APPENDIX 14D

PIPI LARVAE MODELLING ASSESSMENT

MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

New Zealand Government
Te Kāwanatanga o Aotearoa

Pipi Larvae Modelling Report

Effects of Proposed Reclamation and Dredging Layout on Pipi Settlements

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MetOcean SOLUTIONS

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1. Introduction

Northport is a deep-water commercial port strategically situated at Marsden Point near Whangārei in Northland, New Zealand (Figure 1-1).

The Ministry of Business, Innovation and Employment (MBIE) proposes to seek approvals pursuant to the Fast-track Approvals Act 2024 for a shipyard and drydock facility (Northland Shipyard and Drydock Facility, NSDF) abutting the western side of the existing Northport facility at Marsden Point. The project includes a reclamation, vessel haul-out system, and associated wharf structures, dredging and supporting infrastructure.

Key components of the project include:

- Reclamation of approximately 9.5 hectares
- A \`cutout\` to the reclamation where a vessel haul out system is to be located, being a floating drydock or potentially shiplift or other lifting mechanism
- Construction of a piled wharf structure to accommodate vessels either temporarily (before/after haul-out), or for extended periods where works not requiring haul out can be undertaken
- Capital and maintenance drag associated with construction and ongoing operation of the marine maintenance operations facility, including a berth pocket and a vessel turning basin to provide for safe navigation.
- Fixed plan and buildings to accommodate marine maintenance activities and materials
- Sufficient working and laydown areas for maintenance operations, including the ability to transfer vessels to hardstand
- Access to and around the marine maintenance operations facility including a landside area for staff carparking
- Public access around the edge of the reclamation to a public fishing platform.

MetOcean Solutions (MOS, a division of the Meteorological Service of New Zealand) has undertaken a number of numerical hydrodynamic and morphological modelling simulations and dredged plume dispersion simulations related to operations and expansion of Northport, with results presented in MOS reports P0367-01 to P0367-06 (MetOcean Solutions, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f), in 2021 reports P0519-01 to P0519-03 (MetOcean Solutions, 2021a, 2021b, 2021c) and in 2022 reports P0519-10 to P0519-13 (MetOcean Solutions, 2023, 2022a, 2022b).

The two proposed designs are the NSDF (Design West) and the Eastern reclamation and NSDF (Design East and West). Both include dredging and reclamation areas and a piled wharf (see Figure 1-2 and Figure 1-3).

This technical report examines the impact of these proposed scenarios in the dispersion of Pipi (*Paphies australis*) larvae within the region. Pipi are considered a taonga (treasure) by Māori. In Whangārei, they have long been an important food source for local communities and have widespread cultural significance to the local hapū, Patuharakeke. Pipi are surf clams that are native to New Zealand / Aotearoa. They are an important food source and taonga to the communities who live close to them (Biosecurity New Zealand, 2022).

The structure of this report is as follows. Section 1 presents a summary of previous studies undertaken at the site and the datasets used in those studies. Section 2 describes the methodology and model setup. In Section 3, results of hydrodynamic modelling from both Existing and the two proposed bathymetry layouts are presented. Section 4 provides a brief summary of this report. A list of references is given in the last section of the document.

Figure 1-1 Location of Northport within Whangārei Harbour.

Figure 1-2 Concept drawing for the proposed area to be dredged and reclaimed for the Northland drydock and shipyard (Design West).

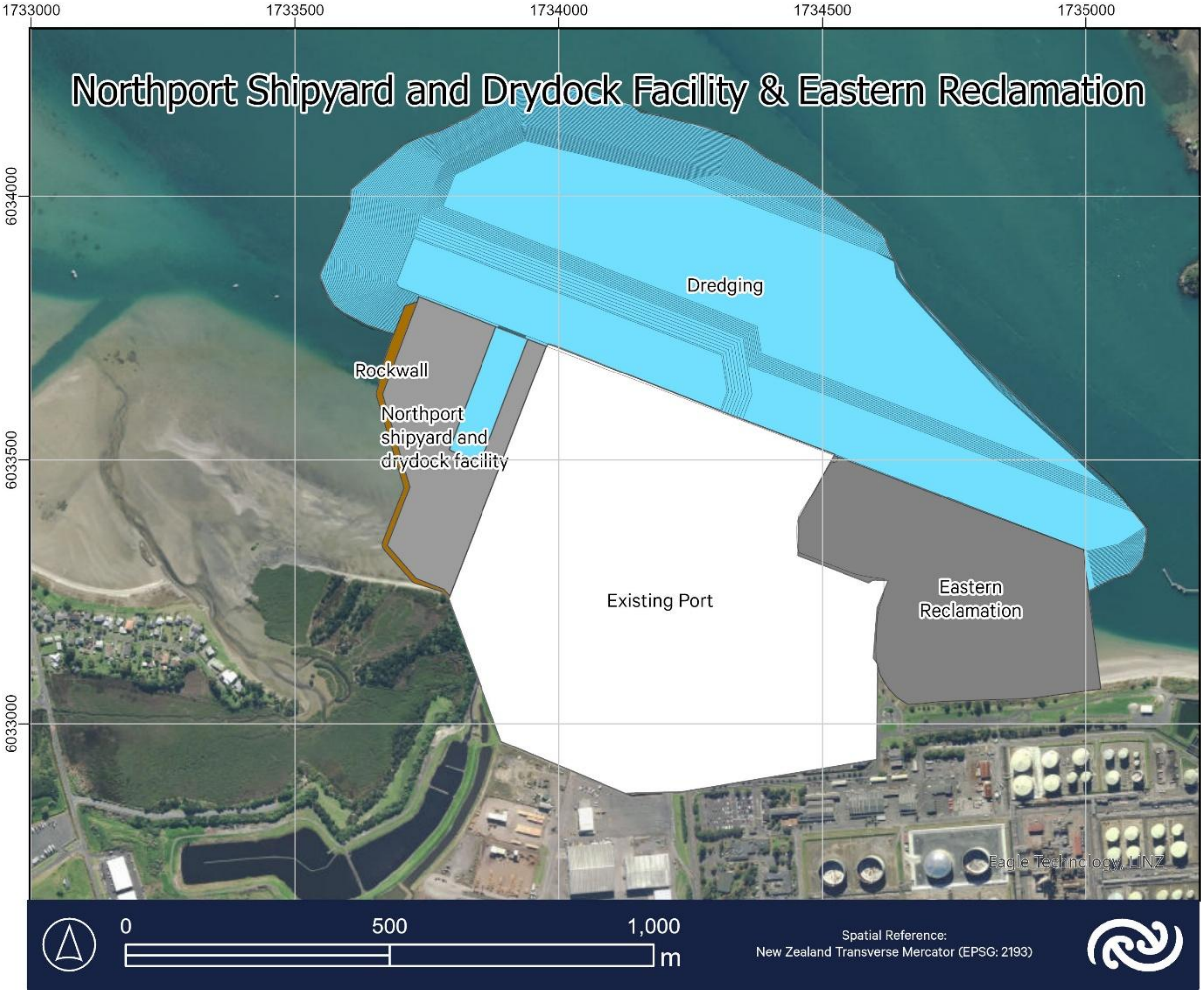

Figure 1-3 Concept drawing for the July 2026 design proposed area to be dredged and reclaimed for the eastern reclamation and the Northland drydock and shipyard (Design East and West).

2.Methodology

2.1 Approach

Over the last 15 years, MetOcean Solutions has undertaken several modelling studies of the Whangārei Harbour. The characterisation of the physical environment of the Whangārei Harbour and the establishment of wave, current and sediment dynamics numerical models began in 2015-2016 with the Refining New Zealand (RNZ) proposed deepening of the shipping channel to Marsden Point Refinery (MetOcean Solutions, 2016). However, this is the first time the pipi larvae distribution has been numerically investigated by MetOcean Solutions. By analysing historical hydrodynamic conditions, a probabilistic approach can determine how bathymetric changes are expected to impact the distribution of pipi larvae. This allows for a statistical characterisation of the spatial dispersion from three key source locations (pers comms, Shane Kelly, Coast and Catchment Environmental Consultants, NZ.) within the region: Mair Bank, Snake Bank and Marsden Bay (Figure 2-1).

In the present study, pipi larvae trajectories were simulated over a 1-month period for three different configurations: 1) the existing bathymetry (Existing), 2) the Eastern and NSDF (Design East and West) and 3) the NSDF (Design West).

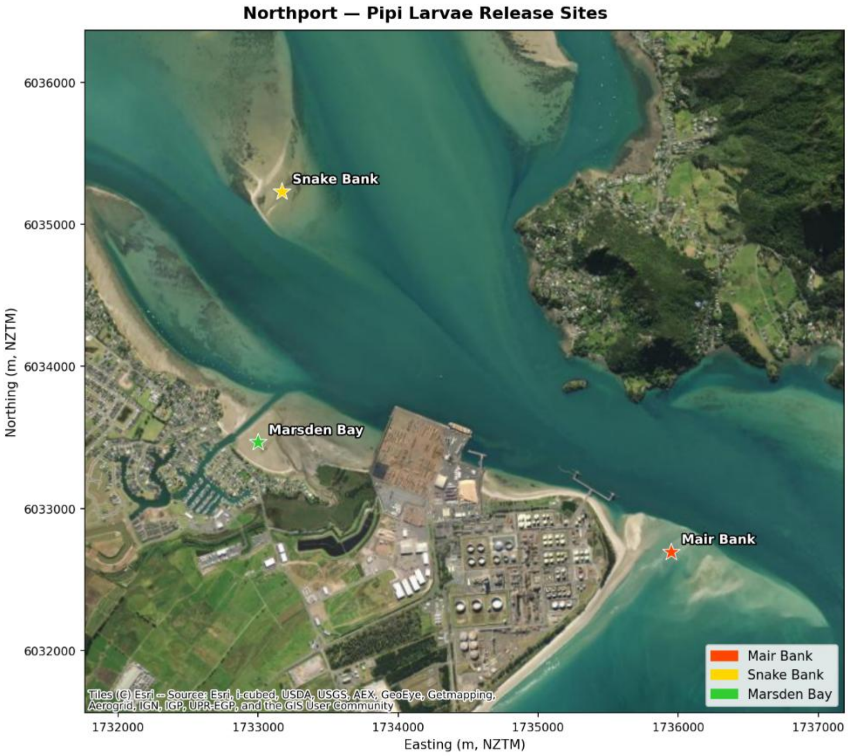

Figure 2-1 Source locations for the pipi larvae modelling.

Table 2-1 Positions of sources for the pipi larvae dispersal simulations.

Site	Longitude	Latitude
Mair Bank	174.5053	-35.8405
Snake Bank	174.4741	-35.8180
Marsden Bay	174.4726	-35.8340

2.2 Hydrodynamics

Details on the hydrodynamic model used to prepare the hydrodynamic dataset input for this larvae modelling are provided in MetOcean Solutions (2026)

2.3 Pipi larvae simulation

2.3.1 OpenDrift model description

The pipi larvae scenarios were simulated using the trajectory modelling framework OpenDrift (Dagestad et al., 2018). OpenDrift is an open-source python-based framework for Lagrangian particle tracking developed by the Norwegian Metereological Institute. The framework is highly modular and can be used for any type of drift calculations in the ocean or atmosphere (i.e., search and rescue, larval drift, plastic drift, hydrocarbon advection).

The simulations were undertaken using the BivalveLarvae module. This module incorporates key biological parameters such as minimum settlement age, maximum pelagic duration of particles, and habitat suitability restrictions for settlement.

The dispersion modelling consists of a trajectory tracking scheme applied to discrete particles in time and space-varying 3D oceanic currents.

$$\frac{dx_p}{dt} = \tilde{u}(x, y, z, t) + u_t$$

$$\frac{dy_p}{dt} = \tilde{v}(x, y, z, t) + v_t$$

$$\frac{dz_p}{dt} = w_t + w_s$$

(2.1 a,b,c)

Where x_p, y_p, z_p are particle 3D coordinates, $\tilde{u}_{(x,y,z,t)}$, $\tilde{v}_{(x,y,z,t)}$ are horizontal ocean currents, u_t, v_t, w_t are the diffusion components representing turbulent motions and w_s is the settling velocity.

In the horizontal plane, particles were advected by ocean currents using a 4th order Runge-Kutta tracking scheme, a numerical analysis method that approximates the curve of the function f between two points by a 4th degree polynomial. Moreover, particles are subject to additional displacement by horizontal diffusion.

In the OpenDrift framework, the horizontal diffusion is included by applying an uncertainty to the horizontal current magnitudes. The magnitude of the current uncertainty was estimated using the general diffusion equation *(2.2)*.

$$\int_{t}^{t+\Delta t} u_t \cdot dt = \sqrt{2 \cdot k_{u,v} \cdot \Delta t} \cdot \theta(-1,1)$$

(2.2)

Where $\theta(-1,1)$ is a random number from a uniform distribution between -1 and 1; Δt is the time step of the model in seconds and $k_{u,v}$is the horizontal eddy diffusivity coefficient in m^2s^{-1}.

In the vertical dimension, particles are subject to both vertical settling (w_s) and diffusive displacement (w_t) due to vertical turbulence through the water column. In OpenDrift, the vertical mixing process is parameterised using a random walk based numerical scheme similar to equation (*2.2*) when using a constant vertical diffusion coefficient k_z (Visser, 1997).

In the modelling of dispersion, the horizontal and vertical diffusion account for mixing and diffusion caused by sub grid scale processes of higher resolution than the computational grid, that are not explicitly resolved by the hydrodynamic model (i.e., eddies).

In the present study, since high resolution flows are available (Section 2.2) , the amount of added diffusion should be limited. A generic horizontal coefficient of 0.1 $m^2s^{-1}$was applied which is consistent with a length scale of order 20-40 m (i.e. approximate grid resolution). The spatial scales of the vertical turbulence in the water column are one or several orders of magnitude smaller than the horizontal ones. The vertical diffusion coefficient was set to a value of 0.001 m^2s^{-1}. The model timestep was set at 300 s.

Particles were tracked until they settled, died or were transported out of the region. Larvae required a minimum of 12 days of age before settlement could occur. If a particle did not encounter a suitable habitat by the maximum age of 21 days, it was assumed to have 'died'. The map of suitable settlement habitat for this report was based on the zones defined by Lundquist and Broekhuizen (2012).

To assess the potential dispersal of pipi larvae, neutrally buoyant particles were released from three key source locations over a 100-meter radius and distributed within the water column. (Figure 2-1). A total of approximately 73,000 particles were released per location for each of the three one-month-long hydrodynamic simulations:

1) the existing bathymetry,

2) the combined Eastern Reclamation and NSDF, and

3) the NSDF

~219,000 particles per hydrodynamic simulation.

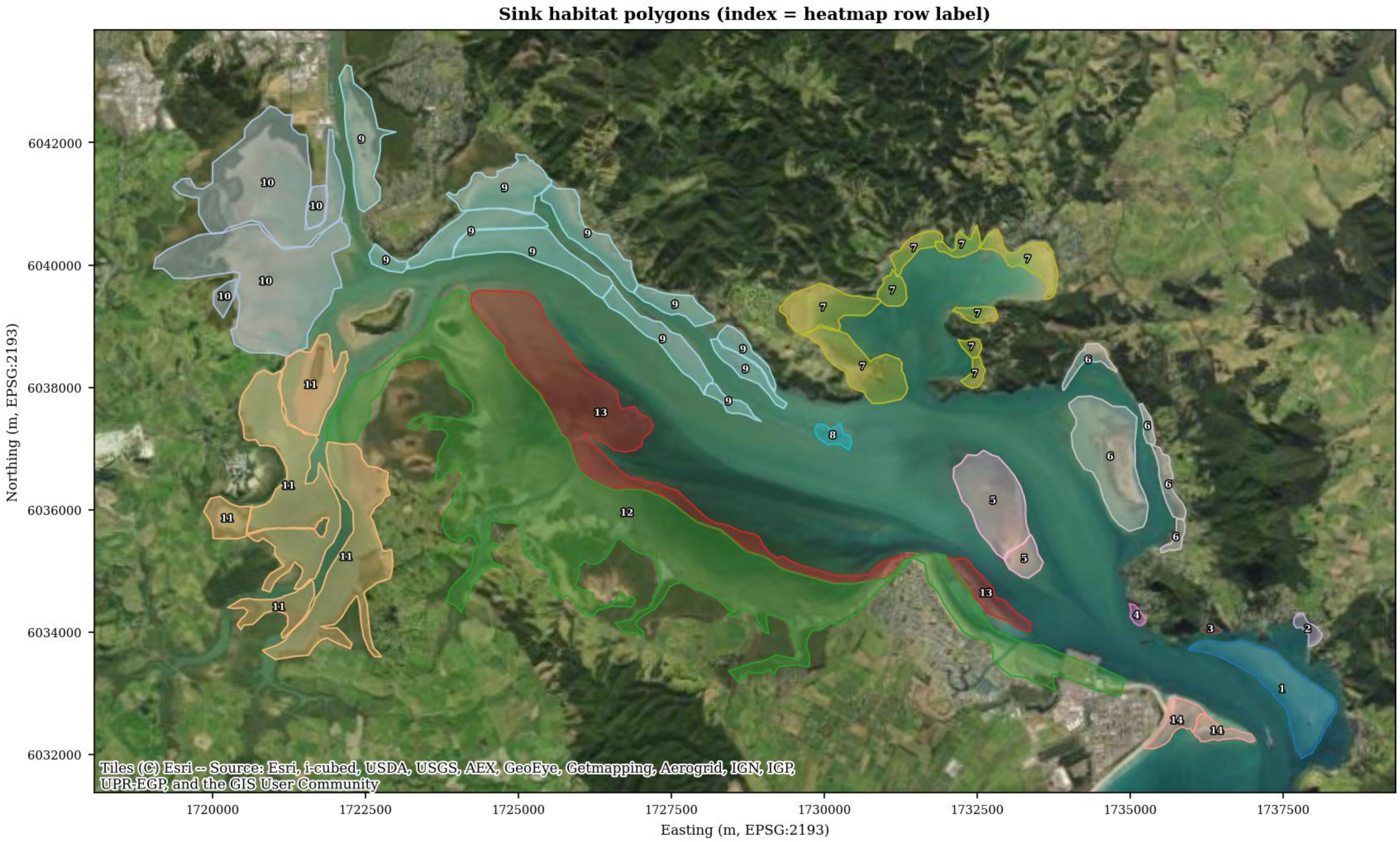

Figure 2-2 Polygons of suitable habitats for pipi larvae.

2.3.2 Post-processing

The Lagrangian Probability Density Functions (PDFs) are a common method for the analysis of particle dispersion as they provide the spatial probability of finding a particle after a given advection time, providing an estimated dispersal pattern in a region.

The particle simulations conducted in this study enable estimation of total particle concentrations representing the pipi larvae cloud across Whangārei Harbour. These concentrations were calculated using a spatial resolution of 30 × 30 m grid cells. Based on the spatial distribution of particles at a given time, defined by their positions (X_{part}, Y_{part}), the particle density across the domain can be estimated by calculating the probability density function, PDF(x,y).

Physical "connectivity" is a commonly used metric to summarise transport and larval dispersal across multidisciplinary studies. Physical connectivity represents the probability of material being transported from a source point to a sink (destination) point over a given timeframe (Mitarai et al., 2009). Connectivity matrices (M) provide a quantitative method to evaluate the particle exchange between regions. The cell M_{ij} displays the percentage of particles released from the source site i (vertical index, Figure 2-1) that reach the destination sites j (horizontal index, Figure 2-2). In the current study, we use these matrices to display coastal connectivity at the end of the simulation. Consequently, each row of the matrix displays the final distribution of settled particles originating form a specific source location. While each column represents the proportion of particles accumulated at a defined suitable from each source site. By comparing the different model simulations, quantitative differences between the simulations can be determined.

3.Results

3.1 Pipi Larval dispersion and connectivity features

To assess the impact of proposed bathymetric changes (and associated hydrodynamic modification) on the spatial distribution of pipi larvae, one-month-long pipi larvae dispersion simulations within Whangārei Harbour from three key source beds were undertaken for each of the hydrodynamic configurations being considered, i.e.;

1. Existing bathymetry
2. The Eastern Reclamation and NSDF
3. The NSDF

The main features from the results are described below, using the probability distribution of the settlement of pipi larvae at the end of the simulation (Figure 3-1 to Figure 3-3) and the connectivity matrices for each hydrodynamic configuration (Figure 3-4 to Figure 3-5).

Simulation results indicate that the proposed structural modifications to the bathymetry do not have a significant influence on the spatial distribution or settlement patterns of pipi larvae within the harbour. Under the evaluated scenarios, the spatial density maps for Mair Bank, Snake Bank and Marsden Bay release locations show comparable geographic settlement footprints across the three hydrodynamic configurations, suggesting no major alterations due to the modified hydrodynamic characterises associated with the proposed bathymetric changes. Based on the results obtained in MetOcean Solutions (2026), this is an expected result, as the hydrodynamic changes caused by the proposed projects are relatively localised.

This localised stability is further confirmed by the connectivity matrices. Across all scenarios, the connectivity matrices show consistent retention and transport dynamics. Sink regions 7 (Parua Bay) and 12 (Marsden Bay) serve as the dominant settlement zones for all three sources, regardless of the bathymetric configuration. Followed by the sink regions 1 (Calliope Bay bank), 6 (Area surrounding McDonald bank) and 9. The marginal fluctuations observed between the three simulations suggest that the reclamation footprints do not significantly disrupt the broader hydrodynamic connectivity of the harbour's pipi populations under the evaluated scenarios and based on the simulated of neutrally buoyant particle assumption and biological restrictions (restricted settlement habitats, minimum age of 12 days and a maximum age of 21 days). The connectivity differences show that under the Eastern Reclamation and NSDF there might be a slight increase in retention of larvae around region 14 (Mair Bank, Figure 3-8).

For completeness, the 'elsewhere' column in the connectivity matrices represents the particles that either left the selected domain or were unable to find a suitable habitat to settle.

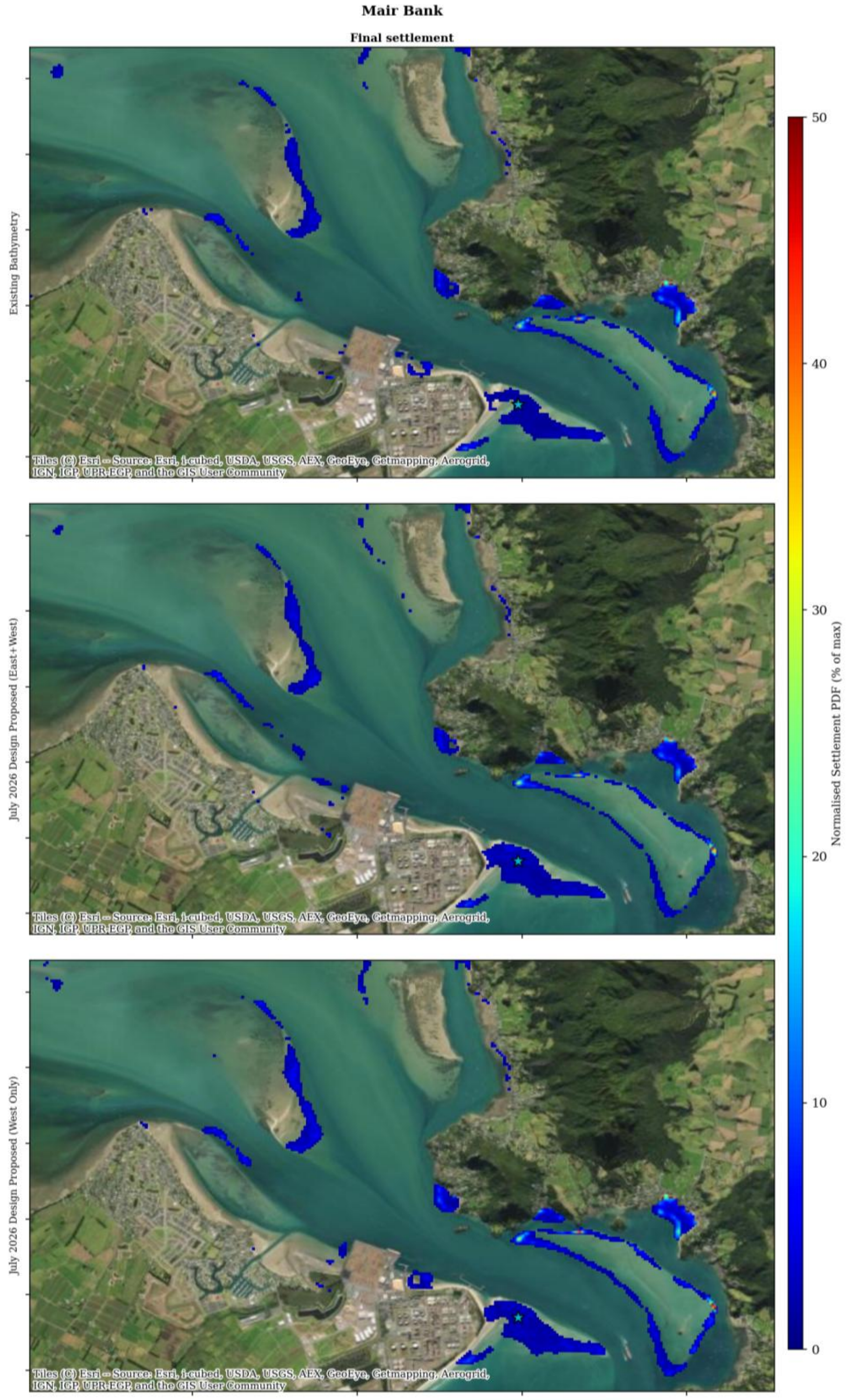

Figure 3-1. Spatial Probability Distribution of settled particles under the three different bathymetry scenarios for the Mair Bank Source (Existing top panel, East + West middle panel, West only bottom panel) . Values below 1% are masked

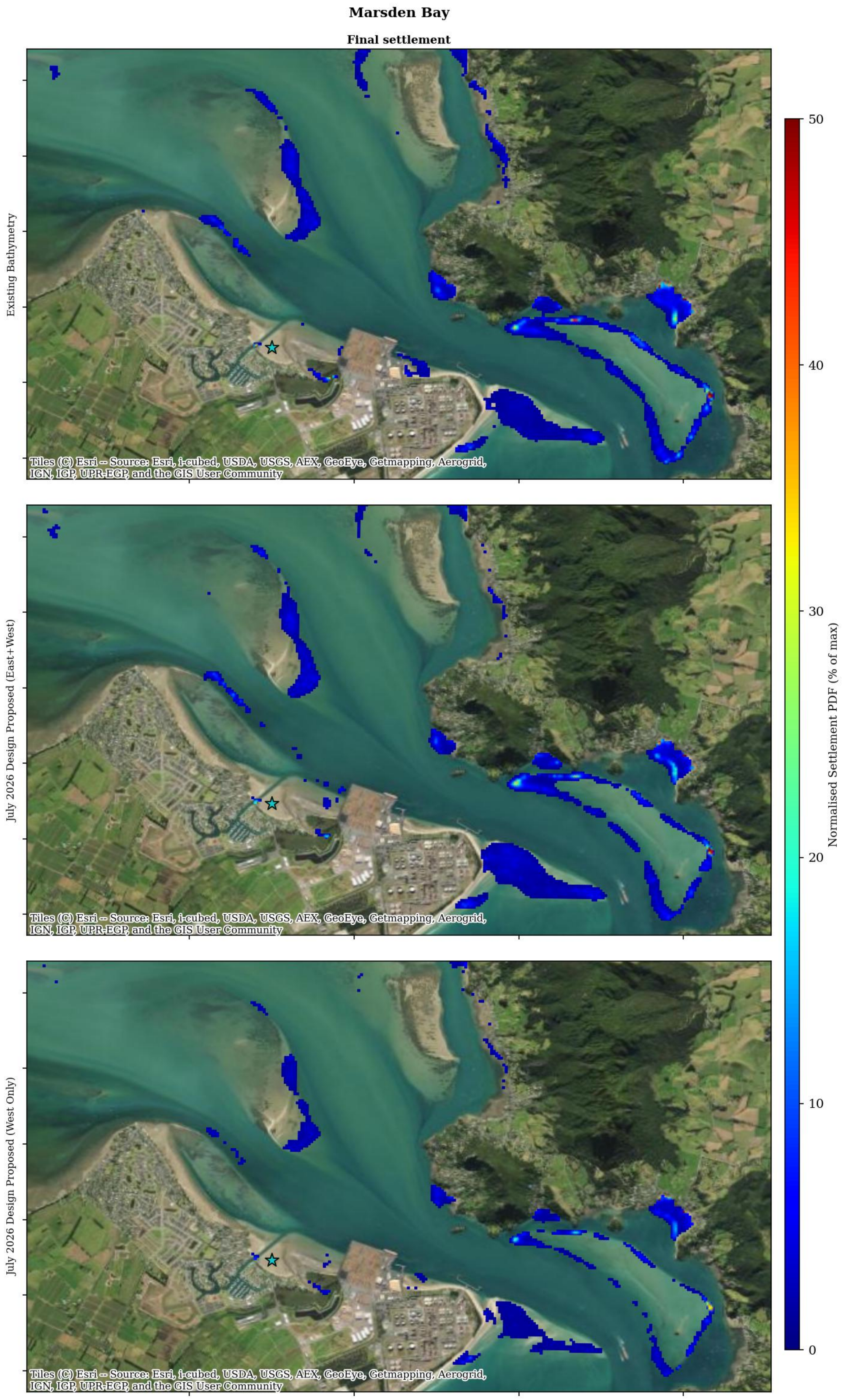

Figure 3-2 Spatial Probability Distribution of settled particles under the three different bathymetry scenarios for the Marsden Bay Source (Existing top panel, East + West middle panel, West only bottom panel). Values below 1% are masked

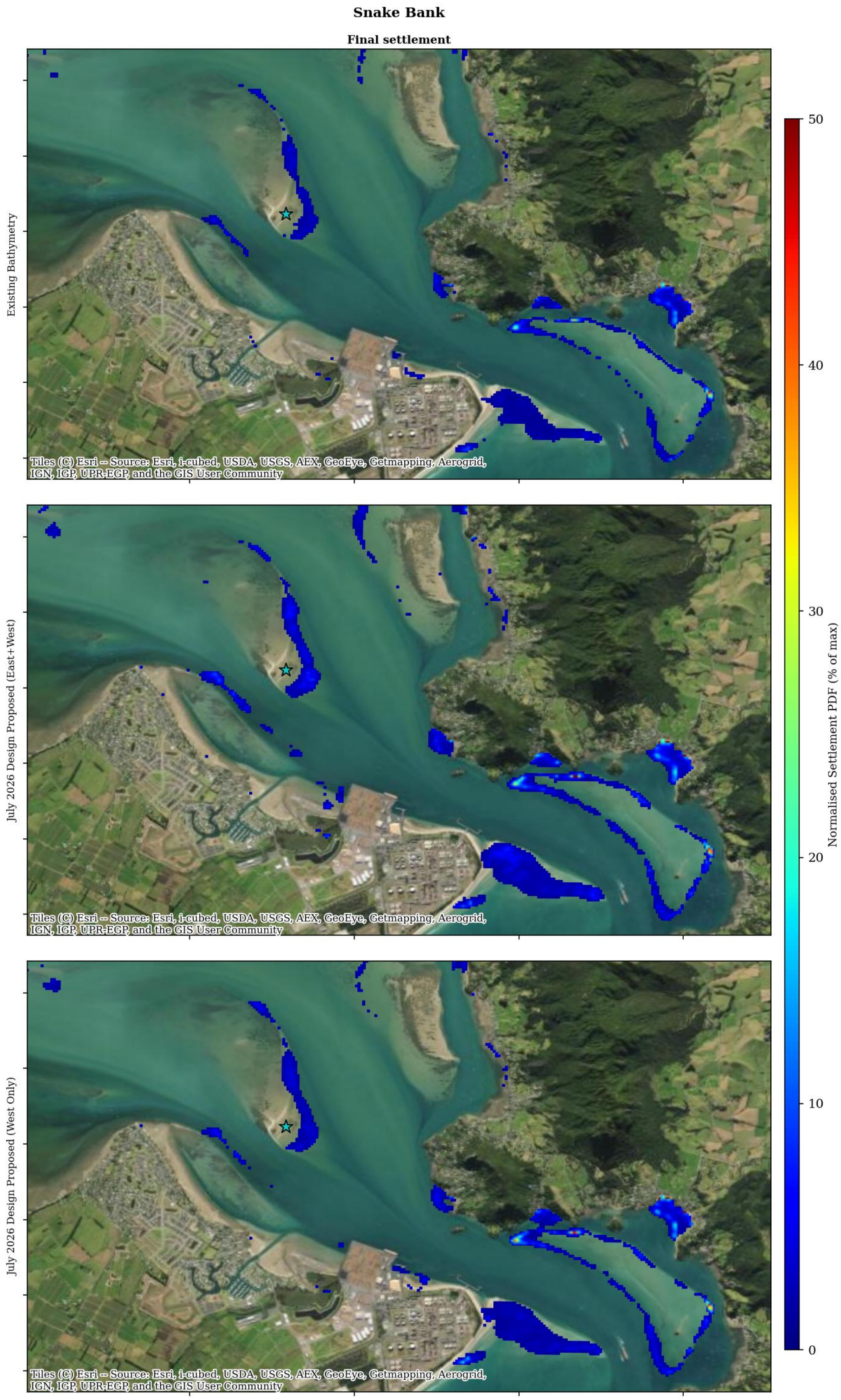

Figure 3-3 Spatial Probability Distribution of settled particles under the three different bathymetry scenarios for the Snake Bank Source (Existing top panel, East + West middle panel, West only bottom panel). Values below 1% are masked

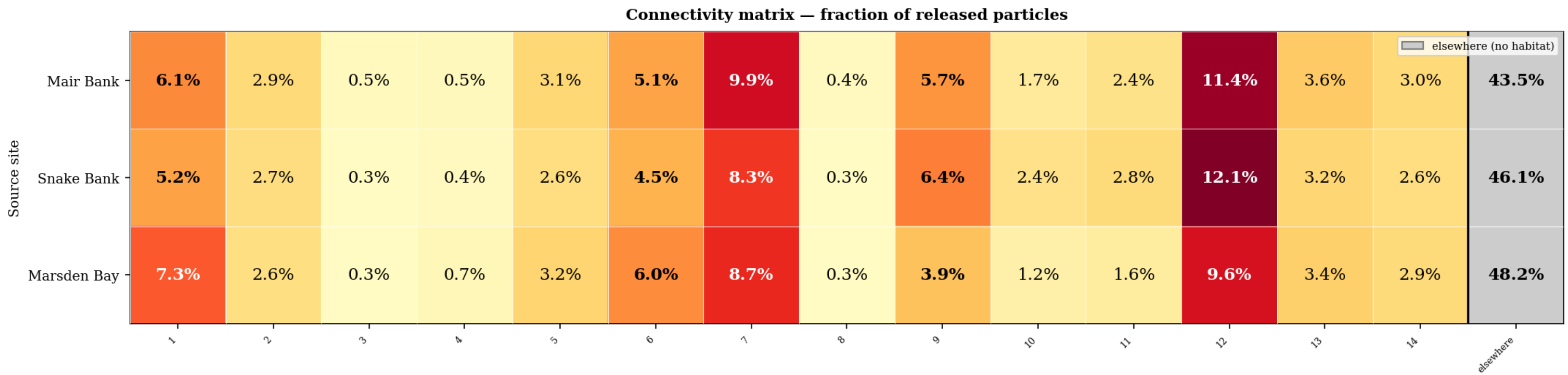

*Figure 3-4 Connectivity Matrix for the **existing bathymetry** scenario for the three key source regions*

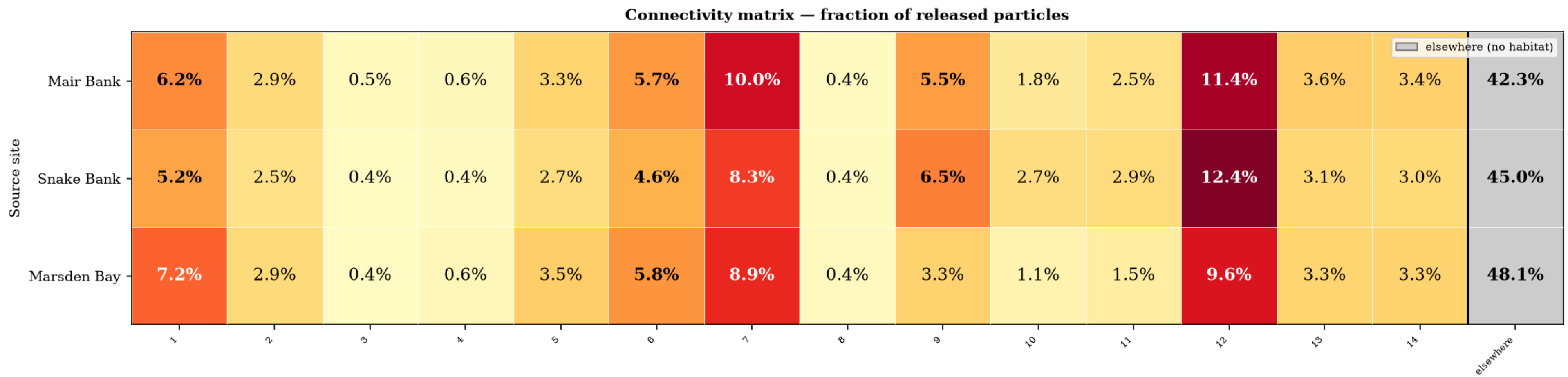

*Figure 3-5 Connectivity Matrix for the **NSDF** scenario for the three key source regions*

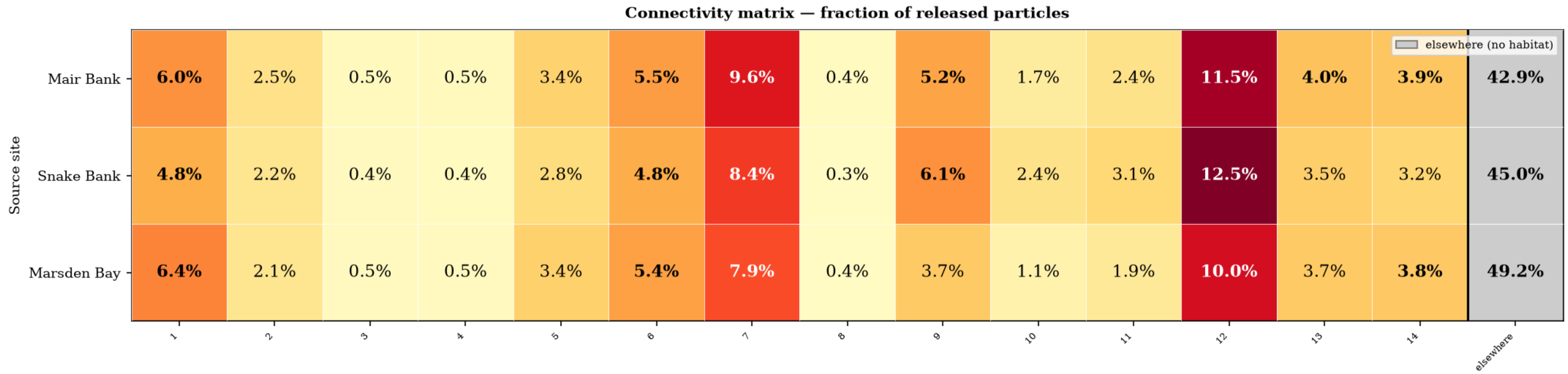

*Figure 3-6 Connectivity Matrix for the **eastern reclamation and NSDF** scenario for the three key source regions*

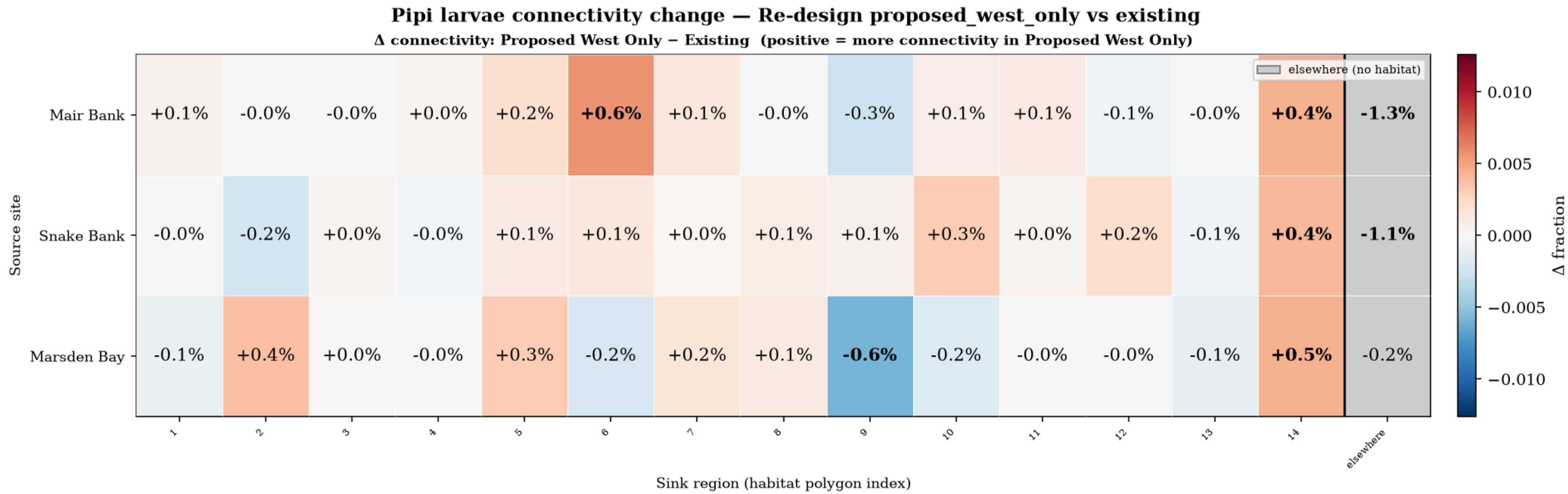

Figure 3-7 Difference between the connectivity of the ***NSDF*** *scenario vs the connectivity of the* ***existing bathymetry*** *scenario. Positive (red colours) suggest higher connectivity between regions under the* ***NSDF*** *scenario.*

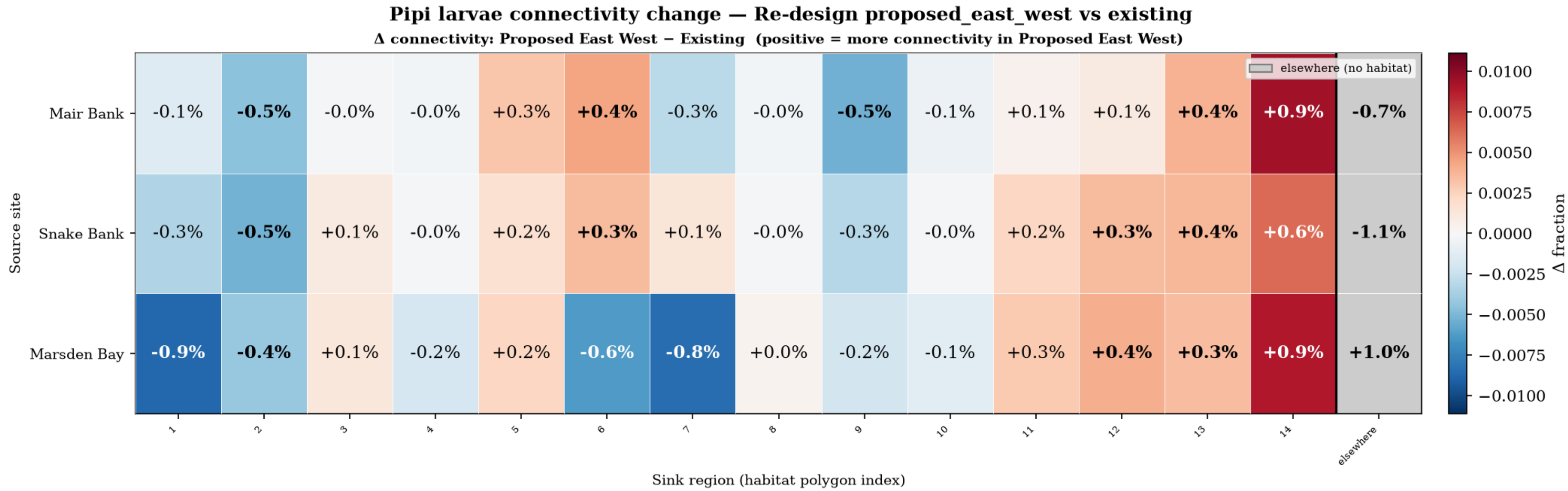

Figure 3-8 Difference between the connectivity of the ***eastern reclamation and NSDF*** *scenario vs the connectivity of the* ***existing bathymetry*** *scenario. Positive (red colours) suggest higher connectivity between regions under* ***the eastern reclamation and NSDF*** *scenario.*

4. Summary

A series of one-month-long simulations were conducted to evaluate the potential effects of proposed bathymetric modifications on the spatial distribution and settlement dynamics of pipi larvae within Whangārei Harbour.

Based on the evaluated scenarios, they key findings are as follows:

- Geographic settlement footprints remain highly comparable across all the three key sources and all the simulated configurations.
- Hydrodynamic transport pathways within the harbour remain stable. Sink regions 7 (Parua Bay) and 12 (Marsden Bay) consistently serve as dominant settlement zones. Followed by the sink regions 1 (Calliope Bay bank), 6 (Area surrounding McDonald bank) and 9.
- The connectivity differences show that under the Eastern Reclamation and NSDF there might be a slight increase in retention of larvae around region 14 (Mair Bank).

These conclusions are specific to the assumed biological and physical parameters of the study described in the methodology section.

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