

***Where has all the sand gone? Understanding the implications of sand movement following renourishment works to protect Threatened tern habitat in the Gippsland Lakes***

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# **Where has all the sand gone? Understanding the implications of sand movement following renourishment works to protect Threatened Tern habitat in the Gippsland Lakes**

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## **Key Points**

- Climate change and other factors are impacting the availability of habitat for beach nesting and shore birds in the Gippsland lakes, including threatened small terns.
- Sand renourishment work have been implemented to help improve the availability of suitable breeding and nesting sites
- Renourishment is an effective technique to restore breeding and nesting habitat for small terns in the Gippsland Lakes
- The resilience and longevity of suitable habitat is variable and careful design and planning can support better ecological outcomes from this physical intervention.

## **Abstract**

A collaborative project was completed in 2016 to use dredge spoil (sand) to renourish nesting habitat for Threatened terns on sand islands within the Gippsland Lakes. Following this, the distribution of sand has changed, along with patterns of use by terns.

An analysis of the redistribution and loss of sand was needed to understand the ecological impacts, and the implications for future management in a changing climate.

The analysis completed in 2020 focused on the persistence of sand from renourishment works in relation to preferred habitat for small terns and sought to answer three key questions: Did the renourishment provide suitable physical habitat for small terns to breed? If so, how long did this habitat remain? And what changes occurred in the sand distribution over time?

Aerial imagery and elevation data, GIS data tools and algorithms were employed to consider change in sand distribution over time. Key metrics were then used to assess the distribution and persistence of favourable habitat conditions.

Renourishment works created substantial areas of habitat for tern breeding, however the progressive loss of desirable habitat area is limiting the ongoing effectiveness of the renourishment works.

The initial success of the habitat creation indicates that the management approach is effective, with the challenge to then consider how renourishment is prioritised and optimised (volumes, timing, placement) into the future to maximise ecological outcomes.

Increased sea level will impact ecological values in estuarine systems, particularly beach nesting birds. Management interventions can assist to 'create' favourable habitat for species.

Understanding the way sand behaves post nourishment, and the required renourishment cycle, is a key tool in helping to maintain vulnerable species and their habitat in a changing landscape.

## **Keywords**

Gippsland Lakes, sand renourishment, Little tern, Fairy tern, partnerships, climate change

## **Introduction**

The Gippsland Lakes are a series of coastal lagoons and fringing wetlands in south-eastern Australia. The lakes extend from Sale Common to Lakes Entrance, covering an area of approximately 60,000 hectares, and are the

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land and waters of the Gunaikurnai people. The lakes receive inflow from five major river systems and are connected to the Southern Ocean by a narrow, artificially maintained channel at Lakes Entrance.

Supporting a diversity of wetland types, the lakes are of high conservation value and are listed as a wetland of international importance under the Ramsar Convention. The ecological values of the site include extensive seagrass beds, a variety of fringing vegetation types, habitat for resident and migratory waterbirds, diverse and abundant fish, and support for other threatened species, including one of only two known populations of the rare Burrunan dolphin. The lakes are central to the tourism for the region, also supporting commercial and recreational fisheries, and have outstanding Aboriginal and European cultural values.

### ***Threatened terns in the Gippsland Lakes***

The Gippsland Lakes support largely annual migratory populations of Fairy Tern (*Sterna nereis*) and Little Tern (*Sterna albifrons*) (Figure 1). Whilst some juvenile birds overwinter within the lakes, the majority of both populations either migrate south from New South Wales or east from western Victoria and South Australia.

Collectively referred to as ‘small terns’, these species are important parts of the Gippsland Lakes Ramsar site, elements (Critical Components processes and Services (CPS)) that are linked to the ecological character of the site, including; C6 Abundance and Diversity of Water birds, P2 Waterbird breeding, and S1 Maintaining Threatened Species with specific reference to small terns. The mechanism against which change in ecological character is assessed is via comparison with limits of acceptable change (LAC).

The Fairy tern is listed as Vulnerable under the IUCN Red List of Threatened Species and under Environment Protection and Biodiversity Conservation Act 1999. The Little Tern (*Sterna albifrons*) is listed as threatened (Flora and Fauna Guarantee Act 1988 Vic.) and is classified as endangered in both NSW and SA.

The Department of Environment Land Water and Planning (DELWP) has been the lead agency involved in the management and monitoring of both Fairy Tern and Little Terns in the Gippsland Lakes for many years.

Habitat restoration works for small tern habitat within the Gippsland Lakes using sand renourishment was undertaken between 2015 and 2017 at critical sites. The objective of these works was to maintain or establish areas of critical habitat for the breeding of threatened small terns. The works also aimed to improve habitable areas for other key species including pelican, black swan, migratory waders other beach nesting birds.



**Figure 1. Little Tern (*Sterna albifrons*) (left) and Fairy Tern (*Sterna nereis*) (right) (Images S.Phillipson).**

### ***Impacts of a changing climate***

The main lakes and the fringing wetlands are in a transition that has been occurring for over 100 years with changes in land use in the catchment, and the establishment of towns and urban development around the Lakes. Into the future, change is likely to increase with an increasing population, and climate change is predicted to alter the system further.

The impact of rising sea levels, and in turn sustained higher lake water surface levels, is likely to impact on important ecological values and habitat along the shorelines, islands and other low-lying areas around the lakes. Inundation modelling undertaken in 2017 showed that, of the five sites where small terns are known to nest within the Gippsland Lakes, 100% of the available nesting habitat is below 0.6m AHD. There is also likely

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to be a loss of available foraging, roosting, breeding and nesting habitat along the shorelines as sea level rises, permanently inundating saltmarsh and limiting the available areas for other shorebirds and beach nesting birds.

### ***Understanding the dynamics of sand following renourishment***

Habitat restoration using sand renourishment and other techniques was undertaken between 2015 and 2017 on Crescent, Pelican, Rigby, and Albifrons Islands, and Horries Spit, in the Gippsland Lakes (Figure 2). The objective of the works was to maintain or establish areas of critical habitat for the breeding of threatened small terns.



**Figure 2. Sand renourishment sites for small tern habitat in the Gippsland Lakes (Alluvium, 2020)**

During this period, channel maintenance dredging works were being completed by Gippsland Ports to improve safety and navigation within the lakes. The five sites listed above represent the total known areas where small terns had either recently or historically nested near the channel dredging operations (Water Technology, 2014). No other sites across the lakes were known to have supported small tern breeding in the recent past (D. Sullivan 2021, pers comms. 17 March).

A collaborative project involving Gippsland Ports, Parks Victoria and the Department of Environment, Land, Water, and Planning was developed to maximise environmental outcomes from the planned maintenance works. The hydrodynamic and geomorphic behaviour of the sites, and likely residence time for sand renourishment works were investigated as part of the project (Water Technology, 2014). A total of around 47,000m<sup>3</sup> of sand was placed across four sites (Albifrons Is. – 8,000m<sup>3</sup>; Crescent Is. – 10,500m<sup>3</sup>; Horries Spit – 13,000m<sup>3</sup>; Pelican Is. – 15,500m<sup>3</sup>). Reprofiting work on Rigby Island were carried out in 2017.

As part of the initial on-ground renourishment works, aerial topographic surveys of renourishment sites immediately after the initial sand placement were conducted. LiDAR derived elevation data from 2010 (1m DEM with 0.5m contours) was also available for all sites. These data formed a baseline for comparison over the following years.

In 2020 an analysis was undertaken to assess the effectiveness of sand renourishment as a management tool to maintain and enhance available breeding and loafing sites on these sand islands. The assessment aimed to collate and interpret the baseline data (LiDAR data and initial post nourishment surveys) and annual aerial survey data to assess the change, including the loss and accumulation in sand profiles over time, and the impact of this on providing suitable habitat for small terns.

Small terns face additional challenges in addition to finding suitable physical habitat, such as predation and disturbance. It is important to note that there are other reasons the terns may not successfully breed, and that a

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renourishment program providing suitable, lasting habitat may not guarantee success.

However, the 2020 analysis aimed to provide guidance on the effectiveness of sand renourishment as one of several management tools to maintain and enhance available breeding and loafing sites on sand islands within the Gippsland Lakes for threatened small tern species. The assessment has provided site managers with a better understanding of the ongoing success and resilience of renourished sites following works.

### **Method**

#### ***Data availability***

A review of the available data was undertaken to determine key metrics able to be measured as part of the analysis. Both high resolution aerial imagery and elevation (LiDAR) data was available for key sites. Observations by subject matter experts, including staff from Birdlife Australia, on habitat preferences for small terns and monitoring of the islands over recent years was also considered. A summary of key data inputs is provided below.

#### ***Aerial imagery***

Orthorectified aerial imagery was available for all sites where renourishment was undertaken. The resolution of imagery varied between 0.033m – 0.15m grid. Imagery was available pre-nourishment, post nourishment and at two subsequent points in time (2017 and 2019). Aerial imagery is used to assess the extent and density of vegetation in the open sand.

#### ***Elevation data***

Available elevation data was used to measure the change in sediment volume, area of open sand above the water level, and calculate the slopes across the site. Spatial extent at each site varied slightly from year to year, with limitations identified for particular data sets and sites.

#### ***Small tern habitat preferences***

A summary of known small tern habitat preferences linked to key metrics is listed in Table 3. This information was based on communications with Bird Life Australia. The assessment of sand distribution was framed in relation to changes to these attributes, to support and inform the ecological implications of physical changes and each site. Key metrics from each monitoring event to the next were assessed quantitatively and qualitatively for each site.

**Table 3. Small tern habitat influences\***

| <b>Attribute</b>     | <b>Data Source(s)</b>  | <b>Impact</b>  |
|----------------------|--|--|
| Available beach area | <ul style="list-style-type: none"><li>• Elevation data</li><li>• Aerial imagery</li></ul>                    | Open sand is required for terns to build their nests<br>They will nest within 150m of the waterline, usually just above the high tide.<br><br>The nests are at risk of being inundated if below the water levels during spring tides and storm surges. |
| Slopes               | <ul style="list-style-type: none"><li>• Elevation data</li></ul>   | The birds prefer gentle slopes with some undulation.   |
| Vegetation           | <ul style="list-style-type: none"><li>• Aerial imagery</li><li>• Oblique and on ground photography</li></ul> | Around 20% vegetation preferred (density)<br>Balance between enough for protection, to hide fledglings, make easier scrapes, improve sand accretion<br><br>Too much increases hiding spots for predators.  |

*\*Based on monitoring observations and subject matter expert input*

### **Metrics**

Methods for the analysis involved interpretation of available aerial imagery and elevation data for all sites, for the years spanning pre-nourishment (pre 2016), and post nourishment (2017 and 2019). Data tools and algorithms within GIS were used to consider change in sand distribution over time.

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Key metrics assessed included: total sediment volume; available beach area; open sand above median water level; area above spring tide; sand slopes; and vegetation extent and density.

The following approach is applied to assess change in the metrics over time:

- **Sediment volume:** To understand the fate of the nourished sand volume, the total change in volume for the sites was measured by generating raster volumes for each year, for the restricted section (where data is available for each year) and to a consistent depth. This ensures the metric is consistent from year to year. Total volume was calculated in m<sup>3</sup>, and loss maps create highlighting areas which have experienced the greatest change.  
The extent of analysis was restricted to the 2017 DEM survey, as this is the maximum extent covered by elevation data at every monitoring event. Volumes are measured to -0.1mAHD.
- **Available beach area above water level:** To measure the area available for nesting, the area above the median water level (0.25mAHD) and spring tide (0.5mAHD) was calculated from contours using the algorithm “split with lines”.
- **Slope:** Change in slope from year to year was documented through key raster statistics (within the restricted section) (maximum and median) and the area of slopes at <2° and <4°.
- **Vegetation:** The extent of dense vegetation growing on open beaches was digitized and measured where it was present. It is understood that clusters of vegetation can make nearby open sand unviable.

**Grid based filtering for ‘ideal’ and ‘moderate’ habitat conditions**

In addition to considering change in the key metrics independently over time, a combination of slope and elevation metrics were assessed as ‘ideal’ and ‘moderate’ habitat metrics (i.e. areas above the spring tide with the gentle slopes preferred by the terns).

Zonal statistics were compiled for mean elevation and slope for a 1x1m grid, to measure areas where the elevation is above the tide level and the slopes at a gentle angle. For reporting, the data was presented showing overlap of areas above 0.5mAHD with less than 2° slope as ‘ideal’ and above 0.5mAHD and less than 4° slopes as ‘moderate’ conditions.

The grid allows for these limits to be reviewed in future if information regarding these factors changes (i.e. if further monitoring and research demonstrates that higher elevations or flatter slopes are preferred).

**Results**

Table 4 below shows changes in total sediment volume at each of the sites assessed. Green figures indicate an increase in sand volume over time, and orange figures indicate a loss of sand from the site (to offshore/alongshore). More detailed results are provided as a case study for Pelican Island.

**Table 4. Total sediment volume (m<sup>3</sup> to -0.2mAHD) and area of ‘ideal’ habitat (m<sup>2</sup> above 0.5mAHD and <2° slope) in each year**

| Year      | Albifrons Is                             | Crescent Is | Horries Spit | Pelican Is | Rigby Is |
|-----------|--|-------------|--------------|------------|----------|
| 2015/2016 | 5,490                                    | 5,190       | 6,380        | 11,420     | N/A      |
| 2017      | 4,670                                    | 4,570       | 6,510        | 13,360     | 9,025    |
| 2019      | 3,740                                    | 3,860       | 5,930        | 14,010     | 7,455    |
| Year      | Area of ‘ideal habitat (m <sup>2</sup> ) |             |              |            |          |
| 2015/2016 | 3,230                                    | 2,350       | 2,340        | 10,980     | N/A      |
| 2017      | 150                                      | 690         | 540          | 11,320     | 740      |
| 2019      | -  | 710         | 540          | 6,470      | 510      |

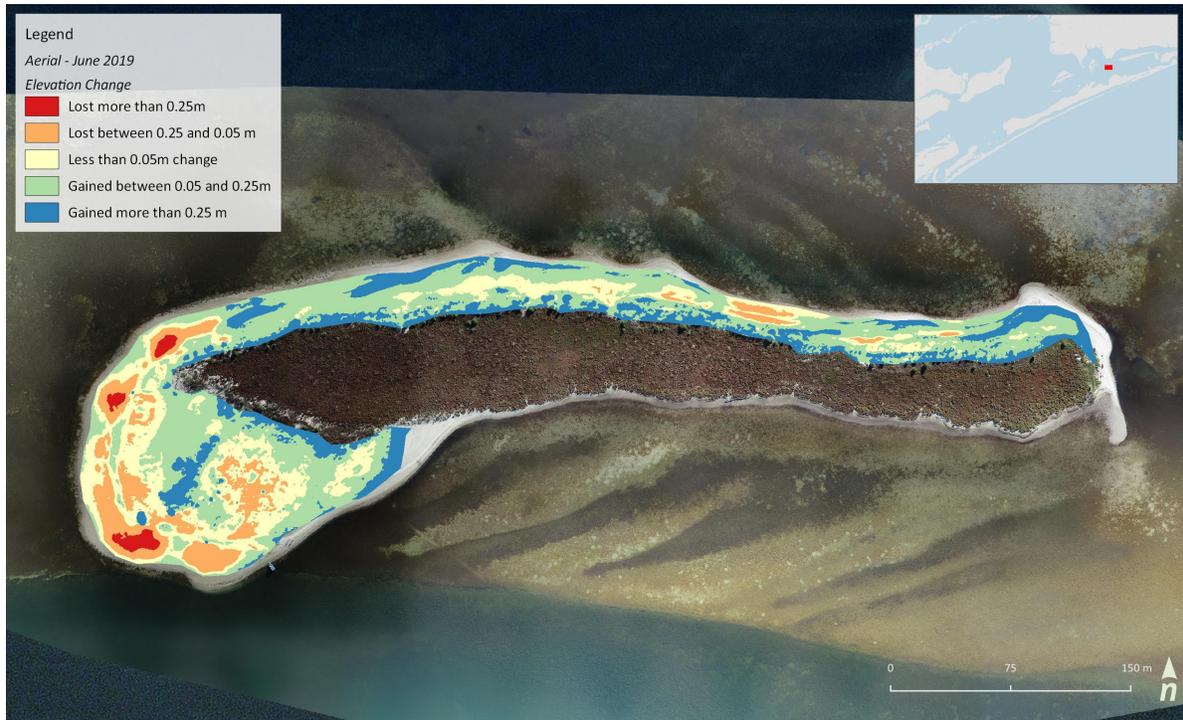
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**Case study – Pelican Island**

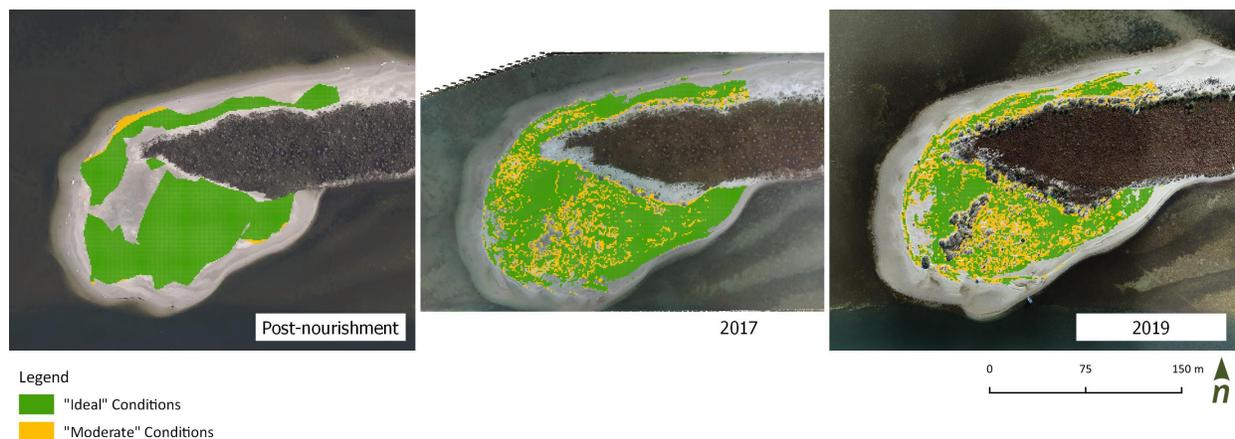
Prior to renourishment, Pelican Island had a thin sand beach at the margins of established vegetation. The vegetation and sand had been retreating, particularly along the north of the island. Based on an appreciation of tern habitat preferences, there was no suitable tern habitat. The initial nourishment provided a substantial increase in favourable tern habitat.

Over the period of analysis (2016 to 2019) Pelican island showed a net accumulation of sand (total volume) as well as an increase in area of sand above both median and spring tide levels (Figure 3, Table 4).



**Figure 3. Pelican Island elevation change, post renourishment to 2019 (Alluvium, 2020)**

However over the same time period, mean slopes increased across the site, with the site developing a less consistent microtopographic landform. The more stable shoreline environment provided by the renourishment works, supplemented by revegetation, appears to have contributed to the expansion of vegetation extent and density. As a result, the ‘ideal’ conditions for tern habitat became more fragmented (Figure 4).



**Figure 4. Pelican Island habitat distribution changes (Alluvium, 2020)**

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**Table 4. Total sediment volume (m<sup>3</sup> to -0.2mAHD) in each year**

| Metric             | Available beach / open space area |  |  |                              |  |                                |  |   | Vegetation  |
|--------------------|-----------------------------------|--|--|------------------------------|--|--------------------------------|--|---|---|
|                    | Volume                            |  | Open sand above median water level (m <sup>2</sup> ) |                              | Area above spring tide (m <sup>2</sup> ) |                                | Slopes   |   |   |
|                    | Information source                | Raster volume from elevation data (to -0.1m) | Contour from elevation data                          | Contour from elevation data  | Slope raster from elevation data         | Aerial and oblique photography |  |   |   |
|                    | Condition                         | Change                                       | Condition  | Change                       | Condition                                | Change                         | Condition  | Change  | Condition   |
| Pre-nourishment    | N/A                               |  | 0  | -                            | 0  | -                              | Steep drop at the edge of the site   | -   | Thick scrub present on the existing island.<br>No veg in area of interest (It's underwater) |
| Post-nourishment   | 11420                             | 11420  | 18,050   | Created 18,050m <sup>2</sup> | 11,050m <sup>2</sup>                     | Created 11,050m <sup>2</sup>   | Mean: 1°<br>Area <2°: 17,010m <sup>2</sup><br>Area <4°: 19,010m <sup>2</sup> | Created gentle slope areas                                    | No vegetation on renourished area. Original part of the island covered with veg.            |
| 2017               | 13360                             | +1940  | 19,850   | +1,800                       | 16,050                                   | +5000                          | Mean: 2°<br>Area <2°: 13,360m <sup>2</sup><br>Area <4°: 17,210m <sup>2</sup> | Slopes have increased, but remain gentle for most of the site | Sparse vegetation present on planted on the western beach                                   |
| 2019               | 14010                             | +650   | 19,850   | 0                            | 14,200                                   | -1850                          | Mean: 4°<br>Area <2°: 10,370m <sup>2</sup><br>Area <4°: 15,370m <sup>2</sup> | As above  | 1055m <sup>2</sup> "dense" vegetation   |
| Change 2016 > 2019 |                                   | +2590  |  | +1800                        |  | +3150                          | Mean slopes: increased by 3°<br>Area <3°: decreased by 5,120m <sup>2</sup>   |   | Dense saltbush and juncus established on the western beach.                                 |

## Conclusions

The following discussion provides some reflections on the key questions of interest for this project, including:

### *Initial effectiveness of renourishment*

The renourishment works created substantial areas of suitable habitat for breeding at all locations. The terns reportedly showed an interest in all sites, with successful breeding at several sites, and attempted breeding at others. Observations from recent years also confirm that the terns are willing and attempting to breed at these locations, maintaining an interest in these sites.

The progressive loss of desirable habitat area over time (suitable area, elevation and slope of sand), and the presence of dense vegetation in some locations, are limiting the longer-term effectiveness of the renourishment works.

However, the initial success of the habitat creation indicates that the management approach is an effective tool for creating suitable habitat for breeding. The challenge is then to consider when and where renourishment is prioritised into the future to maximise habitat outcomes.

### *Renourishment and habitat longevity*

Overall, the net ideal habitat created by renourishment works decreased over the 2 – 3 years following placement. However, across the islands there was variation in the longevity and rates of change. Overall, based on the loss rates observed, a similar renourishment program across all islands would likely require routine nourishment every 2 – 3 years to maintain the areas of ideal habitat created by the works. However, there may

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be opportunity to optimise placement in a way that increases longevity of ideal areas, slopes and elevations of sand placement.

Other influencing factors over 2015 – 2017, including storm events and other local disturbances may have also influenced renourishment longevity, and should be considered in the future design and scoping of nourishment programs.

### ***Changes in sand distribution over time***

The changes in sand distribution and associated ideal habitat areas over time is complex. Some metrics (area, slopes, and ideal habitat areas) gained, while others lost, and there was variation between the same metrics at different sites.

Typically, sand at higher elevations was lost to lower elevations fairly rapidly (over 1 – 2 years), however this also increased the persistence / longevity of the net area at lower elevation / gentle slopes over time, which is considered more ideal habitat for terns.

The role of vegetation in renourishment longevity and sand distribution over time is complex. Where vegetation was present, sand was more likely to persist and even aggrade for a period of time. However too much vegetation can become a deterrent for tern breeding.

Further investigation on ways to optimise vegetation planting to maximise renourishment longevity, while minimising the likelihood of deterring tern breeding, would be beneficial for future sand placement.

## **Acknowledgments**

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