Nutrient Dispersion Modelling for Proposed Marine Finfish Farming Zones in Storm Bay.

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This document provides modelled simulations (using CONNIE3) for the dispersion of farm derived dissolved nutrients from proposed marine farming sites in Storm Bay based on farming information provided by DPIPWE and parameterisations based on both previous modelling and experience developed in discussion with DPIPWE. The assumptions used in the modelling are outlined in Table 1. The figures displayed in this document were chosen by DPIPWE as the most informative and useful representation of the modeling results, in respect to the development of both a monitoring program and categorising the potential impact of broadscale salmon farming in Storm Bay.

Table 1: Assumptions used in parameterisation of the following modelling to assess nutrient dispersion in Storm Bay using CONNIE3.

Parameter	Assumption/ Setting
Release Period	14 days
Dispersal Time	4-days
Decay Rate	4 days
Release Depth	Integrated output from 2 depth categories: 0 - 15m and 15 - 28m
Modelled Period	4 time periods (July, October 2014 and January, April 2015)
Farm inputs	2,295 tonnes of dissolved Nitrogen, generated through the production of a 40,000 tonne biomass, distributed according to farm defined feeding scenarios

See Appendix 1 for detailed rationale regarding the selection of parameters.

Ammonium is the primary form of dissolved nitrogen released from the farms and as such is the main factor addressed in the model outputs. However, ammonium degrades quickly via denitrification and/or biological uptake and as a consequence dissolved inorganic nitrogen (DIN – ammonium and nitrate) is potentially the more persistent form of nitrogen in the system and therefore outputs have also been provided to show how the farm derived nitrogen might relate to natural DIN levels. Note: the model outputs do not provide an estimate of the conversion of ammonium to nitrate for the farm derived nitrogen.

Modelled outputs are shown both as a proportion of the total nitrogen (ammonium) released from the farms (either as dissolved nitrogen (ammonium) or total dissolved inorganic nitrogen (DIN - which is a combination of ammonium and nitrate).

The proportion of the total dissolved nitrogen released is calculated by dividing the total concentration present in each grid cell (a,b,c,..) at the end of the assessment period by the total concentration of nitrogen released over the assessment period (x) (Figure 1).

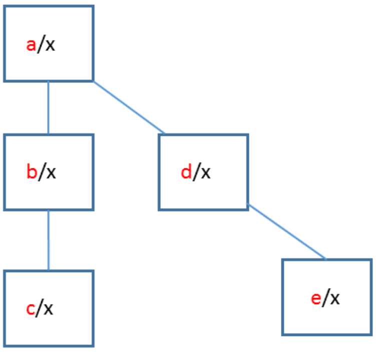


Figure 1: Schematic to help explain the model calculation of Proportional representation of nitrogen. The total concentration that occurred in each grid cell (square) after the assessment period is shown in red (a, b, c, d, e), and this value is divided by the combined load for all farms over the assessment period (x), changing the concentration in each cell to a percentage of the total farm load.

Figure 2 shows the expected dispersion of farm derived dissolved nutrients within the surface waters (0-15m) of Storm Bay as a proportion of the total farm inputs. This data provides a useful representation of the farm nutrient footprint. These plots clearly show the highly dispersive (diluting) nature of the Storm Bay system, with levels very quickly being reduced to less than 1% of the total output. The plots also suggest temporal differences in dispersion, and these are likely a function of both seasonal variations in hydrodynamics and temporal differences in farm inputs (e.g. higher feed inputs are generally required towards the end of the production cycle). Note as this data is proportional, the plots cannot be directly compared in terms of absolute inputs/ load (i.e. 1% in July may not represent the same load as 1% in October). Figure 3 shows the same information but for the deeper waters (15-28m), and in this case it is clear that the dispersion footprints are markedly reduced.

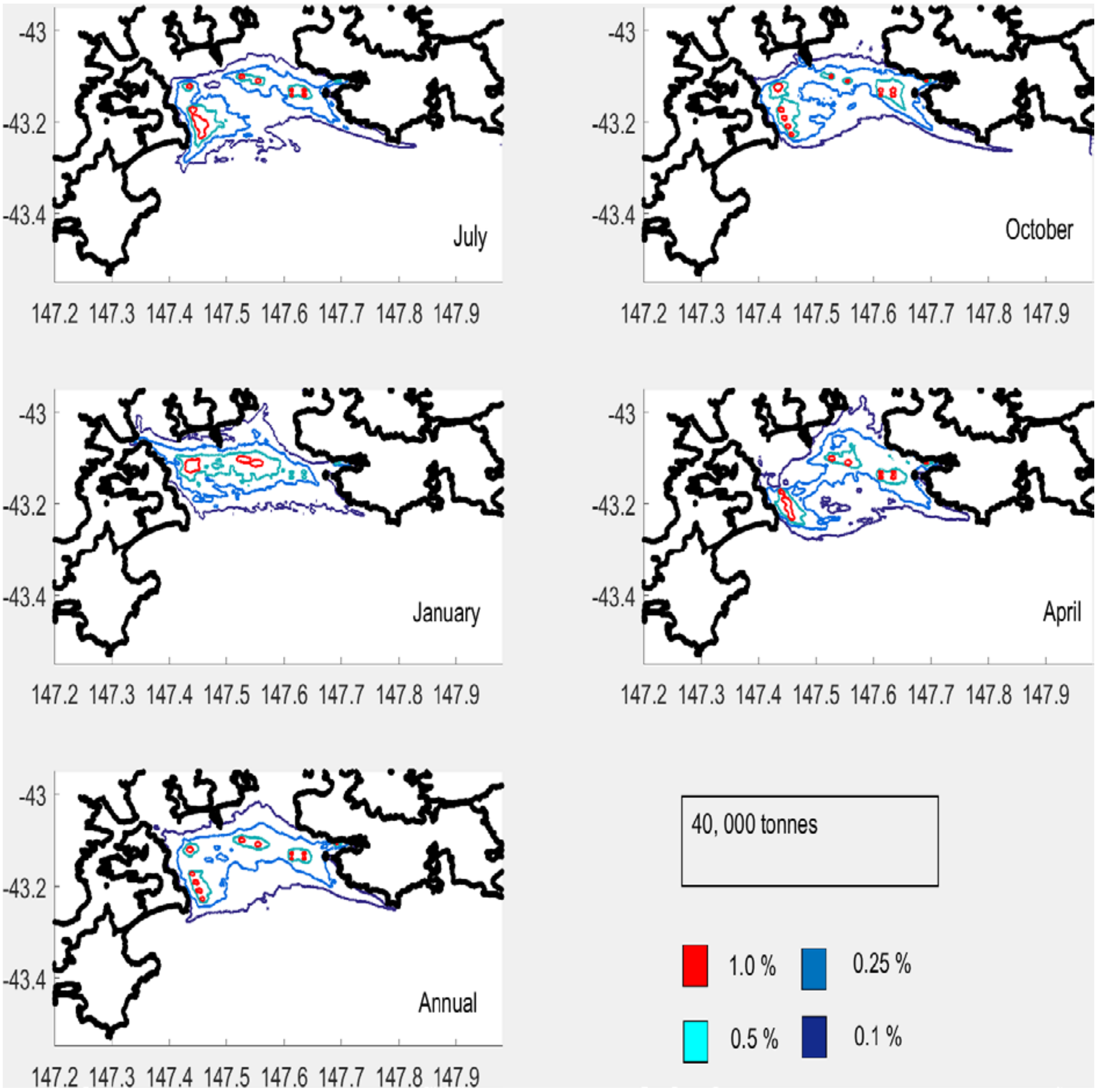


Figure 2: Model representation of the dispersion of dissolved nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 0-15m depth range (see parameterisation in Table 1). Results are shown as the proportion of the total dissolved nitrogen released (with contours shown for 0.1%, 0.25%, 0.5% and 1.0%) over the periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by DPIPWE.

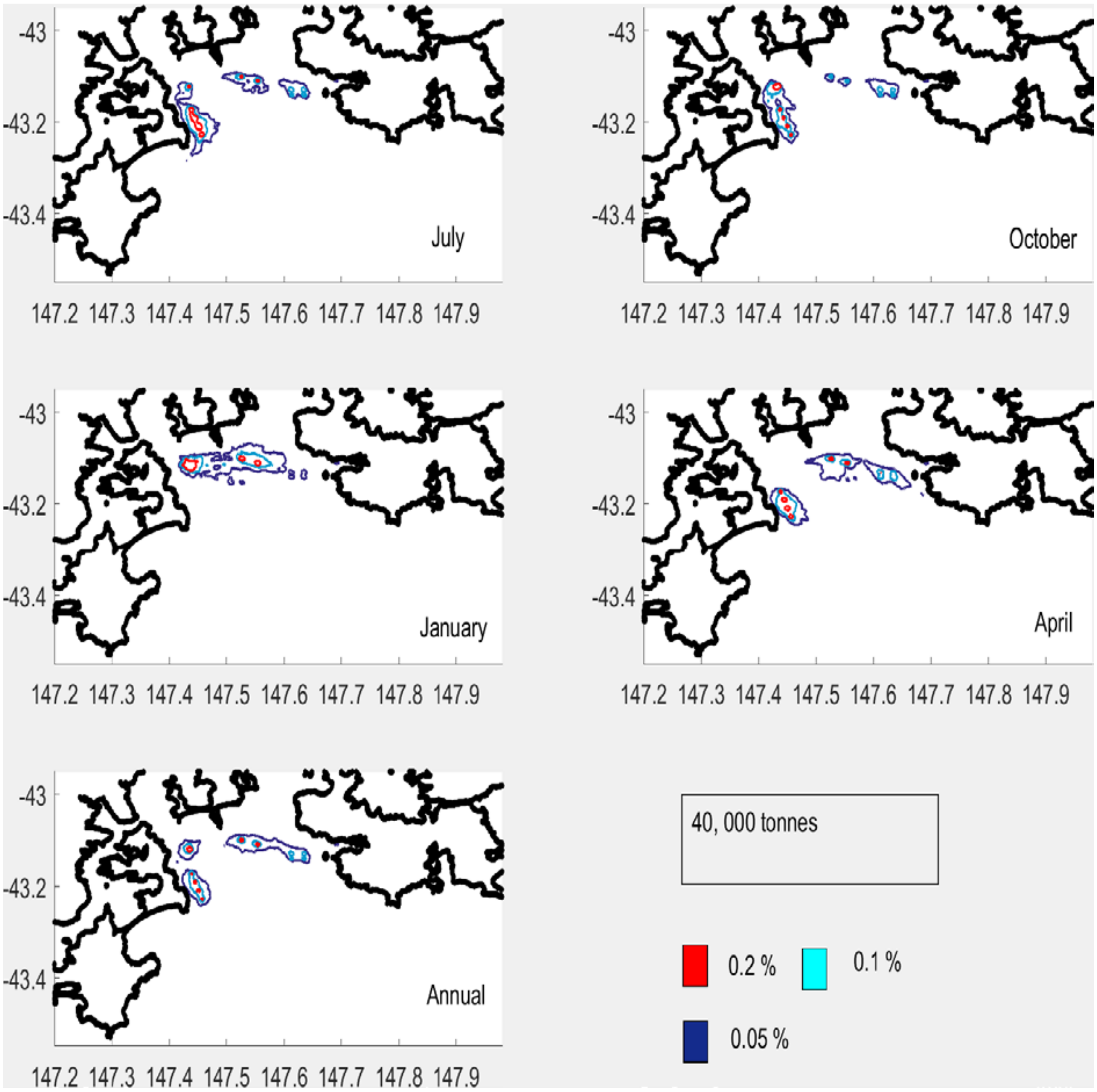


Figure 3: Model representation of the dispersion of dissolved nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 15-28m depth range (see parameterisation in Table 1). Results are shown as the proportion of the total dissolved nitrogen released (with contours shown for 0.05%, 0.1% and 0.2%) over the periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by DPIPWE.

The previous figures showed the dispersion of farm nutrients in isolation i.e. in the absence of any natural background loading. Whilst this provides a picture of the added nutrient distribution it does not provide an understanding of the increase in nitrogen relative to the existing nutrient loads within the system. Consequently, an estimate of background nutrient levels was included in the model based on data from previous research and monitoring undertaken in Storm Bay. This background information was used to calculate risk levels based on ANZECC (2000) guidelines. The ANZECC guidelines provide guidance for the establishment of threshold levels for water quality indicators that can be used to protect environmental values and one of the suggested approaches involves derivation of two indicative management levels using reference condition data, and using these levels in an adaptive management context. This requires a minimum of 24 months of monthly water quality data at a site specific or regional scale to calculate the median (50^{th} percentile) expected level, and attributes that level as the normal “background” condition. A low-risk trigger level can then be calculated based on the 80^{th} percentile of the reference distribution, with the expectation that there would be an increased likelihood of ecological effects above this level; similarly, for the 95^{th} percentile with a greater likelihood of ecological interaction. The data used to calculate both background levels, the 80^{th} and 95^{th} (ammonium only) percentiles were provided by DPIPWE and represent the compilation of data from a number of independent studies in Storm Bay (Table 2).

	July			October			January			April			Annual		
	50th	80th	95th	50th	80th	95th	50th	80th	95th	50th	80th	95th	50th	80th	95th
Ammonium															
Surface	6.8	9.2*	20.1*	6.3	13.8*	25.1+	6.9	10.4	28.2+	7.2	10	16.2+	6.0	9.7	16.3
Depth	6.3	9.2*	20.1*	10.5	13.8*	25.1+	13.6	23.7	28.2+	9.8	14.9	16.2+	8.9	16.1	28.0
DIN															
Surface	42.7	56.1*		13.2	37.3*		8.0	13.7		11.0	18.6		9.8	31.5	
Depth	47.2	56.1*		32.0	37.3*		24.9	53.1		27.8	42.4		25.1	53.9	

Where insufficient numbers of background samples exist to establish percentile values consistent with ANZECC the following values have been used:

*Annual values for the full column

+Seasonal values for the full water column

Table 2: The 50^{th} (median), 80^{th} and 95^{th} percentile values for ammonium ($\mathrm{mg\ N\ m^{-3}}$) and the 50^{th} and 80^{th} percentile values for DIN ($\mathrm{mg\ N\ m^{-3}}$) in surface (1-10 m) and at depth (varied depending on site; typically >= 50m) based on results of water sampling conducted as part of previous sampling in Storm Bay. In all cases nitrogen concentrations represent the average of several sample sites taken across Storm Bay. Data was provided by DPIPWE.

This approach was used to evaluate the distribution of both ammonium and total DIN in Storm Bay. Figures 4 and 5 show the modelled outputs (concentration of farm released ammonium) in combination with the background levels of ammonium whilst figures 6 and 7 show the modelled outputs in combination with background DIN (ammonium + nitrate). Superimposing the predicted footprint from the farms on top of the background levels and adding the 95^{th}, 80^{th} and 50^{th} percentile contours allows visualisation of where nitrogen loads might be expected to exceed background (> 50^{th} percentile) levels, where the likelihood of ecological effects (>80^{th} percentile) might be increased, and a higher likelihood of increased ecological effects (>95^{th}). The modelled output suggests that ammonium levels in surface waters are more likely to exceed background levels and have an ecological effect in the bay (Figure 4) than DIN levels, which show a much smaller interaction footprint at the 80^{th} percentile level (Figure 6). The 95^{th} percentile contour was not included in the plots where background DIN was used as the reference level as concentrations did not reach this value. The modelling also suggests that the potential for adverse interactions is markedly reduced in the bottom waters, and in particular for DIN (Figures 5 and 7); bottom water ammonium did not exceed the 95^{th} percentile (figure 5).

Given that these dispersion plots include defensible ecological performance limits they could provide a basis for establishing a justifiable monitoring program.

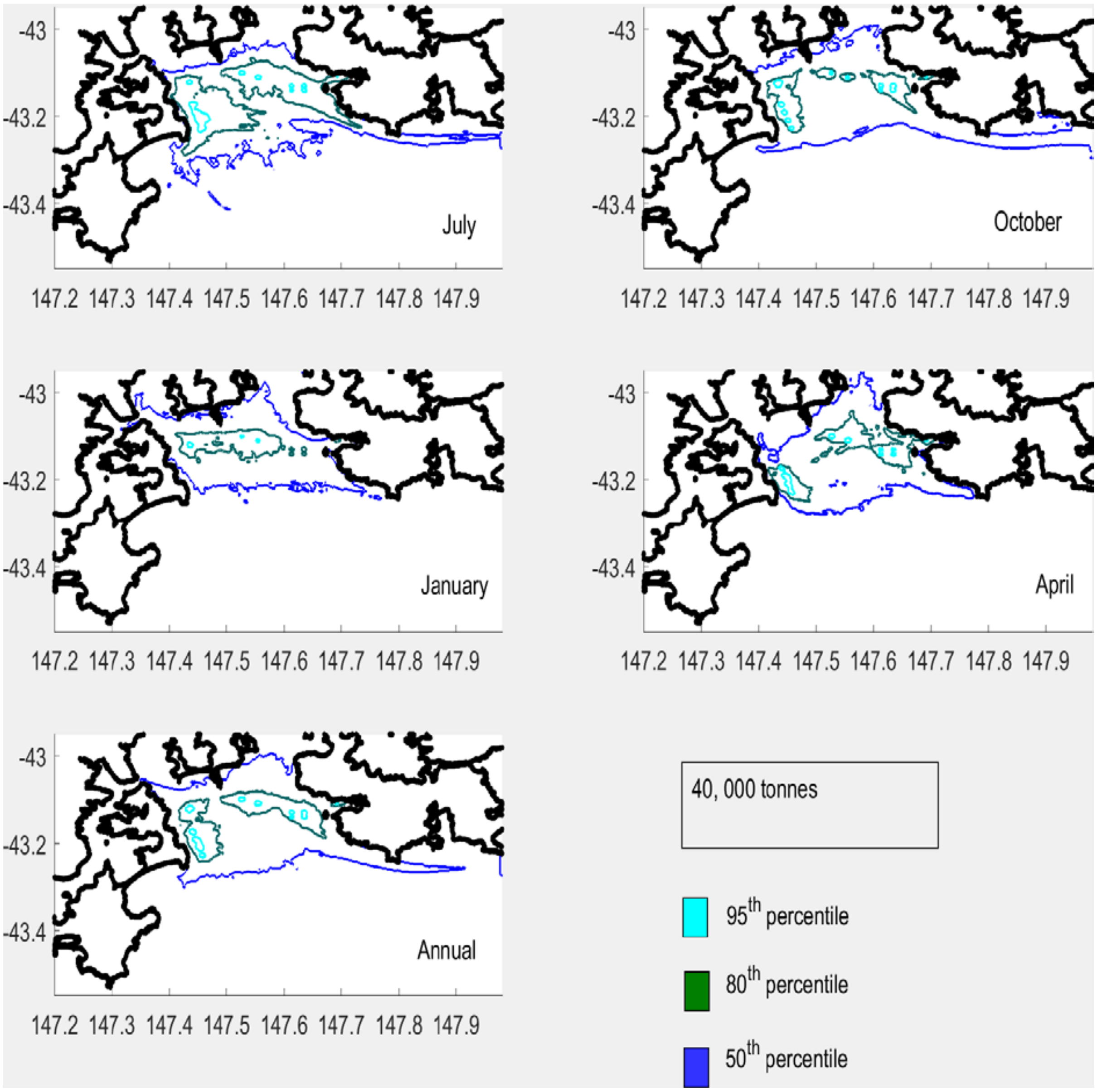


Figure 4: Model representation of the dispersion of dissolved nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 0-15m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) ammonium concentrations based on data (average) from Crawford et al. (pers comm). The contours show the 95th, 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect and where water quality is most likely to be comparable to background. The periods for each figure are periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results, which produces the annual result. Farm input data supplied by DPIPWE.

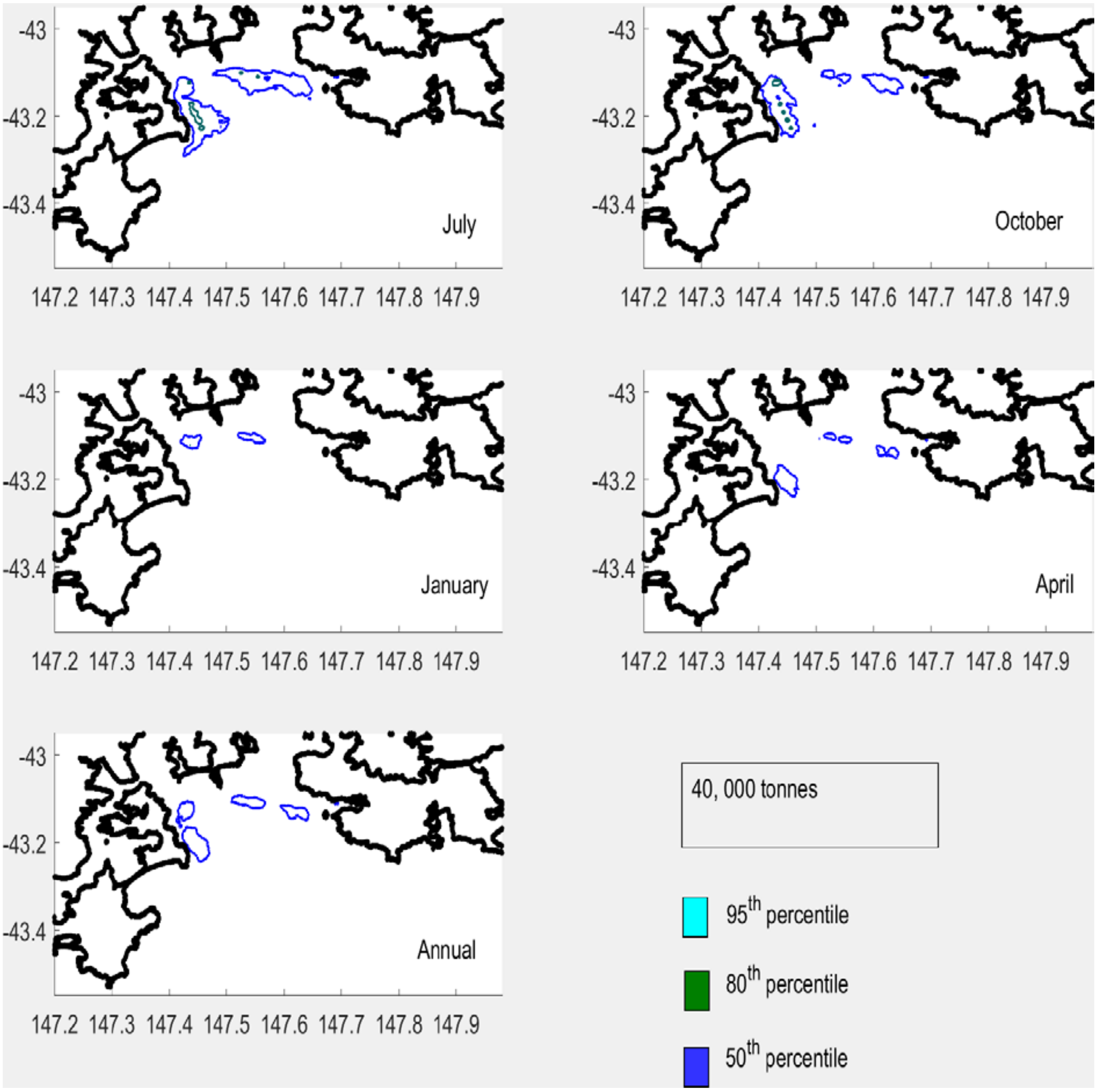


Figure 5: Model representation of the dispersion of dissolved nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 15-28m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) ammonium concentrations based on data (average) from Crawford (pers comm). The contours show the 95th, 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect and where water quality is most likely to be comparable to background. The periods for each figure are periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results, which produces the annual result. Farm input data supplied by DPIPWE.

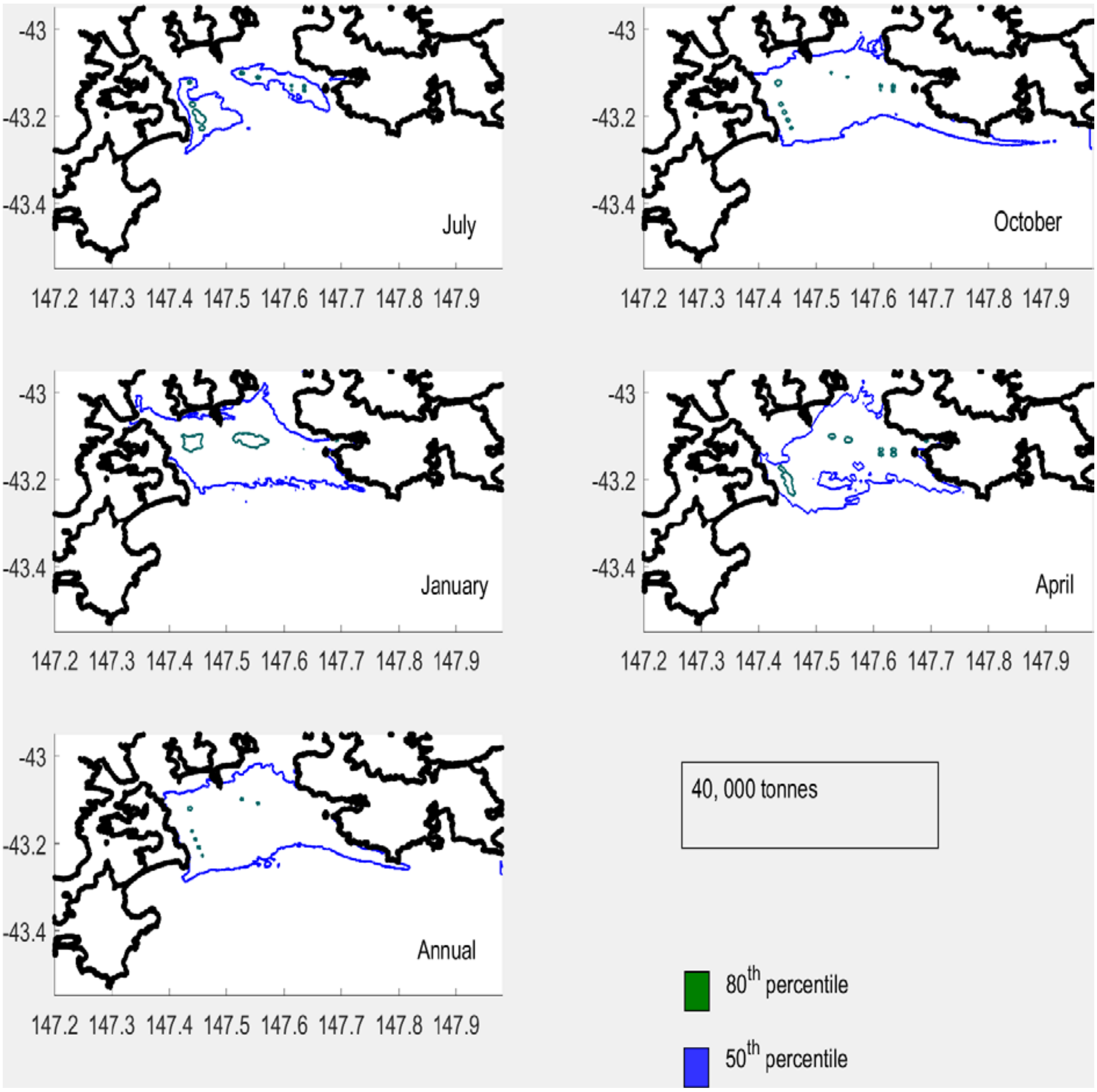


Figure 6: Model representation of the dispersion of nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 0-15m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) DIN (ammonium and nitrate) concentrations based on data (average) from Crawford (pers comm). The contours show the 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect, and where water quality is most likely to be comparable to background. The periods for each figure are periods1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by DPIPWE.

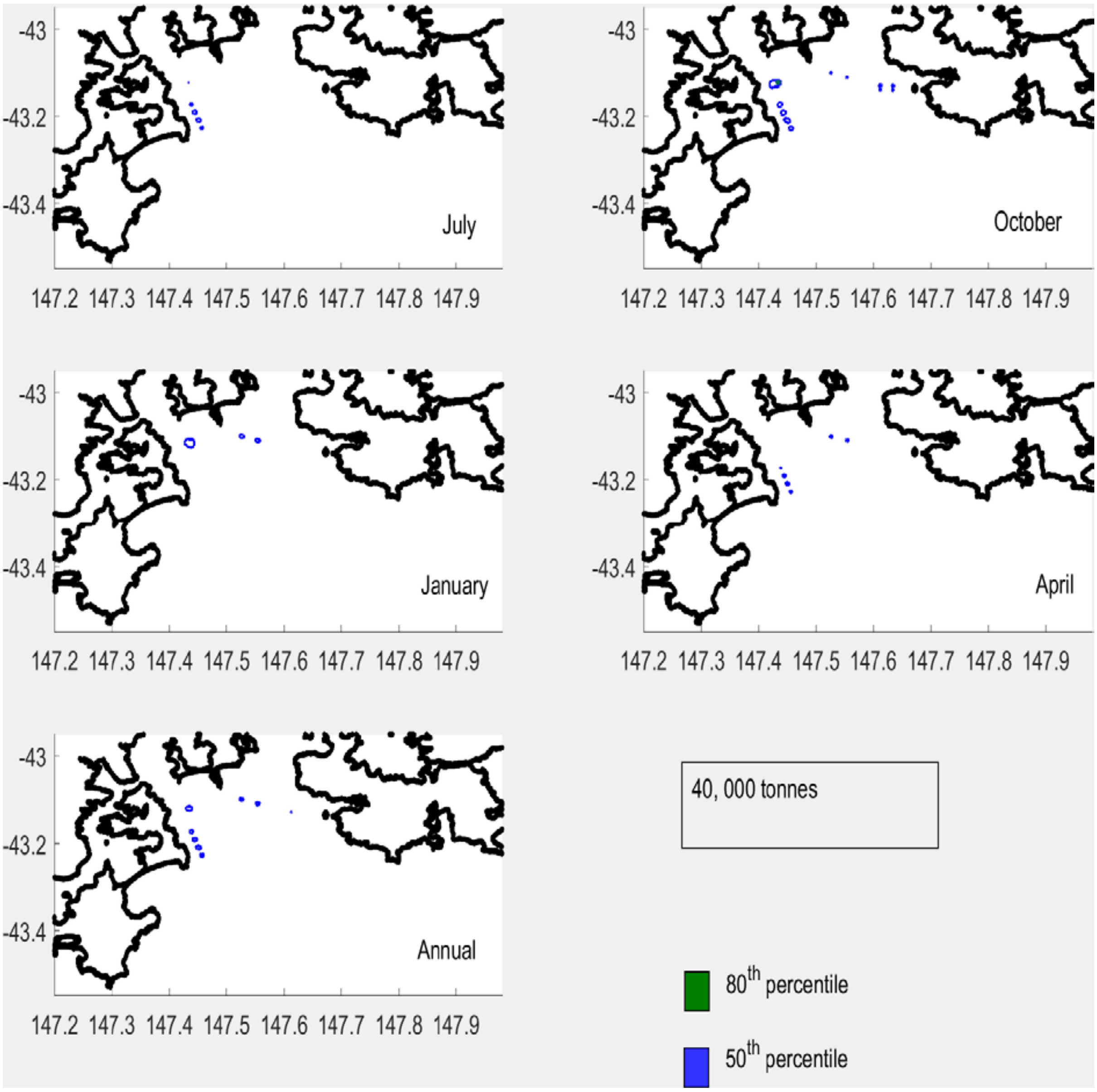


Figure 7: Model representation of the dispersion of nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 15-28m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) DIN (ammonium and nitrate) concentrations based on data from Crawford (pers comm). The contours show the 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect and where water quality is most likely to be comparable to background. The periods for each figure are periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by DPIPWE.

APPENDICES

APPENDIX 1: Outline of Parameterisation Requirements for CONNIE3

In order to help with the understanding and comparison of model outputs generated using CONNIE3 IMAS has prepared this summary of:

1) the parameters that can be varied in CONNIE3, a definition of each parameter and an explanation of requirements and things to be aware of when using CONNIE3 for assessment of nutrient dispersion.
2) IMAS specific parameterisation of the CONNIE3 model; to simulate dispersion of dissolved nutrients from proposed marine farming sites in Storm Bay in order to inform the design of a monitoring program that would align with proposed development (as outlined by DPIPWE), along with a justification as to why those particular parameters/ constraints were selected, and
3) An overview of other considerations for both defining and interpreting CONNIE3 model runs.

1. Overview of CONNIE3 Parameterisation:

The table below outlines the user defined parameterisation options available in CONNIE3.

Parameter	Points To Note
Release period **DEFINITION**: The release period indicates the number of days over which the particles are released. Release period is connected to both dispersal time and decay rate. The release time and dispersal time in combination will define the full period over which the assessment (model) is run - *for example a release time of 14 days, with a dispersal time of 4 days would result in the full model run being 18 days, as any particles released on the last day would require 4 days to reduce to negligible concentrations*. Release time needs to be representative of the interactions you are considering. A single day release is only representative of dispersal from that day, whereas a more extended release would be needed to establish any longer term dispersal patterns.	• Decisions regarding release time will vary depending on the question/ issue to be address and on the particular system – *this may be refined as local knowledge/ system understanding increases*. • The choice of release period will be influenced by both dispersal time and decay rate. To establish a dispersion pattern indicative of the mean flow it is important to make sure that the particles are in the system long enough. *For example - if we release for 1 day and disperse for 4-days, then we only really get a sense of the dispersal in the system for those 5 days (which is very dependent on the 4 days you choose). If we release for 2 weeks, and disperse for 4-days, then we get a sense of the dispersal pattern over 18 days, which may be more informative in terms of longer term flow patterns, tidal cycles etc*.
Decay Rate **DEFINITION**: Decay Rate is employed to represent an integrated measure of the	• Decay rate will vary depending on i) the nature of the particular outputs (e.g. a

influence of natural processes other than hydrodynamic transport (e.g. biological uptake, nitrification) on the concentration of particles in the system. In a natural system decay rate can change markedly, both in space and over time. Decay is an exponential process, with the total amount of particles being reduced in the system each day, by a fraction proportional to the decay rate. In the model this reduction is averaged over all particles which were released at the same time i.e. the model does not randomly remove individual particles, but rather calculates this by fractionally reducing all particles which achieve their decay rate end point/ time.	particular nutrient, feed, faeces or some other particle) and ii) the system processes (e.g. nutrient dynamics in Storm Bay). • Parameterisation can be based on known empirical data or literature values, a reasoned theoretical understanding of the processes or just a "best guess". However, it should be noted that for assessment of nutrient connectivity any of the biological/chemical 'losses' are dynamic processes that display strong spatial and temporal gradients. • It is worth noting that forcing an actual system with high loads of a relatively conservative particle (e.g. nitrogen) has the potential to saturate the system and the biological processes, which may result in a slower decay. • Comparing the effects of different decay rate can be informative - providing a better understanding of the extent to which this parameter can actual change the model output (i.e. a measure of the sensitivity of this parameter in the model) • In an assessment model like CONNIE3 decay rate is constant (spatially and temporally) in the model run, and therefore running the model with different decay rates could be used to explore the potential effect of changes in "natural processes".
Dispersal Time **DEFINITION**: Dispersal Time defines the number of days the particles disperse once they are released. Each day of the release time particles are introduced into the system, they are then moved around the system by the hydrodynamics (currents) for the user defined "dispersal time".	• Where connectivity is being explored, the dispersal time needs to be sufficient for the connectivity to be established. Noting that the connectivity may vary depending on the distance between features of interest (e.g. farms) and with the current regime in the region of interest. • Where a decay rate is defined, then there is little point making the dispersal time longer than the particle decay time, as concentrations will become negligible after the decay time (e.g. after 3 decay times – there will be only 5% of the particles that there would have been in the absence of decay). • The specification of dispersal time will be dictated by the particular question being asked - *for example, whether you want to know how far a particle might travel in a*

	specific timeframe or how long it is until a particle reaches the model boundary? • A useful test is to compare concentrations using a range of dispersal times; as at some point the distribution will become less sensitive to increases in the dispersal time.
Release Depth **DEFINITION:** This defines where the particles are released in the water column. All subsequent dispersal occurs at this depth (unless diurnal migration is specified). CONNIE3 offers release depths of 1, 2, 5, 10, 15, 28, 45 and 72m. Each depth has an associated water current field that is used to push the particles horizontally around the CONNIE grid.	• If the release depth is greater than the local water depth, then particles can't move. • Changing the release depth will alter the distribution pattern observed.
Modelled period **DEFINITION:** This is the historical period (days, months and years) that the model run is initiated and run over.	• This is user defined, and will be "question" specific. • It is generally considered important to ensure that the timeframe captures the major modes of the system being modelled - *for example, if hydrodynamics in the system were dominated by river flow (i.e. low river flow meant low circulation in the estuary) it would be important to include periods of both low (high) river flow. Alternatively, if the system shows high seasonal variability then model runs should be conducted in each season. Similarly, capturing tidal influences may be important. Note: that the model itself can be used to identify this variability.* • Knowledge of the local system is very important in devising potential scenarios and in outlining the modelling period. Previous studies in Storm Bay studies have provided a good understanding of the mean flows and the magnitudes and directions of residual currents in this region.

2. IMAS Specific Parameterisation for Modelling Connectivity of Proposed Salmon Farming Operations in Storm Bay using CONNIE3:

Parameter (Setting)	Rationale/ Justification for Selected Settings
Release period: 14 days	In this instance 14 days was chosen, as it was felt that this was sufficient to cover the spring-neap tidal cycle and other cycles of synoptic weather systems that influence wind and rainfall. If a longer release period was deemed necessary then the model could be run again, this would most likely be justified if there was an expectation of a major shift in the dispersal pattern.
Decay rate: 4 days	There is no single definition of ammonia decay rate in marine systems. Decay rate will vary depending on local nutrient uptake dynamics, and therefore this parameter needs to be informed by local information. Modelling studies in the Derwent and Huon Estuaries and D'Entrecasteaux Channel have shown that the greatest loss of nitrogen in this system is through denitrification (the process that converts nitrate to nitrogen gas). Results from modelling in these regions (Wild-Allen and Andrewartha 2016, DHD model) suggest that ammonia would appear to be converted to nitrate in the water column at a constant rate of approximately 10% per day. The other major sink for ammonia is phytoplankton uptake, which is highly dynamic (both temporally and spatially). However, if we consider the phytoplankton uptake as having a similar influence on ammonia level to that of water column assimilation, i.e. 10% each, then the cumulative loss would be 20% per day. We also assume 10% of farm derived ammonia (released in the top 15m) is lost to the lower layers, giving a total approximate loss of 30%, which is broadly equivalent to a 4-day decay rate. We have also run the model with both a decay rate of 8-days (in the case that these losses are significantly slower) and no decay to compare the results and provide a better understanding as to the sensitivity of this parameter. We found spatial concentration differences between the 4 and 8-day decay results ranged between 0.5 – 2 mg $\mathrm{N\ m^{-3}}$. A 1-2 day decay rate may be relevant to represent a situation where nutrients are taken up very quickly (e.g. during a phytoplankton bloom). However, the aim of this modelling was to establish a "realistic" risk-based understanding of connectivity between sites, and this scenario is not representative of typical conditions in Storm Bay; on that basis analysis with a shorter decay rate was deemed inappropriate.
Dispersal time: 4 days	The dispersal time matches the decay-rate used. In this case we selected the longest dispersal time possible , as it was felt that a 4-day dispersal period would provide

	plenty of time for particles (nutrients) to move between farm sites in Storm Bay, and therefore would definitely show the extent to which nutrient distributions might overlap.
Modelled Period: 4 time periods - 1st July, October (2014) and January, April (2015).	Note: CONNIE3 has capacity to model scenarios in Storm Bay for years 2014 – 2016. The times in this case were selected to capture temporal (seasonal) variation. Note: Assessing the effects of long term inter-annual variations in hydrodynamic dispersal patterns and connectivity would require generation of data specific to that question/ objective. *We did not observe any major seasonal differences in the results. If the results did suggest seasonal changes then it would be useful to assess those patterns over a number of years to establish the level of inter-annual variability.*

3. Overview of Other Considerations for both Defining and Interpreting CONNIE3 Model Runs:

- It is important to remember that this early stage modelling (CONNIE3) is only indicative of the system conditions, and as such the results should be interpreted with the relevant degree of caution. To fully categorise the state of the system would require a greater level of model validation and the observations would need to be tested/ confirmed, particularly where these relate to the potential for biological outcomes/ interactions. That said, the estimates of connectivity are likely to be fairly reliable as the hydrodynamic patterns in Storm Bay are reasonably well understood and have been derived from environmental forcing that is well represented.

- Where empirical data is available then the timeframes proposed in the parameterisations can be adjusted accordingly.

- **Decay rate** is used to simulate the combined effect of a number of particle (nutrient uptake) processes and as such this variable has an important influence on the outputs for the CONNIE3 model. Any information that would allow this proxy to be more accurately determined should be carefully considered. Currently, the exponential decay captures the dynamics of loss of nutrients through both chemical and biological processes. However, it is important to note that the overall loss of particles (nutrients) from the system actually includes both the effect of '**decay'** and '**advection'** – the concentration gradient is a function of the combined effect of these two factors. The hydrodynamic model within CONNIE3 calculates the transport effect separately, so this should not be included in the characterisation of decay rate.

- When converting particle concentrations to ammonia concentrations (based on farm input loads) it is possible to "weight" the different depth layers independently. For example, you can assume equivalent amounts of nutrients are released in each depth category or that more nutrients are released at one depth than another. In the IMAS calculations it was assumed that the same fraction of the total amount nutrients was released in each depth layer (i.e. ¼ of the nutrient load was released in the 1m layer, ¼ in the 5m layer, etc). This assumption is based on CSIRO's previous work on salmon farms in the region (Wild-Allen et al. 2010) where nutrients were released evenly in the top 12m.
  Note: where ammonia is reported in the bottom layer of the model (15-28m) this is because it has been transported there from the upper layers, there was no release in the bottom layer.

- Both input (biomass/ feed) loads and farm locations need to be realistic for each scenario, as these parameters have a significant effect on modelling output. Input loads and farm locations used in this modelling reflect proponent information provided by DPIPWE.

- The run length should be long enough to clearly address the question being asked.
  In this case to establish the circulation and nutrient dispersion from the proposed farms. Running the model for a month (in each of the seasonal periods to be considered), will show the difference between the 2 and 4 week run times and therefore select which is most appropriate. Where the objective is to obtain an understanding of longer-term patterns then a longer release period might be better.

- Vertical integration is not currently part of the preferred options in the CONNIE3. Where data need to be integrated across multiple dispersion depths this must be undertaken as a post-processing analysis. IMAS have done this for the outputs modelling connectivity of proposed salmon farming operations in Storm Bay. It would be worth considering establishing a standardised protocol for post-processing.

References:

- ANZECC (2000) Australian and New Zealand Water Quality Guidelines for Fresh and Marine Sources. Canberra
- Herzfeld M (2008) Connectivity in Storm Bay. Technical report provided to DPIPWE.
- Wild-Allen K, Herzfeld M, Thompson P, Rosebrock U, Parslow J, Volkman J (2010) Applied coastal biogeochemical modelling to quantify the environmental impact of fish farm nutrients and inform managers. J Marine Syst. 81:134-147.
- Wild-Allen K, Andrewartha J (2016) Connectivity between estuaries influences nutrient transport, cycling and water quality. Journal of Marine Chemistry 185: 12-26.

APPENDIX 2:
Figures 1-6 for Tassal Pty Ltd

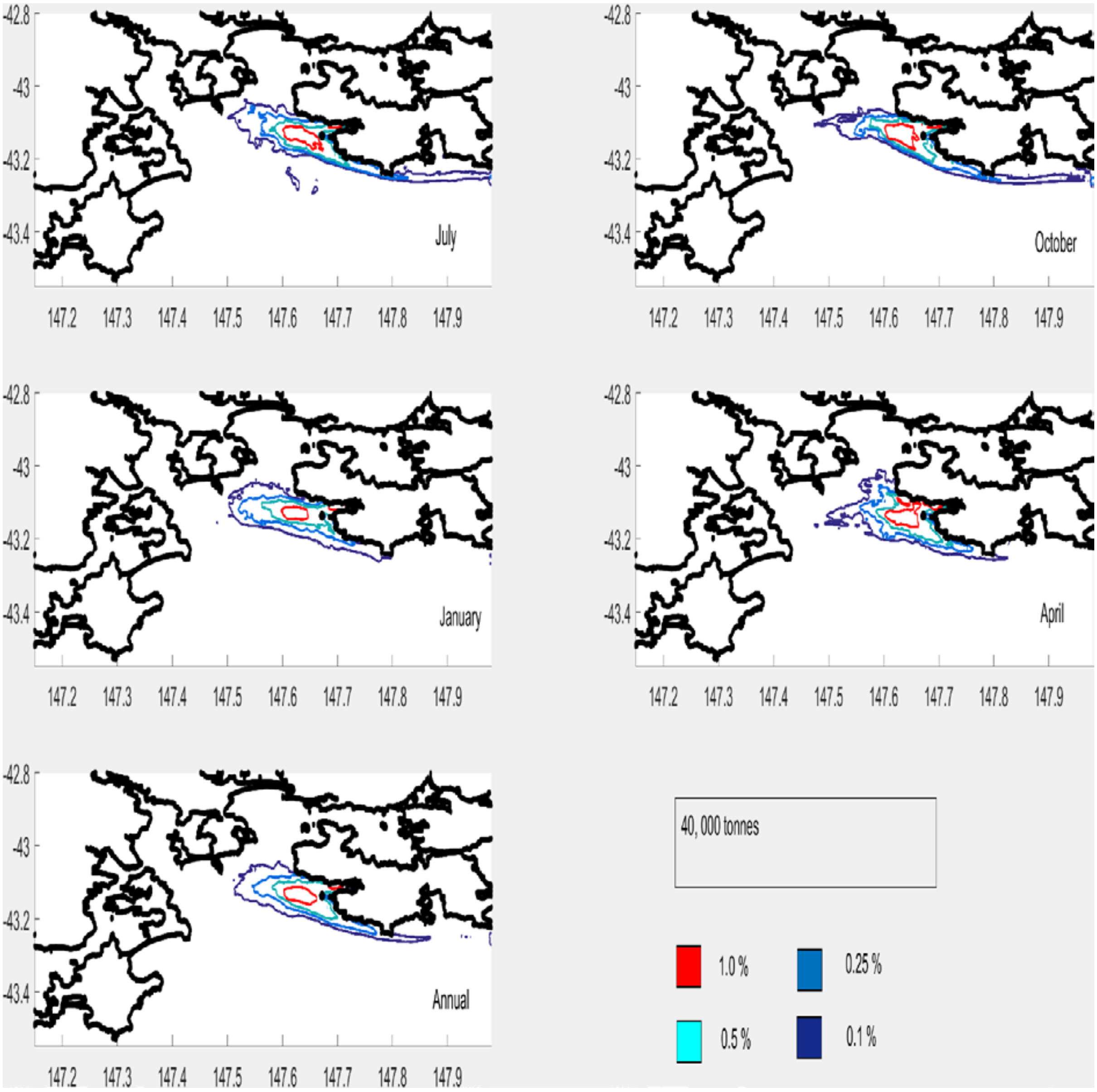
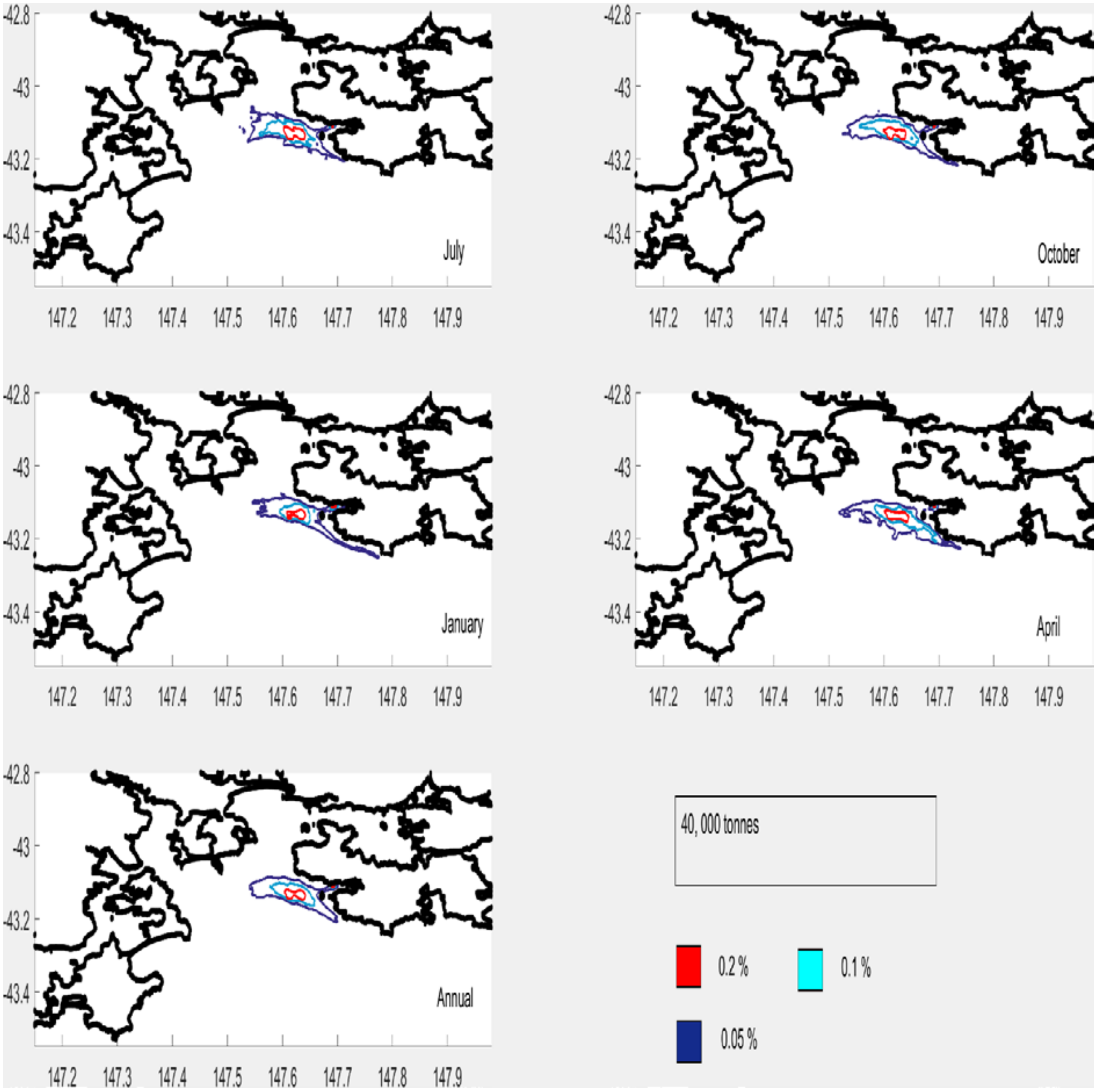


Figure 1: Model representation of the dispersion of dissolved nitrogen released from the proposed Tassal Pty Ltd farms in Storm Bay integrated over the 0-15m depth range (see parameterisation in Table 1). Results are shown as the proportion of the total dissolved nitrogen released (with contours shown for 0.1%, 0.25%, 0.5% and 1.0%) over the periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by Tassal Pty Ltd/DPIPWE.



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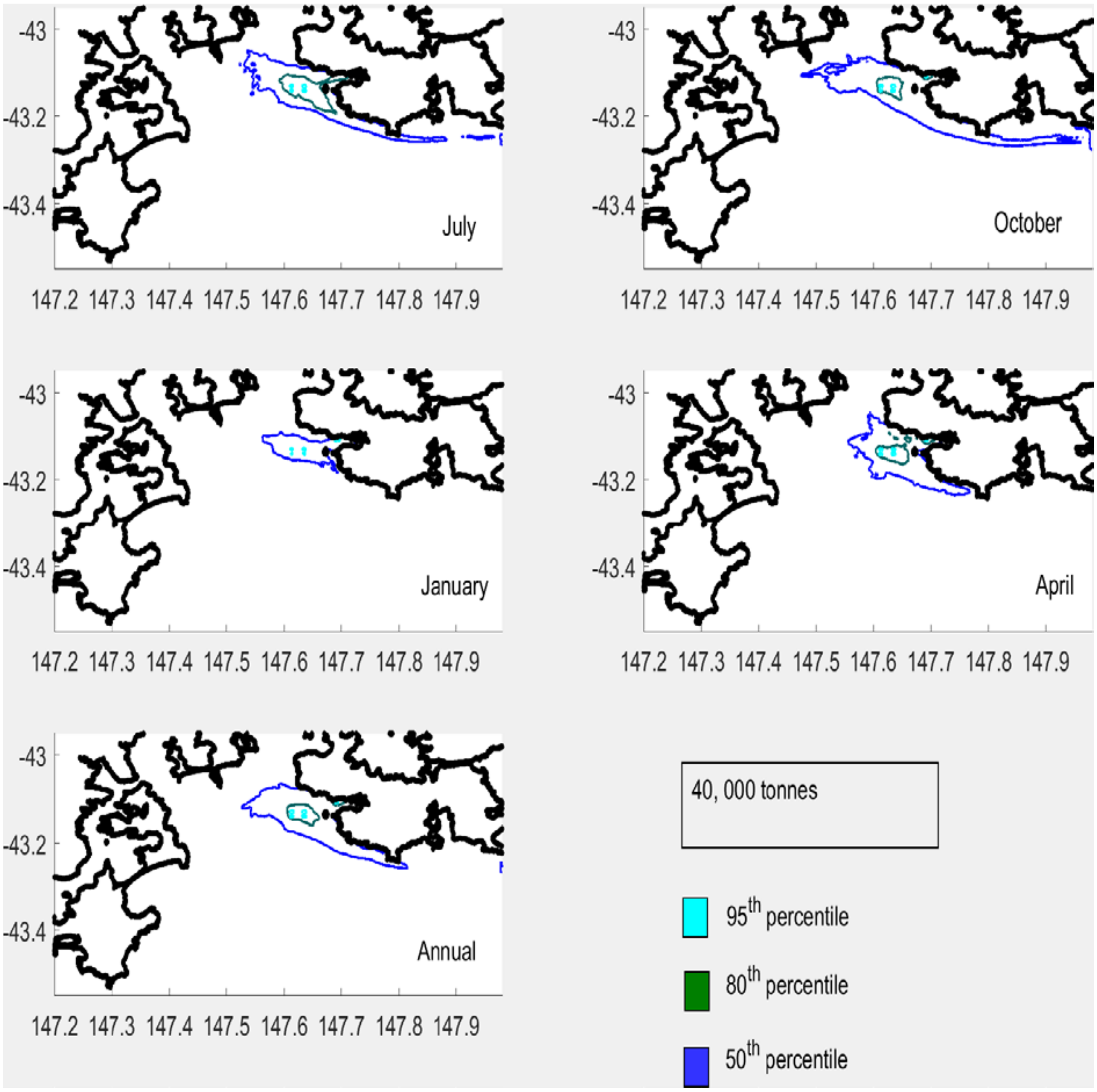

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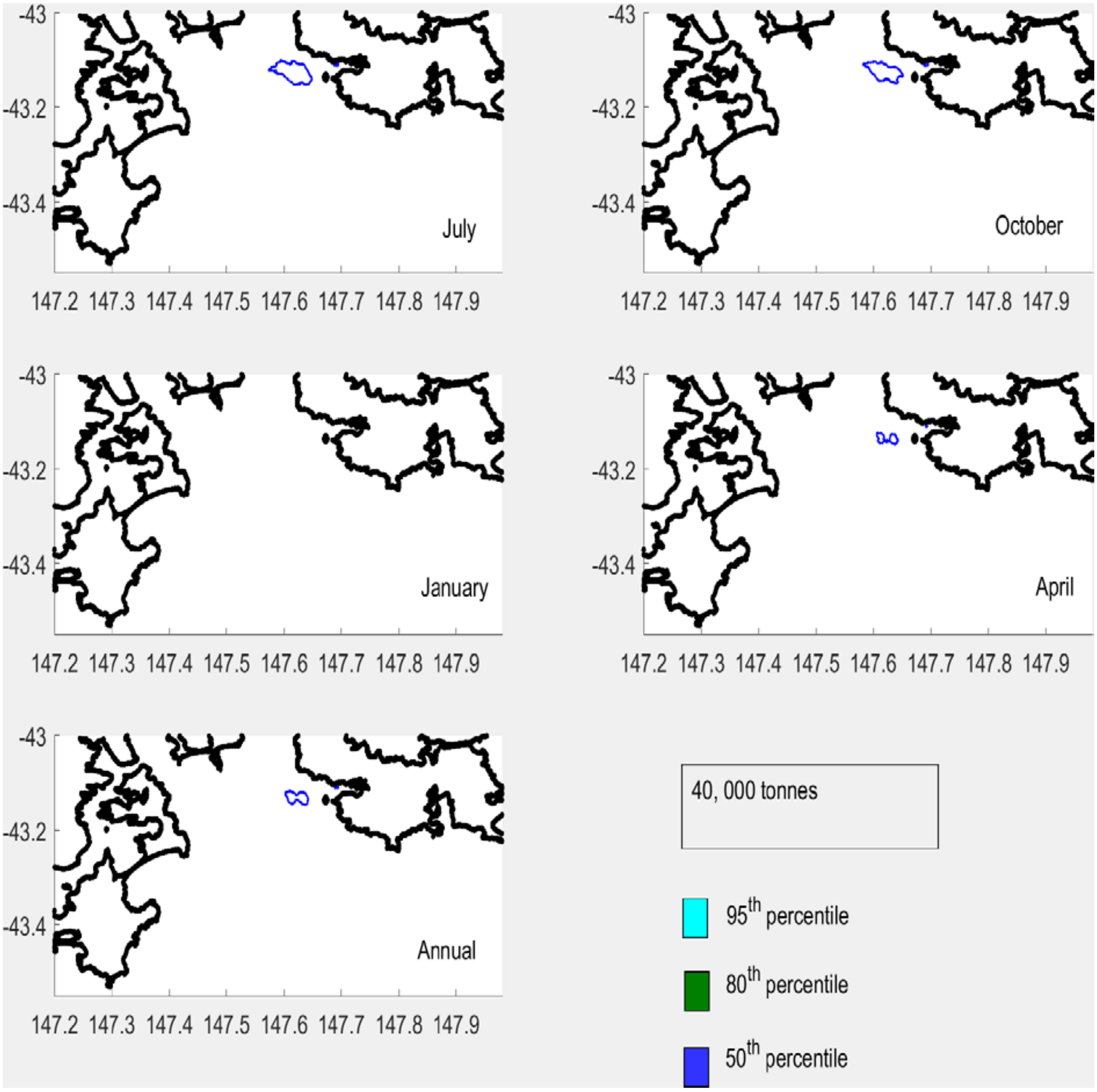

Figure 4: Model representation of the dispersion of dissolved nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 15-28m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) ammonium concentrations based on data (average) from Crawford (pers comm). The contours show the 95th, 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect and where water quality is most likely to be comparable to background. The periods for each figure are periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results, which produces the annual result. Farm input data supplied by Tassal Pty Ltd/DPIPWE.

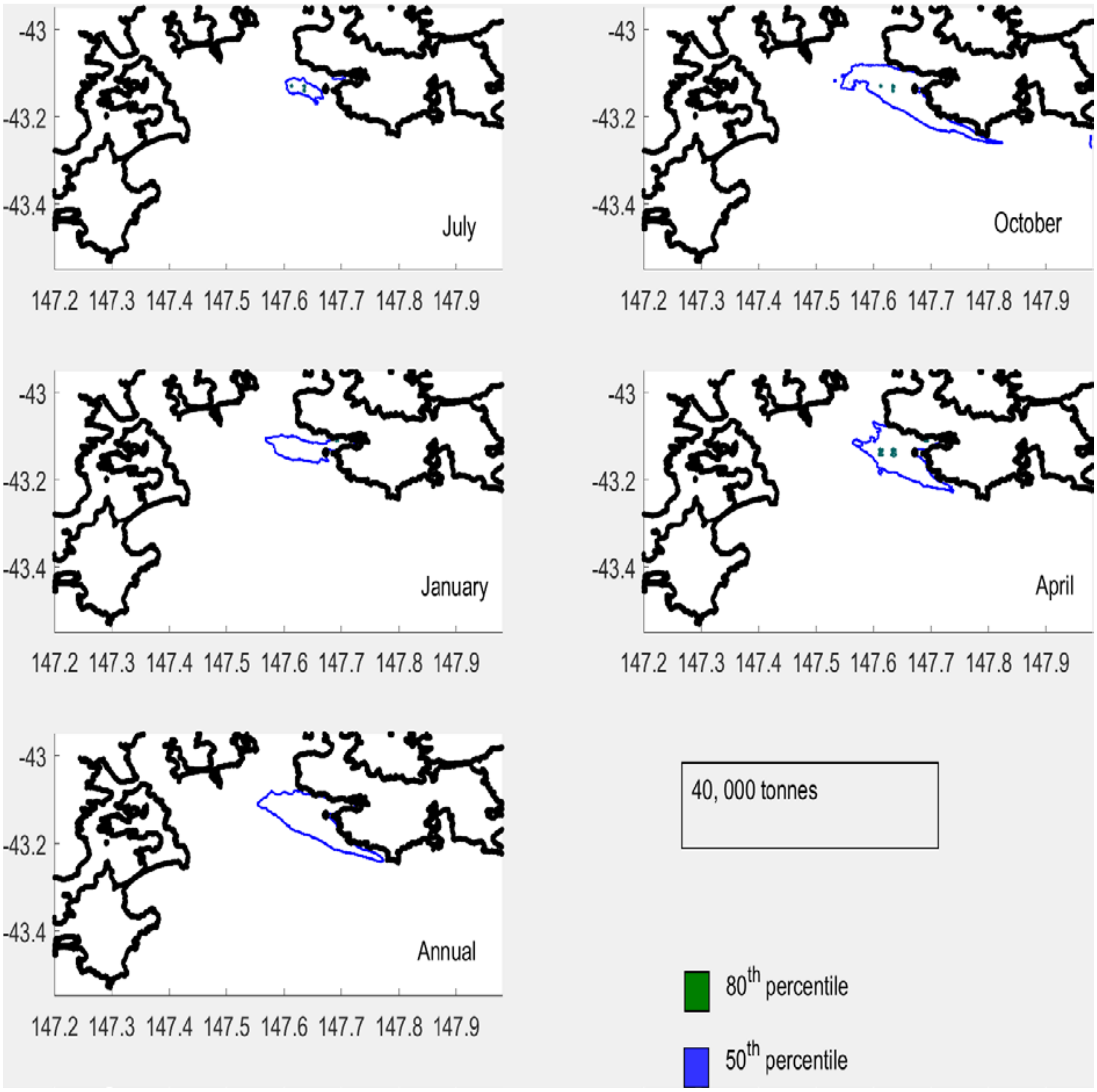

Figure 5: Model representation of the dispersion of nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 0-15m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) DIN (ammonium and nitrate) concentrations based on data (average) from Crawford (pers comm). The contours show the 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect, and where water quality is most likely to be comparable to background. The periods for each figure are periods1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by Tassal Pty Ltd/DPIPWE.

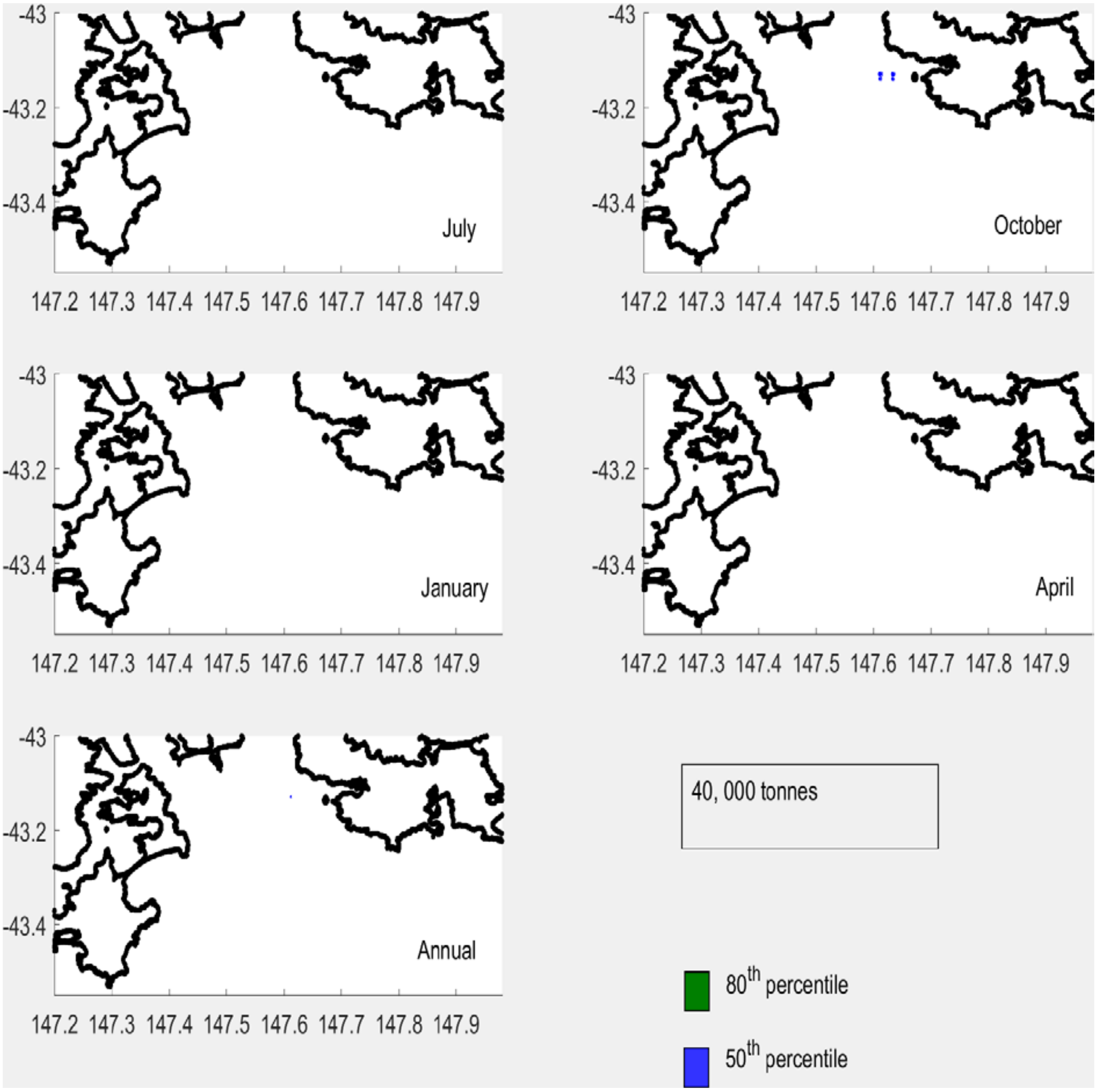

Figure 6: Model representation of the dispersion of nitrogen (ammonium) released from the proposed farms in Storm Bay integrated over the 15-28m depth range (see parameterisation in Table 1). The concentrations shown include a measure of background (median) DIN (ammonium and nitrate) concentrations based on data from Crawford (pers comm). The contours show the 80th and 50th percentiles. Note: based on the ANZECC (2000) guidelines the area above the 80th percentile contour has a higher likelihood of showing an environmental effect when farms are operational. The area below the 50th percentile contour represents the region where there is least likely to be any observable effect and where water quality is most likely to be comparable to background. The periods for each figure are periods: 1st – 14th July 2014, 1st – 14th October 2014, 1st – 14th January 2015, 1st – 14th April 2015 and an average of the previous 4 results which produces the annual result. Farm input data supplied by Tassal Pty Ltd/DPIPWE.