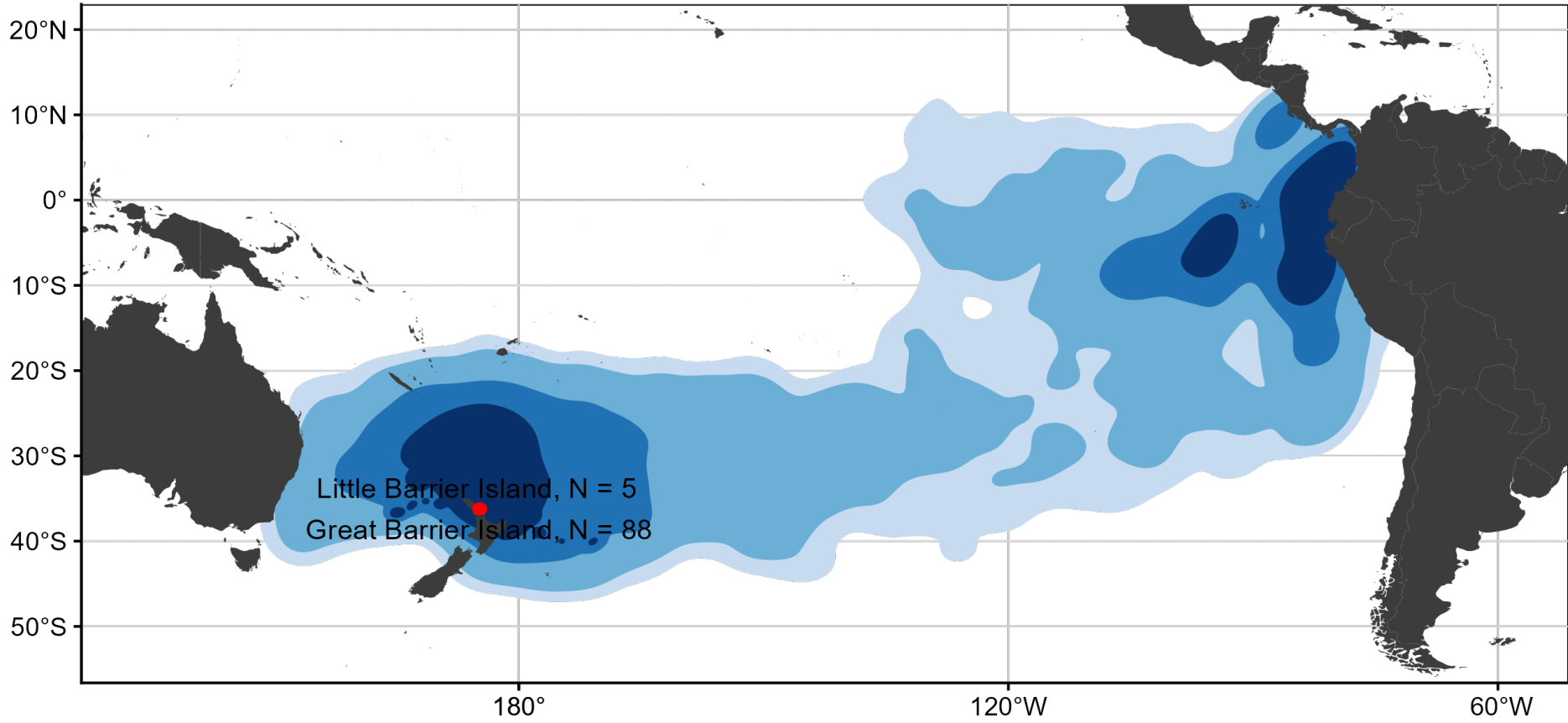
- 99.42% dives < 10 m
- Diving capability 17.31

Minimum depth of **10 m** for unprotected hooks

Distribution:  99% 95% 75% 50%



# Black Petrel



Distribution: 99% 95% 75% 50%

- 74.4% dives < 10 m
- 94.4% dives < 20 m
- Diving capability 38.5 m

Minimum depth of **20 m** for unprotected hooks







# ACKNOWLEDGEMENTS



Department of  
Conservation  
*Te Papa Atawhai*



**BIRDS**  
NEW ZEALAND  
*Te Kāhui Mātai Manu o Aotearoa*



**WMIL**



Centre for Biodiversity and Restoration Ecology



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