ORGANIC ENRICHMENT IN THE VICINITY OF THREE PROPOSED FINFISH AQUACULTURE SITES IN SHELBURNE COUNTY, NOVA SCOTIA

Context

On May 31, 2011, Fisheries and Oceans Canada's (DFO) Habitat Management Division, Maritimes Region, requested that DFO Science, Maritimes Region, provide advice regarding organic enrichment in the vicinity of three proposed finfish aquaculture sites at Middle Head, Jordan Bay and Blue Island in Shelburne County, Nova Scotia, as well as the likelihood of the proposed development project having negative impacts on fish habitat. The request for advice is in support of Habitat Management's review of an environmental assessment (EA) of a proposed aquaculture development project pursuant to the *Canadian Environmental Assessment Act*. Specifically, Habitat Management asked:

1) What is the area of sensitivity for organic enrichment predicted by DEPOMOD for each aquaculture site, based on a stocking level of 700,000 fish at the:
    a) maximum daily feed rate; and
    b) average daily feed rate.

2) What is the area of sensitivity for organic enrichment predicted by DEPOMOD for each aquaculture site, based on a stocking level of 1,000,000 fish at the:
    a) maximum daily feed rate; and
    b) average daily feed rate.

3) At what daily feed rate would the deposition rate of 5 g m^{-2} d^{-1} be exceeded for each site.

4) What is the area of sensitivity for organic enrichment for all three sites at the maximum feed rate when resuspension is turned on?

DFO's Science Special Response Process was used to respond to this request due to the short deadline for advice of August 31, 2011. This Science Response report was developed and reviewed through email correspondence. No review meeting was held.

Background

Habitat Management, Maritimes Region, is reviewing an EA for three marine finfish aquaculture sites to be located in Shelburne County, Nova Scotia (Figure 1, Appendix 2), to determine if they are likely to result in negative impacts to fish and fish habitat. One component identified in the Habitat Management risk assessment of the proposed aquaculture development project is the risk of organic enrichment impacts on fish habitat in the vicinity of the proposed development sites. As part of the Federal EA process, DFO may provide advice to Transport Canada regarding any impacts that fall under DFO's mandate. In addition, DFO may advise the Nova Scotia Department of Fisheries and Aquaculture on the proposed aquaculture development. Refer to Canadian Environmental Assessment Registry reference number 11-01-61095 for more information regarding the EA of the proposed development project.

Analysis

DEPOMOD (version 2.2) software was used to predict the impacts of solid wastes on the seafloor in the vicinity of the proposed aquaculture sites. DEPOMOD is a commercially available computer model (Cromey et al. 2002) that was developed in Scotland, and has also been used to predict the benthic impacts of salmon farming in British Columbia (Chamberlain and Stucchi 2007; Chamberlain et al. 2005). Studies on the use of DEPOMOD have also been conducted at some existing and proposed salmon farms in southwestern New Brunswick (SWNB) and Nova Scotia (Page et al. 2009; DFO 2009; Page et al. in preparation).

Using cage locations and sizes, feed rates, current velocity data, bathymetry in the vicinity of the site, feed wastage rates and feed and fecal particle sinking rates, DEPOMOD predicts the spatial distribution of organic carbon deposition on the seafloor (in g C m^{-2} d^{-1}) resulting from estimates of waste feed and feces produced by farmed fish in cages. These deposition rates can be related to the site classifications for fish farms in New Brunswick and Nova Scotia, based on sediment sulfide concentrations in annual monitoring (NBDENV 2006; NSDFA 2011), using Table 1 (based on information in Hargrave et al. 2008 and Hargrave 2010).

The following describes the outputs from the DEPOMOD runs that were completed in relation to the proposed aquaculture sites. Detailed information pertaining to the methodology and data inputs used in the DEPOMOD runs are located within Appendix 1.

Response

Current Velocity

Current rose diagrams for each proposed site are shown in Figure 2 (Appendix 2). Variation in current direction with depth was observed, especially at Middle Head and Blue Island. At Middle Head, the near surface current direction was mainly to the southeast, at mid-depth to the northwest and southeast, and near bottom to the north-northwest and east-southeast. At Jordan Bay, the current direction was mainly to the north-northwest and south-southeast at all three depths. At Blue Island, the near surface direction was mainly to the south-southeast, at mid-depth to the north-northwest, and near bottom to the north-northwest and south-southeast.

Current speed data are shown in Figure 3 and Table 6 (Appendix 2). Mean and maximum speeds were lowest at Jordan Bay; this site also had the lowest percentage of near bottom records greater than the DEPOMOD resuspension threshold of 9.5 cm s^{-1}. At all three sites, mean and maximum current speeds were highest near the surface.

Carbon Deposition Rates

Contour plots of the DEPOMOD predicted carbon deposition rates are shown in Figures 4-6 (Appendix 2). The areas of the contours are shown in Tables 7-8 (Appendix 2). Parameters for the linear relationship between the feed rate and highest predicted deposition rate within the DEPOMOD domain are shown in Table 9 and stocking rates that would maintain the carbon deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain are shown in Table 10 (Appendix 2).

Middle Head (Site 1357)

a) *Resuspension Off*

With resuspension off, DEPOMOD predicted large areas with elevated carbon deposition rates when using the proposed maximum feed rate with 1,000,000 fish stocked: 101,200 m^2 with carbon deposition rates >5 g C m^{-2} d^{-1} and 65,300 m^2 with anoxic conditions (>10 g C m^{-2} d^{-1}). With 700,000 fish stocked (and maximum feed rate), these areas were reduced to 74,900 m^2 for carbon deposition rates >5 g C m^{-2} d^{-1} and 47,600 m^2 with anoxic conditions. At the higher stocking level there were 6 more cages and the cage array covered a larger area; also, there was a slightly larger number of fish per cage and a slightly higher feed rate per cage.

Using the proposed average feed rate, the area with deposition rates >5 g C m^{-2} d^{-1} was reduced to 43,100 m^2 with 1,000,000 fish stocked and to 29,200 m^2 with 700,000 fish, while the area with anoxic conditions was reduced to 900 m^2 with 1,000,000 fish stocked and to 30 m^2 with 700,000 fish.

The highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate and 1,000,000 fish stocked was 38.5 g C m^{-2} d^{-1}, about three times higher than when using the proposed average feed rate (12.2 g C m^{-2} d^{-1}). With 700,000 fish stocked, the highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate was 34.5 g C m^{-2} d^{-1}, also about three times higher than when using the proposed average feed rate (8.2 g C m^{-2} d^{-1}). The proposed maximum feed rates (1,050 kg d^{-1} per cage with 700,000 fish and 1,184 kg d^{-1} per cage with 1,000,000 fish) were about three times the proposed average feed rates (339 kg d^{-1} per cage with 700,000 fish and 374 kg d^{-1} per cage with 1,000,000 fish).

The estimated feed rate that would maintain the predicted deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain (derived from the linear relationship between the feed rate and the highest predicted deposition rate within the DEPOMOD domain) was 151 kg d^{-1} per cage. During the period of maximum feeding (when fish biomass is highest), this feed rate would support a stocking rate of 4,200 – 4,300 fish per cage (compared to proposed stocking of 29,167 – 33,333 fish per cage).

b) *Resuspension On*

With resuspension on, the area with deposition rates >5 g C m^{-2} d^{-1} when using the proposed maximum feed rate with 1,000,000 fish stocked decreased by 27% to 74,200 m^2, while with 700,000 fish stocked, the area decreased by 27% to 54,600 m^2. The areas with anoxic conditions decreased by 21% to 51,800 m^2 with 1,000,000 fish stocked, and by 24% to 36,100 m^2 stocked with 700,000 fish.

Using the proposed average feed rate, the area with deposition rates >5 g C m^{-2} d^{-1} with 1,000,000 fish stocked decreased by 85% to 6,300 m^2, while with 700,000 fish stocked, the area decreased by 96% to 1,300 m^2. The area with anoxic conditions was 0 m^2 at both stocking levels.

The highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate and 1,000,000 fish stocked was 345.7 g C m^{-2} d^{-1}, more than five times higher than when using the proposed average feed rate (7.2 g C m^{-2} d^{-1}). With 700,000 fish stocked, the highest predicted deposition rate within the DEPOMOD domain using the proposed

maximum feed rate was 30.7 g C m^{-2} d^{-1}, also more than four times higher than when using the proposed average feed rate (7.2 g C m^{-2} d^{-1}).

The estimated feed rate that would maintain the predicted deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain (derived from the linear relationship between the feed rate and the highest predicted deposition rate within the DEPOMOD domain) was 274 kg d^{-1} per cage. During the period of maximum feeding (when fish biomass is highest), this feed rate would support a stocking rate of 7,600 – 7,700 fish per cage.

Jordan Bay (Site 1358)

a) *Resuspension Off*

With resuspension off, DEPOMOD predicted large areas with elevated carbon deposition rates when using the proposed maximum feed rate with 1,000,000 fish stocked: 78,100 m^2 with carbon deposition rates >5 g C m^{-2} d^{-1} and 56,100 m^2 with anoxic conditions (>10 g C m^{-2} d^{-1}). With 700,000 fish stocked (and maximum feed rate), these areas were reduced to 61,600 m^2 for carbon deposition rates >5 g C m^{-2} d^{-1} and 42,900 m^2 with anoxic conditions. At the higher stocking level there were 6 more cages and the cage array covered a larger area; also, there was a slightly larger number of fish per cage and a slightly higher feed rate per cage.

Using the proposed average feed rate, the area with deposition rates >5 g C m^{-2} d^{-1} was reduced to 36,700 m^2 with 1,000,000 fish stocked and to 26,000 m^2 with 700,000 fish, while the area with anoxic conditions was reduced to 13,000 m^2 with 1,000,000 fish stocked and to 8,000 m^2 with 700,000 fish.

The highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate and 1,000,000 fish stocked was 68.5 g C m^{-2} d^{-1}, about three times higher than when using the proposed average feed rate (21.6 g C m^{-2} d^{-1}). With 700,000 fish stocked, the highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate was 57.6 g C m^{-2} d^{-1}, also about three times higher than when using the proposed average feed rate (18.6 g C m^{-2} d^{-1}).

The estimated feed rate that would maintain the predicted deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain (derived from the linear relationship between the feed rate and the highest predicted deposition rate within the DEPOMOD domain) was 93 kg d^{-1} per cage. During the period of maximum feeding (when fish biomass is highest), this feed rate would support a stocking rate of 2,600 fish per cage.

b) *Resuspension On*

With resuspension on, the area with deposition rates >5 g C m^{-2} d^{-1} when using the proposed maximum feed rate with 1,000,000 fish stocked decreased by only 6% to 73,500 m^2, while with 700,000 fish stocked, the area decreased by 7% to 56,000 m^2. The areas with anoxic conditions decreased by 5% to 53,100 m^2 with 1,000,000 fish stocked, and by 8% to 38,300 m^2 stocked with 700,000 fish stocked.

Using the proposed average feed rate, the area with deposition rates >5 g C m^{-2} d^{-1} with 1,000,000 fish stocked decreased by 19% to 29,800 m^2, while with 700,000 fish, the area decreased by 20% to 20,900 m^2. The areas with anoxic conditions decreased by 23% to 10,000 m^2 with 1,000,000 fish stocked, and by 30% to 5,600 m^2 with 700,000 fish.

The highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate and 1,000,000 fish stocked was 67.4 g C m^{-2} d^{-1}, more than three times higher than when using the proposed average feed rate (20.6 g C m^{-2} d^{-1}). With 700,000 fish stocked, the highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate was 56.5 g C m^{-2} d^{-1}, also about three times higher than when using the proposed average feed rate (17.5 g C m^{-2} d^{-1}).

The estimated feed rate that would maintain the predicted deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain (derived from the linear relationship between the feed rate and the highest predicted deposition rate within the DEPOMOD domain) was 113 kg d^{-1} per cage. During the period of maximum feeding (when fish biomass is highest), this feed rate would support a stocking rate of 3,100 – 3,200 fish per cage.

Blue Island (Site 1359)

a) *Resuspension Off*

With resuspension off, DEPOMOD predicted large areas with elevated carbon deposition rates when using the proposed maximum feed rate with 1,000,000 fish stocked: 100,900 m^2 with carbon deposition rates >5 g C m^{-2} d^{-1} and 64,800 m^2 with anoxic conditions (>10 g C m^{-} d^{-1}). With 700,000 fish stocked (and maximum feed rate), these areas were reduced to 77,200 m^2 for carbon deposition rates >5 g C m^{-2} d^{-1} and 46,900 m^2 with anoxic conditions. At the higher stocking level there were 6 more cages and the cage array covered a larger area; also, there was a slightly larger number of fish per cage and a slightly higher feed rate per cage.

When using the proposed average feed rate, the area with deposition rates >5 g C m^{-2} d^{-1} was reduced to 40,000 m^2 with 1,000,000 fish stocked and to 25,700 m^2 with 700,000 fish. The area with anoxic conditions was reduced to 3,800 m^2 with 1,000,000 fish stocked and to 200 m^2 with 700,000 fish.

The highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate and 1,000 000 fish stocked was 44.3 g C m^{-2} d^{-1}, about three times higher than when using the proposed average feed rate (14.0 g C m^{-2} d^{-1}). With 700,000 fish stocked, the highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate was 37.4 g C m^{-2} d^{-1}, also about three times higher than when using the proposed average feed rate (12.1 g C m^{-2} d^{-1}).

The estimated feed rate that would maintain the predicted deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain (derived from the linear relationship between the feed rate and the highest predicted deposition rate within the DEPOMOD domain) was 141 kg d^{-1} per cage. During the period of maximum feeding (when fish biomass is highest), this feed rate would support a stocking rate of 3,900 - 4,000 fish per cage.

b) *Resuspension On*

With resuspension on, the area with deposition rates >5 g C m^{-2} d^{-1} when using the proposed maximum feed rate with 1,000,000 fish stocked decreased by 48% to 52,600 m^2, while with 700,000 fish stocked, the area decreased by 54% to 35,500 m^2. The areas with anoxic conditions decreased by 58% to 27,300 m^2 with 1,000,000 fish stocked, and by 66% to 16,000 m^2 stocked with 700,000 fish.

Using the proposed average feed rate, the area with deposition rates >5 g C m^{-2} d^{-1} (including areas with anoxic conditions) decreased to 0 m^2 at both stocking rates.

The highest predicted deposition rate within the DEPOMOD domain using the proposed maximum feed rate and 1,000,000 fish stocked was 33.8 g C m^{-2} d^{-1}, much higher than when using the proposed average feed rate (4.4 g C m^{-2} d^{-1}). With 700,000 fish stocked, the highest predicted deposition rate within the DEPOMOD domain using the maximum feed rate was 27.0 g C m^{-2} d^{-1}, also much higher than when using the proposed average feed rate (3.6 g C m^{-2} d^{-1}).

The estimated feed rate that would maintain the predicted deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domain (derived from the linear relationship between the feed rate and the highest predicted deposition rate within the DEPOMOD domain) was 388 kg d^{-1} per cage. During the period of maximum feeding (when fish biomass is highest), this feed rate would support a stocking rate of 10,800 – 10,900 fish per cage.

Comparisons Among Sites

With 1,000,000 fish stocked, the proposed maximum feed rate, and resuspension off, the predicted areas with elevated carbon deposition rates were quite similar in size among the three sites: the area with deposition rates >5 g C m^{-2} d^{-1} ranged from 78,100 – 101,200 m^2, and the area with anoxic sediments ranged from 56,100 – 65,300 m^2. Using the proposed average feed rate, the areas with deposition rates >5 g C m^{-2} d^{-1} were also similar in size among the sites, ranging from 36,700 – 43,100 m^2, but the Jordan Bay site had a larger area with anoxic conditions (13,000 m^2), compared to 900 m^2 at Middle Head and 3,800 m^2 at Blue Island. With 700,000 fish stocked, comparisons among sites produced similar results to that observed at 1,000,000 fish, but with lower values in all cases.

Running DEPOMOD with resuspension on resulted in decreases in the sizes of the areas with deposition rates >5 g C m^{-2} d^{-1} and anoxic conditions at all three sites. The effects of resuspension were greatest at Blue Island and least at Jordan Bay. At Jordan Bay, inclusion of resuspension decreased the area with deposition rates >5 g C m^{-2} d^{-1} by 6-7% using proposed maximum feed rates and by 19-20% using proposed average feed rates; while at Middle Head, the reduction was 27% using proposed maximum feed rates and 85-96% using proposed average feed rates; and at Blue Island, the reduction was 48-54% using proposed maximum feed rates and 100% using proposed average feed rates. These results reflect differences in the current speeds, which were lowest at Jordan Bay and highest at Blue Island (Table 6 and Figures 2-3, Appendix 2).

The highest predicted carbon deposition rates within the DEPOMOD domains using maximum proposed feeding rates varied among sites, with highest values at Jordan Bay (58 and 68 g C m^{-2} d^{-1} with resuspension off at stocking levels of 700,000 and 1,000,000, respectively; 56 and 67 g C m^{-2} d^{-1} with resuspension on); rates were much lower at Middle Head (35 and 38 g C m^{-2} d^{-1} with resuspension off; 30 and 35 g C m^{-2} d^{-1} with resuspension on) and Blue Island (34 and 41 g C m^{-2} d^{-1} with resuspension off; 24 and 31 g C m^{-2} d^{-1} with resuspension on). With resuspension on, the reduction in the highest predicted deposition rate within the DEPOMOD domain was greatest at Blue Island (24-28%), least at Jordan Bay (2%), and intermediate at Middle Head (10-12%).

Because resuspension results in the transport of some particles away from the vicinity of the farm, the predicted areas with elevated deposition rates were smaller when DEPOMOD was run with resuspension on. The resuspension module was validated at some Scottish salmon farms

(Cromey et al. 2002) where average near-bottom current speeds were low (3.6-6.2 cm s^{-1}). However, at a British Columbia farm, where the average near-bottom current speed was higher (7.9 cm s^{-1}), the resuspension module was found to overestimate the transport of particles away from farms (Chamberlain and Stucchi 2007); this also appears to be the case at some farms in SWNB where DEPOMOD has been tested, except where current speeds are very low (Page et al. in preparation). This suggests that DEPOMOD predictions with resuspension on should be used with caution, as it is not known if the threshold resuspension current speed of 9.5 cm s^{-1} (near bottom), as well as the default consolidation time of 4 days, are appropriate for the conditions at the aquaculture sites examined in this study. The average near-bottom current speed at the Jordan Bay site (6.3 cm s^{-1}) was at the upper end of the range of average near-bottom current speeds in the Cromey et al. (2002) study. However, at the other two sites, average near-bottom current speeds were higher (7.6-8.0 cm s^{-1}), similar to those in the Chamberlain and Stucchi (2007) study.

Summary

The following responses address the specific questions asked by Habitat Mangement. These responses assume that the area of sensitivity is the area where DEPOMOD predicts that the carbon deposition rate will exceed 5 g C m^{-2} d^{-1}.

1) What is the area of sensitivity for organic enrichment predicted by DEPOMOD (with resuspension off) for each aquaculture site, based on a stocking level of 700,000 fish at the:

    a) maximum daily feed rate

    Middle Head: 74,900 m^2
    Jordan Bay: 60,200 m^2
    Blue Island: 77,200 m^2

    b) average daily feed rate

    Middle Head: 29,200 m^2
    Jordan Bay: 26,000 m^2
    Blue Island: 25,700 m^2

2) What is the area of sensitivity for organic enrichment predicted by DEPOMOD (with resuspension off) for each aquaculture site, based on a stocking level of 1,000,000 fish at the:

    a) maximum daily feed rate

    Middle Head: 101,200 m^2
    Jordan Bay: 78,100 m^2
    Blue Island: 100,900 m^2

    b) average daily feed rate.

    Middle Head: 43,100 m^2
    Jordan Bay: 36,700 m^2
    Blue Island: 40,000 m^2

3) At what daily feed rate would the deposition rate of 5 g m^{-2} d^{-1} be exceeded for each site (with resuspension off)?

   The predicted carbon deposition rate (in any grid cell within the DEPOMOD domain) will exceed 5 g C m^{-2} d^{-1} at the following feed rates:

   Middle Head: 151 kg d^{-1} per cage
   Jordan Bay: 93 kg d^{-1} per cage
   Blue Island: 141 kg d^{-1} per cage

4) What is the area of sensitivity for organic enrichment for all three sites at the maximum feed rate when resuspension is turned on?

   a) stocking level of 700,000 fish

   Middle Head: 54,600 m^2
   Jordan Bay: 56,000 m^2
   Blue Island: 35,500 m^2

   b) stocking level of 1,000,000 fish

   Middle Head: 74,200 m^2
   Jordan Bay: 73,500 m^2
   Blue Island: 52,600 m^2

Conclusions

With the DEPOMOD resuspension module turned off, predicted areas of impact were quite similar in size among the three sites at both stocking rates: large areas with predicted deposition rates >5 g C m^{-2} d^{-1} and large areas with anoxic conditions (<10 g C m^{-2} d^{-1}) were predicted at all three sites, using proposed maximum and average feed rates.

With resuspension on, the areas with deposition rates >5 g C m^{-2} d^{-1} were smaller at all three sites, but there were differences among the sites. Using maximum feed rates, the predicted areas with deposition rates >5 g C m^{-2} d^{-1} were still substantial at all sites, but with the largest areas at Jordan Bay and the smallest at Blue Island. Using average feed rates, the areas with deposition rates >5 g C m^{-2} d^{-1} were still substantial at Jordan Bay, but were small at Middle Head and non-existent at Blue Island.

With resuspension off, the highest predicted deposition rates within the DEPOMOD domains (using proposed maximum and average feed rates) were highest at Jordan Bay; rates at the other two sites were similar to each other, both much lower than at Jordan Bay. With resuspension on, the highest predicted deposition rates within the DEPOMOD domains were lower at all three sites, with the reduction greatest at Blue Island and smallest at Jordan Bay.

Considerable reduction in feed and stocking rates would be required to keep deposition rates ≤5 g C m^{-2} d^{-1} at all grid cells within the DEPOMOD domain at the time of maximum feeding (highest fish biomass) at all three sites.

Contributors

Name	*Affiliation*
F. Page	DFO Maritimes, Science
B. Chang	DFO Maritimes, Science
R. Losier	DFO Maritimes, Science

Approved by:

Alain Vézina
Regional Director of Science, DFO Maritimes Region
Dartmouth, Nova Scotia
Ph. 902-426-3490
Date: 15 December 2011

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Appendices

Appendix 1

Methodology

Cage locations and sizes, proposed feed rates, and current velocity data were provided by the proponent (SIMC and SMEI 2010 and 2011; plus additional information provided by Sweeney International Management Corp. on behalf of the proponent, Kelly Cove Salmon Ltd.). Current velocity data were collected by Sweeney International Management Corp. using a 600 kHz RDI Sentinel Acoustic Doppler Current Profiler (ADCP), mounted on the seafloor near the centre of each proposed lease. The locations, times, and durations of the current meter deployments are shown in Table 2 (the exact location of the current meter deployment within the proposed Jordan Bay lease was not available). The ADCP measured current speed and direction at 15-min time intervals and 1-m depth intervals throughout the water column.

DEPOMOD was used to predict carbon deposition rates, using the scenario of continuous release of food; this is the scenario typically used for proposed or operational farms. The model predicts deposition rates within a domain defined by the user; grid cell size is also defined by the user. The domain size for this study was 1000 × 1000 m and the grid cell size was 10 × 10 m. DEPOMOD allows the user to define separate major and minor grids; however, in this study, only one grid was used for the entire domain.

DEPOMOD includes a resuspension module, which has the option to have resuspension turned on or off. The model was first run with resuspension turned off, and then with resuspension on. The threshold (critical shear stress) for resuspension in DEPOMOD is set at a near-bottom current speed of approximately 9.5 cm s^{-1}, and cannot be changed. Resuspension only affects unconsolidated particles; the model was run using the default particle consolidation time of 4 days.

Contour plots of the predicted carbon deposition rates per grid cell were produced using MapInfo Vertical Mapper (version 3.0) software. Rectangular interpolation was used, with the default values calculated by the program for cell size (0.0001 cell units) and search radius (0.0039 map units). The contour intervals were defined by the carbon deposition rates corresponding to the sediment classifications in Table 1. Deposition rates <0.3 g C m^{-2} d^{-1} were considered to be background levels; this was the carbon deposition rate at control sites in SWNB reported by Hargrave (1994).

In cases where the predicted carbon deposition rate exceeded 5 g C m^{-2} d^{-1} in any of the grid cells within the DEPOMOD domain, there was interest in determining the highest feed rate that would result in the carbon deposition rates in all grid cells being maintained below this value. In DEPOMOD, the relationship between the feed rate and the highest predicted carbon deposition rate (in any grid cell) is linear:

$$D_{Max} = a + bF$$

where D_{Max} is the highest predicted carbon deposition rate (g C m^{-2} d^{-1}) of all grid cells in the DEPOMOD domain, F is the feed rate (kg d^{-1} per cage), a is the y-axis intercept, and b is the slope of the line. The values for a and b for any site can be determined by plotting the feed rate vs. the maximum predicted carbon deposition rate for two or more feed rates at each site. F_{D5}, the feed rate that would result in D_{Max} = 5 g C m^{-2} d^{-1} can then be estimated from the

relationship. S_{D5}, the highest number of fish per cage which will maintain $D_{Max} \leq 5$ g C m^{-2} d^{-1}, can then be calculated as

$$S_{D5} = \frac{F_{D5}}{F_{Max}} S_{Proposed}$$

where F_{Max} is the proposed maximum feed rate (in kg d^{-1} per cage), and $S_{Proposed}$ is the proposed number of fish per cage.

Input data

Production information for the proposed farms at both proposed stocking rates is given in Table 3 (Appendix 2). It is proposed to initially stock 700,000 smolts in 24 cages at each farm (in 2012 at Jordan Bay and Blue Island; in 2013 at Middle Head), and then to increase to 1,000,000 smolts in 30 cages at each farm for the next stocking (in 2015 at Jordan Bay and Blue Island; in 2016 at Middle Head). DEPOMOD was run at both stocking rates for each farm, assuming no mortalities.

DEPOMOD was run using the proposed maximum and average feed rates per cage at each stocking level. The maximum feed rates were about three times the average feed rates. The stocking and feed rates per cage were slightly higher when a total of 1,000,000 smolt were stocked.

For current velocity input, hourly records (the default time step) were extracted for three depth layers (the number of layers recommended by Cromey et al. 2002) from the raw current meter datafiles, after the datafiles were checked for errors. The three depth layers were: near surface, mid-depth, and near bottom (see Table 4, Appendix 2).

Bathymetry data were obtained from the Canadian Hydrographic Service (CHS). A grid of depth values corresponding to the centre of each DEPOMOD grid cell was created by interpolation from the CHS data. Average depths, relative to chart datum (lowest normal tide), within each proposed lease area were:

Middle Head (site 1357):	18.8 m
Jordan Bay (site 1358):	12.7 m
Blue Island (site 1359):	18.4 m

The mean tidal height was set at 1.4 m above chart datum in the DEPOMOD main input dialog screen.

Other DEPOMOD input values used are shown in Table 5 (Appendix 2). In most cases, these were either DEPOMOD default values, or from Cromey et al. (2002) or Chamberlain and Stucchi (2007).

Appendix 2

Table 1. Site classifications for fish farms in New Brunswick (NBDENV 2006) and Nova Scotia (NSDFA 2011) based on sediment sulfide concentrations, with equivalent carbon deposition rates (based on Hargrave et al. 2008 and Hargrave 2010).

Site classification: New Brunswick	Site classification: Nova Scotia	Sediment sulfide concentration (µM)	Carbon deposition rate (DEPOMOD) (g C m^{-2} d^{-1})
Oxic A	Oxic A	<750	<1.0
Oxic B	Oxic B	750–1,500	1.0–2.0
Hypoxic A	Hypoxic A	1,500–3,000	2.0–5.0
Hypoxic B	Hypoxic B	3,000–4,500	5.0–7.5
Hypoxic C		4,500–6,000	7.5–10.0
Anoxic	Anoxic	>6,000	>10.0

Table 2. Dates and durations of current meter deployments at proposed salmon farms in the Shelburne area. The exact location of the Jordan Bay deployment was not available (n/a), but it was within the proposed lease boundary (see Figure 1).

Location	Site	Latitude	Longitude	Start date	End date	Duration (days)
Middle Head	1357	43.64297°N	65.26759°W	04 May 2010	31 May 2010	27
Jordan Bay	1358	n/a	n/a	27 Apr 2011	20 May 2011	23
Blue Island	1359	43.68057°N	65.20458°W	29 Oct 2010	26 Nov 2010	28

Table 3. Production information for three proposed salmon farms in the Shelburne area, at stocking levels of 700 000 and 1 000 000 fish per site. The values were the same for all three farms, except the cage net depth, which was 8 m at the Jordan Bay farm and 10 m at the other two farms.

Parameter	700 000 smolts	1 000 000 smolts
Lease area	40.0 ha	40.0 ha
Number of cages	24	30
Cage circumference	100 m	100 m
Cage diameter	32 m	32 m
Cage net depth (below water surface)	8-10 m	8-10 m
Number of fish per cage	29,167	33,333
Average feed rate per cage	339 kg d^{-1}	374 kg d^{-1}
Maximum feed rate per cage	1,050 kg d^{-1}	1,184 kg d^{-1}

Table 4. Depth layers of current velocity data used in DEPOMOD runs at three farms in the Shelburne area. The average water depth is the average distance from the water surface to the seafloor at the current meter deployment location, based on the Canadian Hydrographic Service bathymetry and tide data.

Farm	Average water depth at current meter (m)	Depth layer	Number of hourly records	Location of depth layer
Middle Head (Site 1357)	20.0	Near surface	650	2.5 m below surface
		Mid-depth	650	8.6 m above bottom
		Near bottom	650	3.6 m above bottom
Jordan Bay (site 1358)	14.2	Near surface	543	2.5 m below surface
		Mid-depth	543	7.7 m above bottom
		Near bottom	543	4.7 m above bottom
Blue Island (site 1359)	20.0	Near surface	672	2.5 m below surface
		Mid-depth	672	10.6 m above bottom
		Near bottom	672	3.6 m above bottom

Table 5. DEPOMOD input parameter values.

Parameter	Value
Grid generation module	
Grid cell dimensions (major and minor grids)	10 × 10 m
Number of major grid cells	99 × 99
Number of minor grid cells	98 × 98
Particle tracking module	
Material type	Carbon
Food release type	Continuous release of food
Particle Information (see Chamberlain and Stucchi 2007; Cromey et al. 2002)	
Food water content	10%
Food digestibility	90%
Food wasted as % of food fed	3%
Carbon as % of feed pellets (dry weight)	57%
C as % of feces (dry weight)	33%
Settling velocity of feed pellets (mean ± SD)	10.8 ± 2.7 cm s^{-1}
Settling velocity of feces (mean ± SD)	3.2 ± 1.1 cm s^{-1}
Current velocity data (see Cromey et al. 2002)	
Current velocity layers	3: near surface, mid-depth, near bottom
Current velocity time step (default value)	3,600 s (1 h)
Turbulence model (default values)	
Random walk model	Yes
Dispersion coefficient (x)	0.100 m^{-2} s^{-1}
Dispersion coefficient (y)	0.100 m^{-2} s^{-1}
Dispersion coefficient (z)	0.001 m^{-2} s^{-1}
Particle trajectory model (default values)	
Number of particles released (for each particle type, per cage, at every time step)	10
Trajectory evaluation accuracy	High (60 s)
Resuspension module	
Number of loops to run model for	2
Consolidation time of particles (default value)	4 days
Critical erosion threshold (non-adjustable)	9.5 cm s^{-1}

Table 6. Summary of current speed data from current meter deployments at three proposed salmon farms in the Shelburne area. The values shown are based on hourly current speed records during current meter deployments of 23-28 days (see Table 2). A near bottom current speed ≈9.5 cm s^{-1} is the critical shear stress threshold for resuspension in DEPOMOD.

	Current speed (cm s^{-1})			% of near bottom records
Depth layer	Minimum	Mean	Maximum	>9.5 cm s^{-1}
Middle Head (site 1357)				
Near surface	1.3	9.9	31.5	
Mid-depth	1.5	8.2	21.2	
Near bottom	1.7	7.6	21.1	23.8
Jordan Bay (site 1358)				
Near surface	1.5	7.7	22.0	
Mid-depth	0.8	6.8	21.6	
Near bottom	0.4	6.3	14.8	12.3
Blue Island (site 1359)				
Near surface	1.3	10.1	36.7	
Mid-depth	0.8	7.6	27.0	
Near bottom	0.7	8.0	25.7	31.3

Table 7a. DEPOMOD predictions of contour areas for ranges of carbon deposition rates at three proposed salmon farms near Shelburne, NS at a stocking level of 700,000 smolts, using the proposed maximum feed rate (1,050 kg d^{-1} per cage). Oxic A areas exclude areas with background deposition rates (<0.3 g C m^{-2} d^{-1}).

Site classification	Carbon deposition rate (g C m^{-2} d^{-1})	Contour area (m^2) (maximum feed rate)		Change due to resuspension	
		Resuspension off	Resuspension on	Area (m^2)	% change
Middle Head (site 1357)					
Oxic A	0.3-1.0	21,300	9,800	-11,500	-54
Oxic B	1.0-2.0	10,500	9,900	-600	-6
Hypoxic A	2.0-5.0	19,100	21,700	2,600	14
Hypoxic B	5.0-7.5	17,000	10,000	-7,000	-41
Hypoxic C	7.5-10.0	10,300	8,500	-1,800	-17
Anoxic	>10.0	47,600	36,100	-11,500	-24
>5 g C m^{-2} d^{-1}	*>5.0*	*74,900*	*54,600*	*-20,300*	*-27*
Jordan Bay (site 1358)					
Oxic A	0.3-1.0	13,400	7,600	-5,800	-43
Oxic B	1.0-2.0	7,700	10,700	3,000	39
Hypoxic A	2.0-5.0	23,400	19,000	-4,400	-19
Hypoxic B	5.0-7.5	10,300	9,400	-900	-9
Hypoxic C	7.5-10.0	8,400	8,300	-100	-1
Anoxic	>10.0	41,500	38,300	-3,200	-8
>5 g C m^{-2} d^{-1}	*>5.0*	60,200	56,000	-4,200	-7
Blue Island (site 1359)					
Oxic A	0.3-1.0	20,700	18,000	-2,700	-13
Oxic B	1.0-2.0	10,900	15,100	4,200	39
Hypoxic A	2.0-5.0	15,800	19,400	3,600	23
Hypoxic B	5.0-7.5	19,200	12,200	-7,000	-36
Hypoxic C	7.5-10.0	11,100	7,300	-3,800	-34
Anoxic	>10.0	46,900	16,000	-30,900	-66
>5 g C m^{-2} d^{-1}	>5.0	77,200	35,500	-41,700	-54

Table 7b. DEPOMOD predictions of contour areas for ranges of carbon deposition rates at three proposed salmon farms near Shelburne, NS at a stocking level of 700,000 smolts, using the proposed average feed rate (339 kg d^{-1} per cage). Oxic A areas exclude areas with background deposition rates (<0.3 g C m^{-2} d^{-1}).

Site classification	Carbon deposition rate (g C m^{-2} d^{-1})	Contour area (m^2) (average feed rate)		Change due to resuspension	
		Resuspension off	Resuspension on	Area (m^2)	% change
Middle Head (site 1357)					
Oxic A	0.3-1.0	18,400	21,000	2,600	14
Oxic B	1.0-2.0	22,300	16,300	-6,000	-27
Hypoxic A	2.0-5.0	35,600	24,400	-11,200	-31
Hypoxic B	5.0-7.5	21,500	1,300	-20,200	-94
Hypoxic C	7.5-10.0	7,700	0	-7,700	-100
Anoxic	>10.0	30	0	-30	-100
>5 g C m^{-2} d^{-1}	>5.0	29,200	1,300	-27,900	-99
Jordan Bay (site 1358)					
Oxic A	0.3-1.0	19,300	16,400	-2,900	-15
Oxic B	1.0-2.0	17,800	12,500	-5,300	-30
Hypoxic A	2.0-5.0	28,700	23,900	-4,800	-17
Hypoxic B	5.0-7.5	11,000	9,100	-1,900	-17
Hypoxic C	7.5-10.0	7,000	6,200	-800	-11
Anoxic	>10.0	8,000	5,600	-2,400	-30
>5 g C m^{-2} d^{-1}	>5.0	26,000	20,900	-5,100	*-20*
Blue Island (site 1359)					
Oxic A	0.3-1.0	18,800	34,600	15,800	84
Oxic B	1.0-2.0	20,400	14,900	-5,500	-27
Hypoxic A	2.0-5.0	40,200	3,500	-36,700	-91
Hypoxic B	5.0-7.5	16,500	0	-16,500	-100
Hypoxic C	7.5-10.0	9,000	0	-9,000	-100
Anoxic	>10.0	200	0	-200	-100
>5 g C m^{-2} d^{-1}	*>5.0*	*25,700*	*0*	*-25,700*	*-100*

Table 8a. DEPOMOD predictions of contour areas for ranges of carbon deposition rates at three proposed salmon farms near Shelburne, NS at a stocking level of 1,000,000 smolts, using the proposed maximum feed rate (1,184 kg d^{-1} per cage). Oxic A areas exclude areas with background deposition rates (<0.3 g C m^{-2} d^{-1}).

Site classification	Carbon deposition rate (g C m^{-2} d^{-1})	Contour area (m^2) (maximum feed rate)		Change due to resuspension	
		Resuspension off	Resuspension on	Area (m^2)	% change
Middle Head (site 1357)					
Oxic A	0.3-1.0	23,300	11,200	-12,100	-52
Oxic B	1.0-2.0	12,300	7,700	-4,600	-37
Hypoxic A	2.0-5.0	17,800	28,300	10,500	59
Hypoxic B	5.0-7.5	22,900	12,400	-10,500	-46
Hypoxic C	7.5-10.0	13,000	10,000	-3,000	-23
Anoxic	>10.0	65,300	51,800	-13,500	-21
>5 g C m^{-2} d^{-1}	*>5.0*	*101,200*	*74,200*	*-27,000*	*-27*
Jordan Bay (site 1358)					
Oxic A	0.3-1.0	14,600	9,800	-4,800	-33
Oxic B	1.0-2.0	8,200	10,600	2,400	29
Hypoxic A	2.0-5.0	27,500	24,000	-3,500	-13
Hypoxic B	5.0-7.5	12,300	11,200	-1,100	-9
Hypoxic C	7.5-10.0	9,700	9,200	-500	-5
Anoxic	>10.0	56,100	53,100	-3,000	-5
>5 g C m^{-2} d^{-1}	*>5.0*	*78,100*	*73,500*	*-4,600*	*-6*
Blue Island (site 1359)					
Oxic A	0.3-1.0	25,400	17,100	-8,300	-33
Oxic B	1.0-2.0	12,400	19,800	7,400	60
Hypoxic A	2.0-5.0	16,300	22,700	6,400	39
Hypoxic B	5.0-7.5	22,300	13,800	-8,500	-38
Hypoxic C	7.5-10.0	13,800	11,500	-2,300	-17
Anoxic	>10.0	64,800	27,300	-37,500	-58
>5 g C m^{-2} d^{-1}	*>5.0*	*100,900*	*52,600*	*-48,300*	*-48*

Table 8b. DEPOMOD predictions of contour areas for ranges of carbon deposition rates at three proposed salmon farms near Shelburne, NS at a stocking level of 1,000,000 smolts, using the proposed average feed rate (374 kg d^{-1} per cage). Oxic A areas exclude areas with background deposition rates (<0.3 g C m^{-2} d^{-1}).

Site classification	Carbon deposition rate (g C m^{-2} d^{-1})	Contour area (m^2) (average feed rate)		Change due to resuspension	
		Resuspension off	Resuspension on	Area (m^2)	% change
Middle Head (site 1357)					
Oxic A	0.3-1.0	21,600	26,400	4,800	31
Oxic B	1.0-2.0	23,600	17,600	-6,000	-14
Hypoxic A	2.0-5.0	44,000	34,300	-9,700	-22
Hypoxic B	5.0-7.5	28,200	6,300	-21,900	-88
Hypoxic C	7.5-10.0	14,000	0	-14,000	-100
Anoxic	>10.0	900	0	-900	-100
>5 g C m^{-2} d^{-1}	*>5.0*	*43,100*	*6,300*	*-36,800*	*-91*
Jordan Bay (site 1358)					
Oxic A	0.3-1.0	21,000	20,500	-500	20
Oxic B	1.0-2.0	22,400	15,000	-7,400	-36
Hypoxic A	2.0-5.0	35,000	30,000	-5,000	-11
Hypoxic B	5.0-7.5	14,600	11,800	-2,800	-21
Hypoxic C	7.5-10.0	9,100	8,000	-1,100	-12
Anoxic	>10.0	13,000	10,000	-3,000	-26
>5 g C m^{-2} d^{-1}	*>5.0*	*36,700*	*29,800*	*-6,900*	*-21*
Blue Island (site 1359)					
Oxic A	0.3-1.0	21,400	42,900	21,500	100
Oxic B	1.0-2.0	20,500	19,700	-800	-4
Hypoxic A	2.0-5.0	48,700	8,900	-39,800	-82
Hypoxic B	5.0-7.5	24,000	0	-24,000	-100
Hypoxic C	7.5-10.0	12,200	0	-12,200	-100
Anoxic	>10.0	3,800	0	-3,800	-100
>5 g C m^{-2} d^{-1}	*>5.0*	*40,000*	*0*	*-40,000*	*-100*

Table 9. Linear relationships between the feed rate (kg d^{-1} per cage) and the highest predicted carbon deposition rate (g C m^{-2} d^{-1}) within the DEPOMOD domain. Also shown is the feed rate that would result in a highest deposition rate of 5 g C m^{-2} d^{-1} based on the relationships. The relationships are derived from predicted highest deposition rates at 4 feed rates at each site: 339, 374, 1,050, and 1,184 kg d^{-1} per cage.

Site	Resuspension	Slope (*b*)	y-axis intercept (*a*)	r^2	Feed rate (kg d^{-1} per cage) resulting in a highest carbon deposition rate of 5 g C m^{-2} d^{-1}
Middle Head (site 1357)	off	0.033	-0.06	>0.99	151
Jordan Bay (site 1358)	off	0.057	-0.31	>0.99	93
Blue Island (site 1359)	off	0.037	-0.19	>0.99	141
Middle Head (site 1357)	on	0.033	-3.95	>0.99	274
Jordan Bay (site 1358)	on	0.057	-1.40	>0.99	113
Blue Island (site 1359)	on	0.035	-8.54	>0.99	388

Table 10. Feed and stocking rates required to maintain the predicted carbon deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells within the DEPOMOD domains at three proposed salmon farms near Shelburne, NS.

Location	Proposed stocking rate (number of fish per cage)	Highest predicted deposition rate using proposed maximum feed rate (g C m^{-2} d^{-1})	Feed rate (kg d^{-1} per cage) to maintain deposition rate ≤5 g C m^{-2} d^{-1} in all grid cells	Number of fish per cage to maintain deposition rate ≤5 g C m^{-2} d^{-1} at time of maximum feeding
Stocking in 24 cages (700 000 fish) – resuspension off				
Middle Head (site 1357)	29,167	34.8	151	4,200
Jordan Bay (site 1358)	29,167	57.6	93	2,600
Blue Island (site 1359)	29,167	37.4	141	3,900
Stocking in 30 cages (1 000 000 fish) – resuspension off				
Middle Head (site 1357)	33,333	38.5	151	4,300
Jordan Bay (site 1358)	33,333	68.5	93	2,600
Blue Island (site 1359)	33,333	44.3	141	4,000
Stocking in 24 cages (700 000 fish) – resuspension on				
Middle Head (site 1357)	29,167	30.7	274	7,600
Jordan Bay (site 1358)	29,167	56.5	113	3,100
Blue Island (site 1359)	29,167	27.0	388	10,800
Stocking in 30 cages (1 000 000 fish) – resuspension on				
Middle Head (site 1357)	33,333	34.5	274	7,700
Jordan Bay (site 1358)	33,333	67.4	113	3,200
Blue Island (site 1359)	33,333	33.8	388	10,900

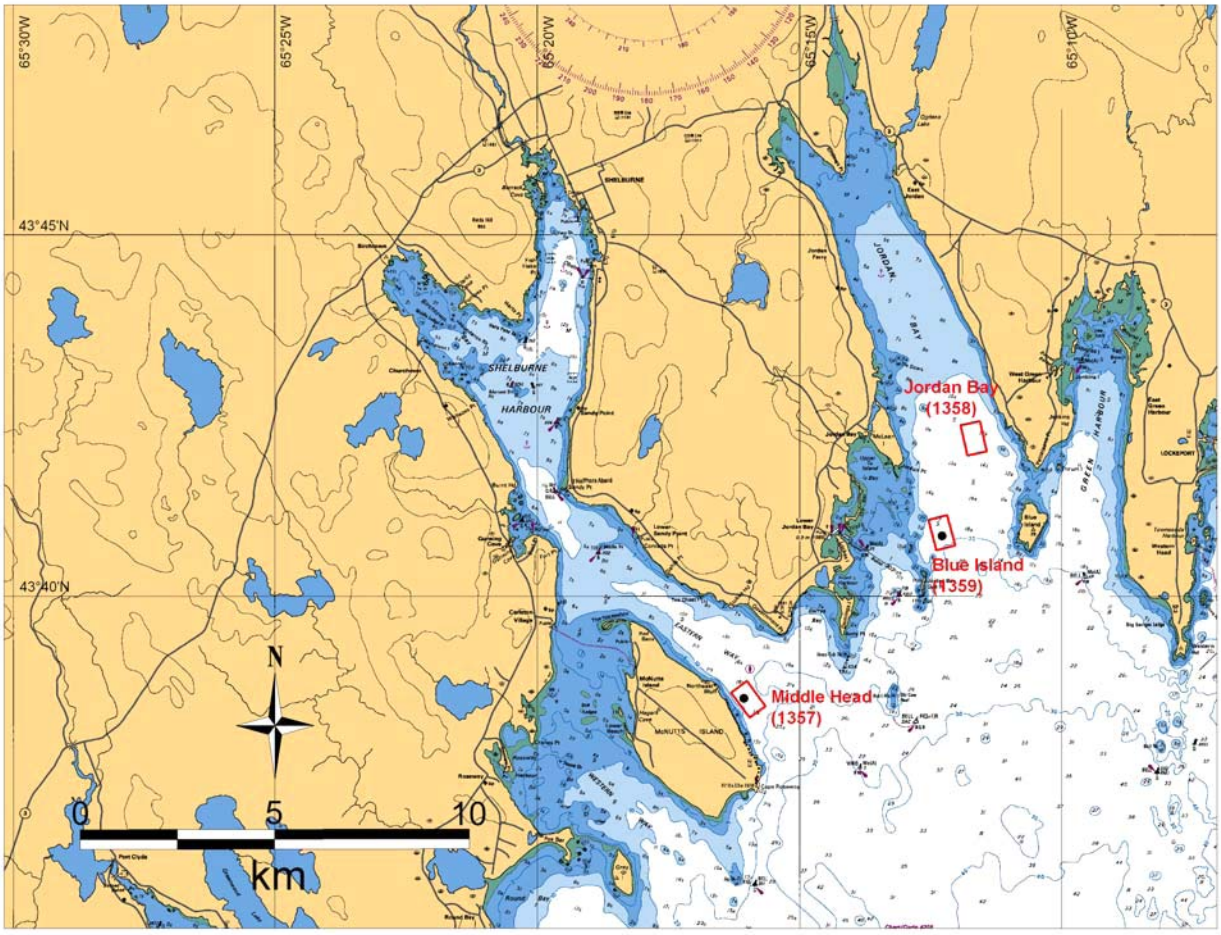

Figure 1. Map of the Shelburne area showing locations of three proposed salmon farms. Black dots indicate current meter deployments; the Jordan Bay current meter deployment was within the proposed site boundaries, but the exact location was not available. Background map is Canadian Hydrographic Service chart 4241: Lockeport to Cape Sable (2002).

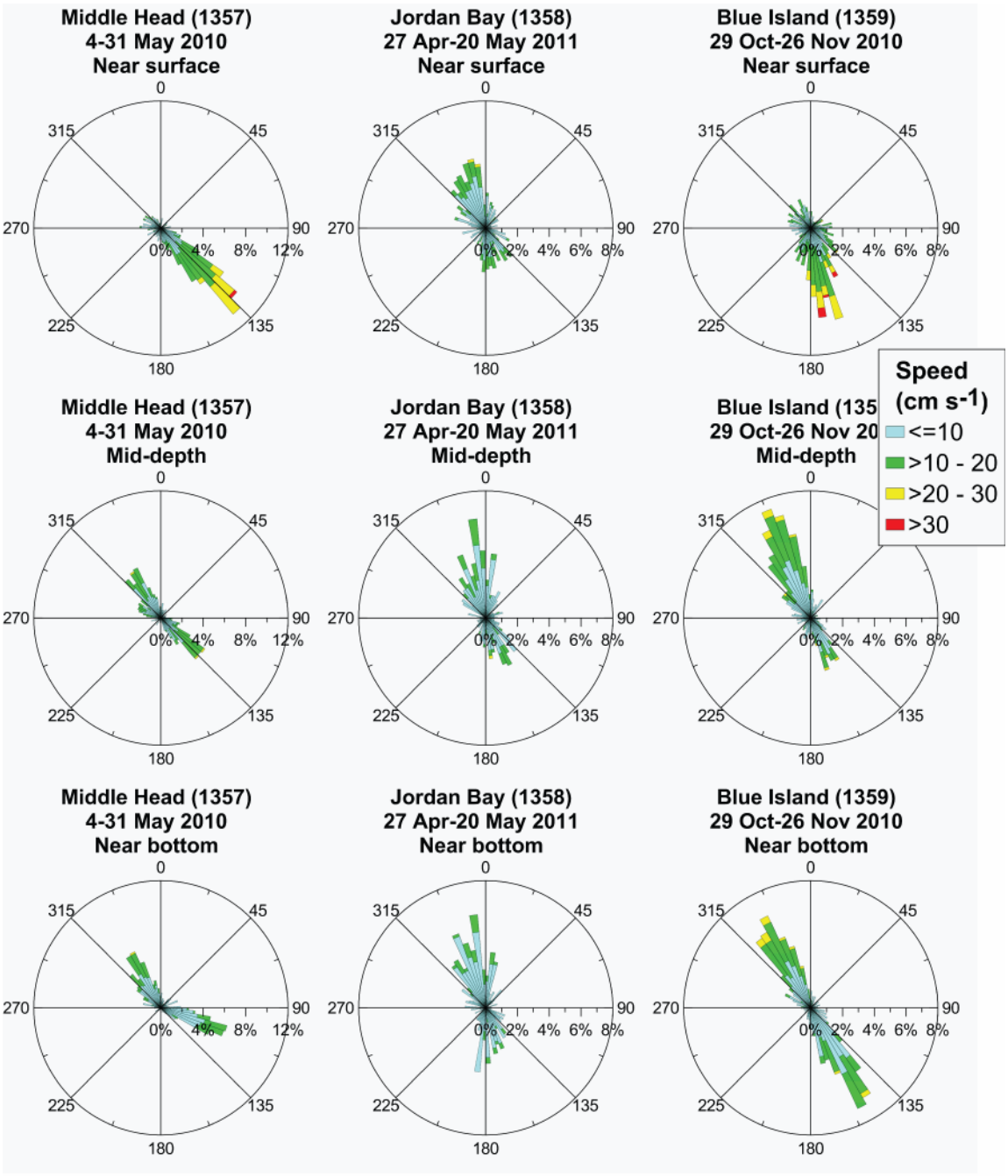

Figure 2. Current rose diagrams for ADCP current meter deployments at Middle Head (site 1357; left column), Jordan Bay (site 1358; middle column), and Blue Island (site 1359; right column). Data are shown are hourly records for three depth layers: near-surface (top row), mid-depth (middle row), and near-bottom (bottom row).

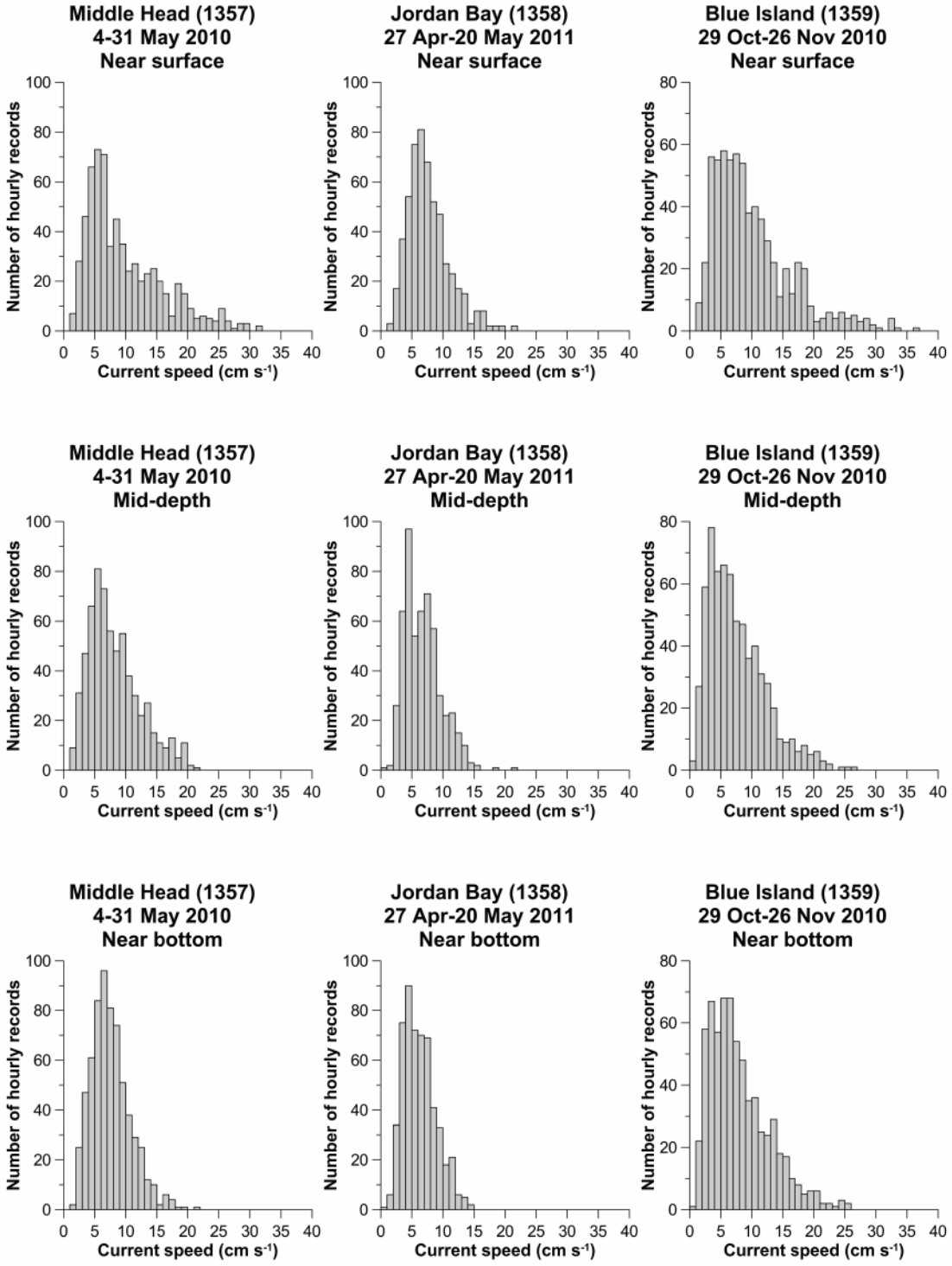

Figure 3. Current speed histograms for ADCP current meter deployments at Middle Head (site 1357; left column), Jordan Bay (site 1358; middle column), and Blue Island (site 1359; right column). Data are shown for three depth layers: near-surface (top row), mid-depth (middle row), and near-bottom (bottom row).

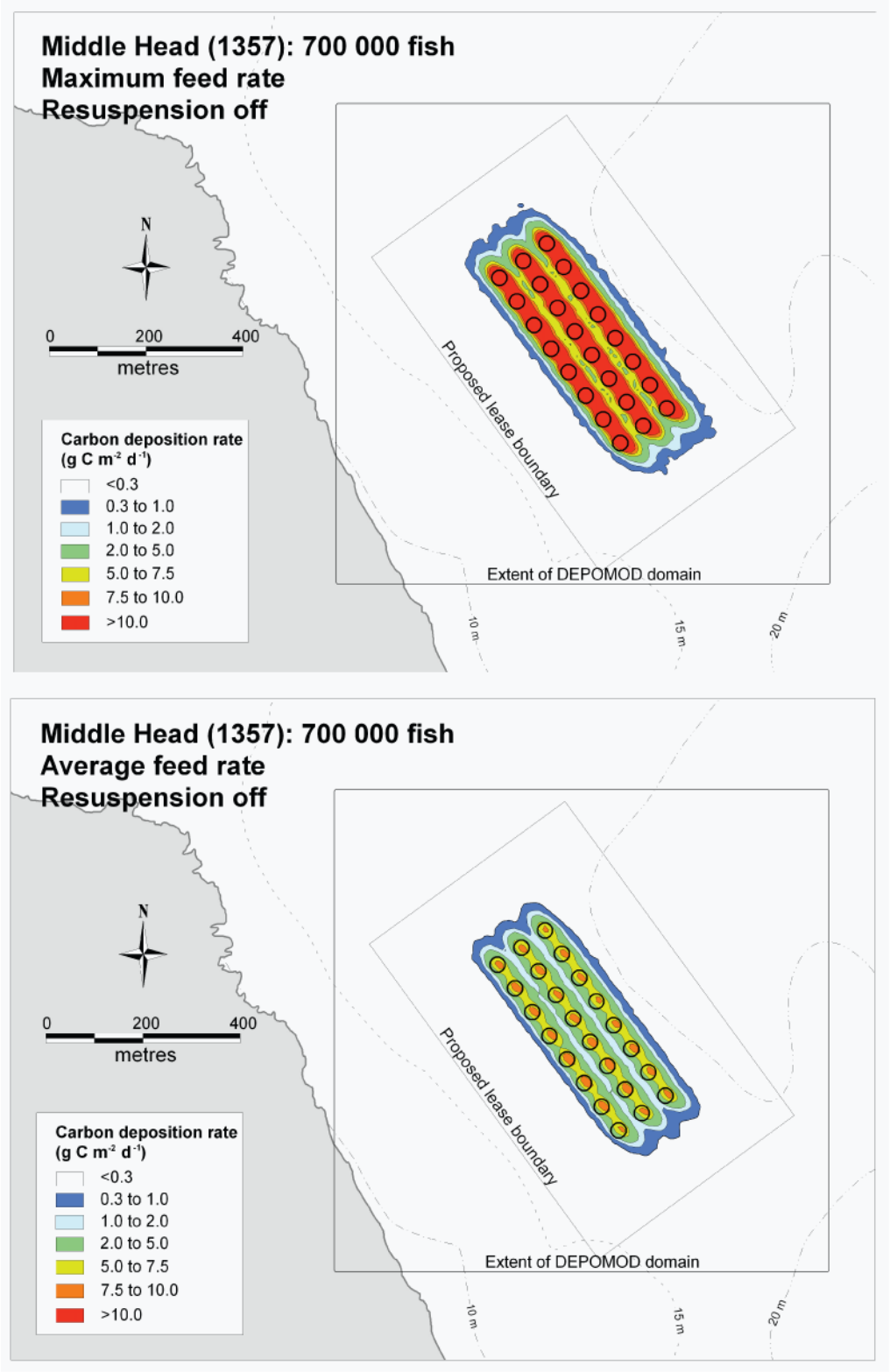

Figure 4a. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Middle Head salmon farm (site 1357), with a total of 700,000 fish in 24 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension off.

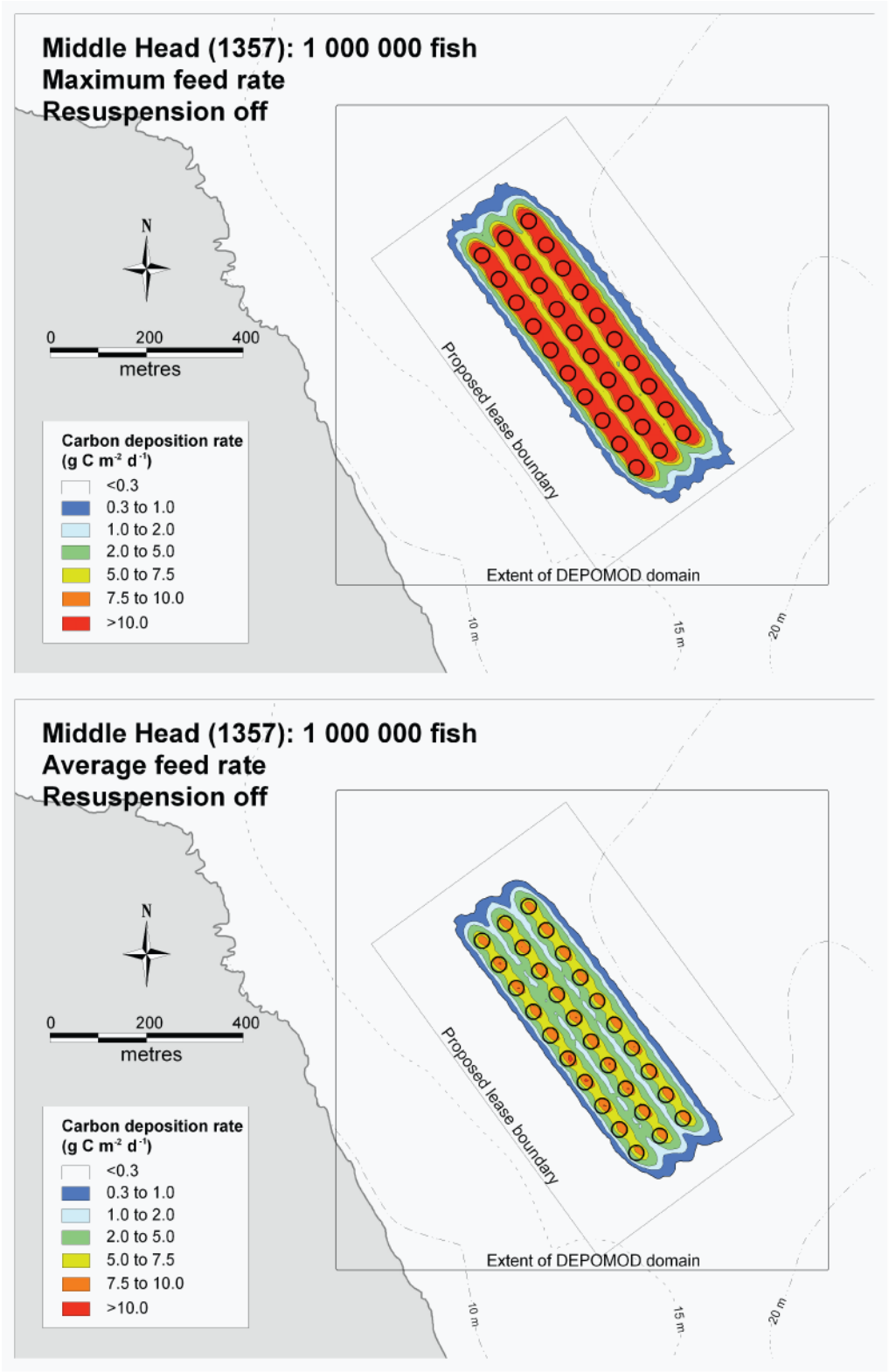

Figure 4b. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Middle Head salmon farm (site 1357), with a total of 1,000,000 fish in 30 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension off.

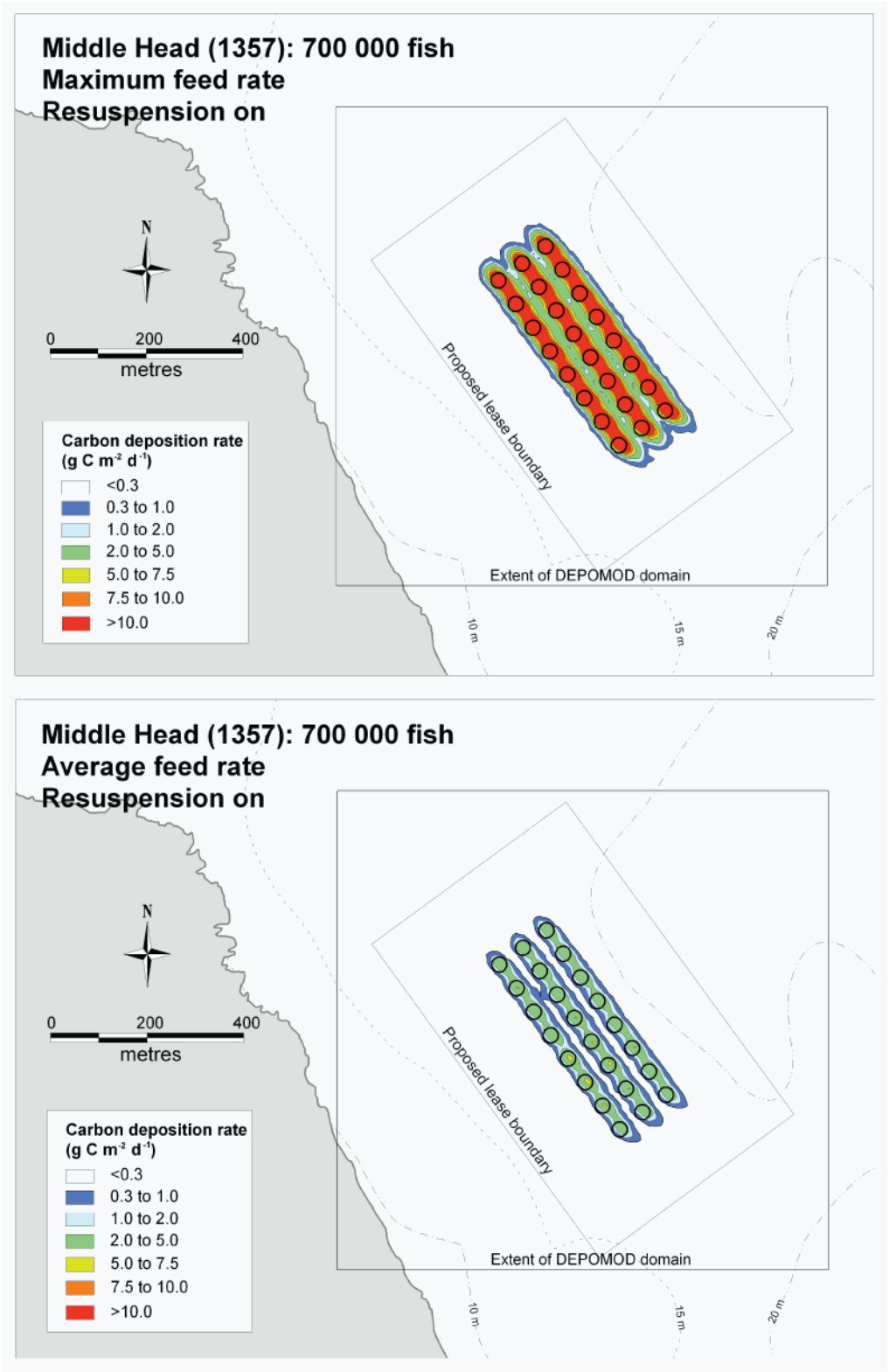

Figure 4c. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Middle Head salmon farm (site 1357), with a total of 700,000 fish in 24 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension on.

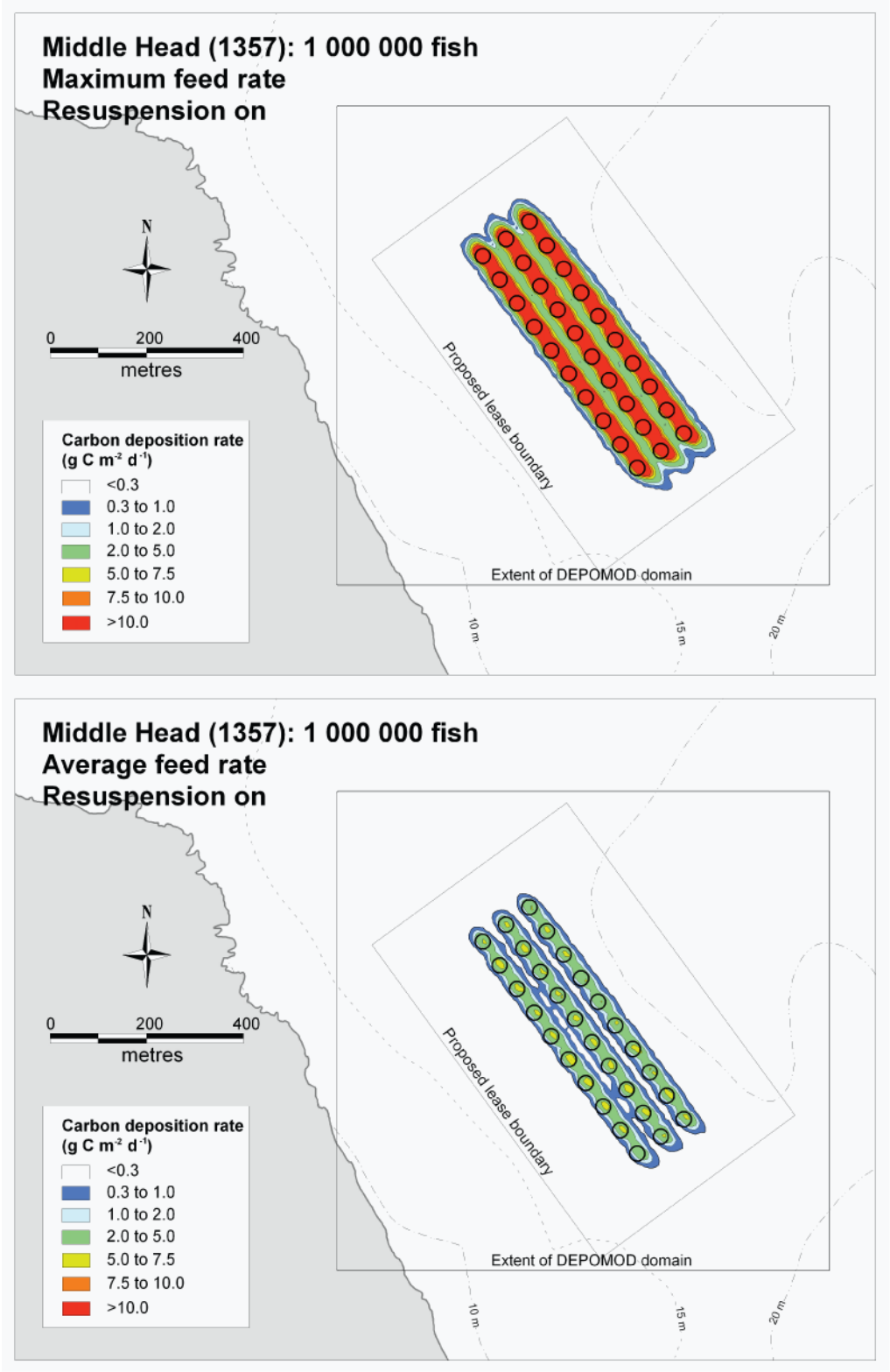

Figure 4d. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Middle Head salmon farm (site 1357), with a total of 1,000,000 fish in 30 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension on.

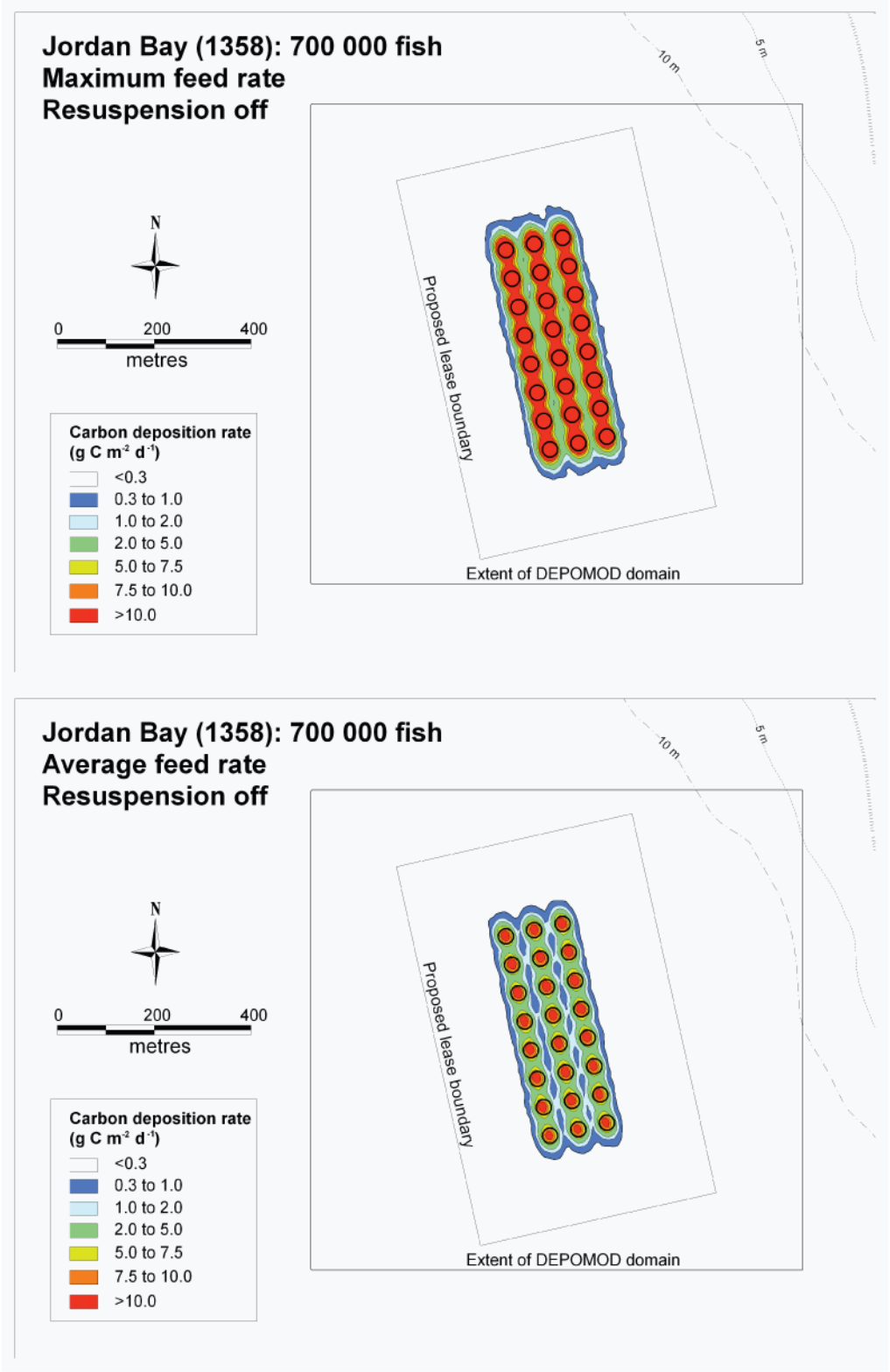

Figure 5a. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Jordan Bay salmon farm (site 1358), with a total of 700,000 fish in 24 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension off.

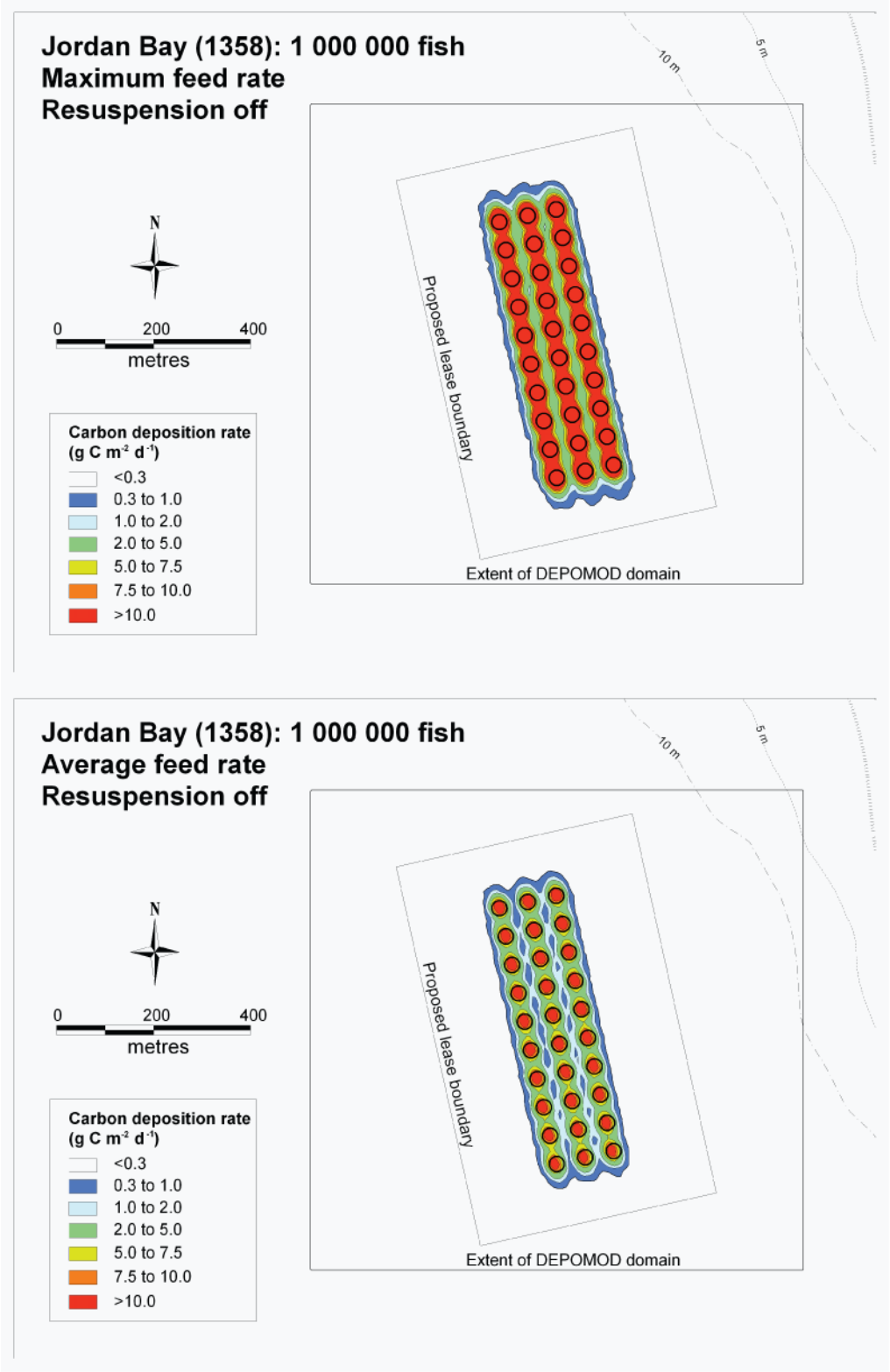

Figure 5b. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Jordan Bay salmon farm (site 1358), with a total of 1,000,000 fish in 30 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension off.

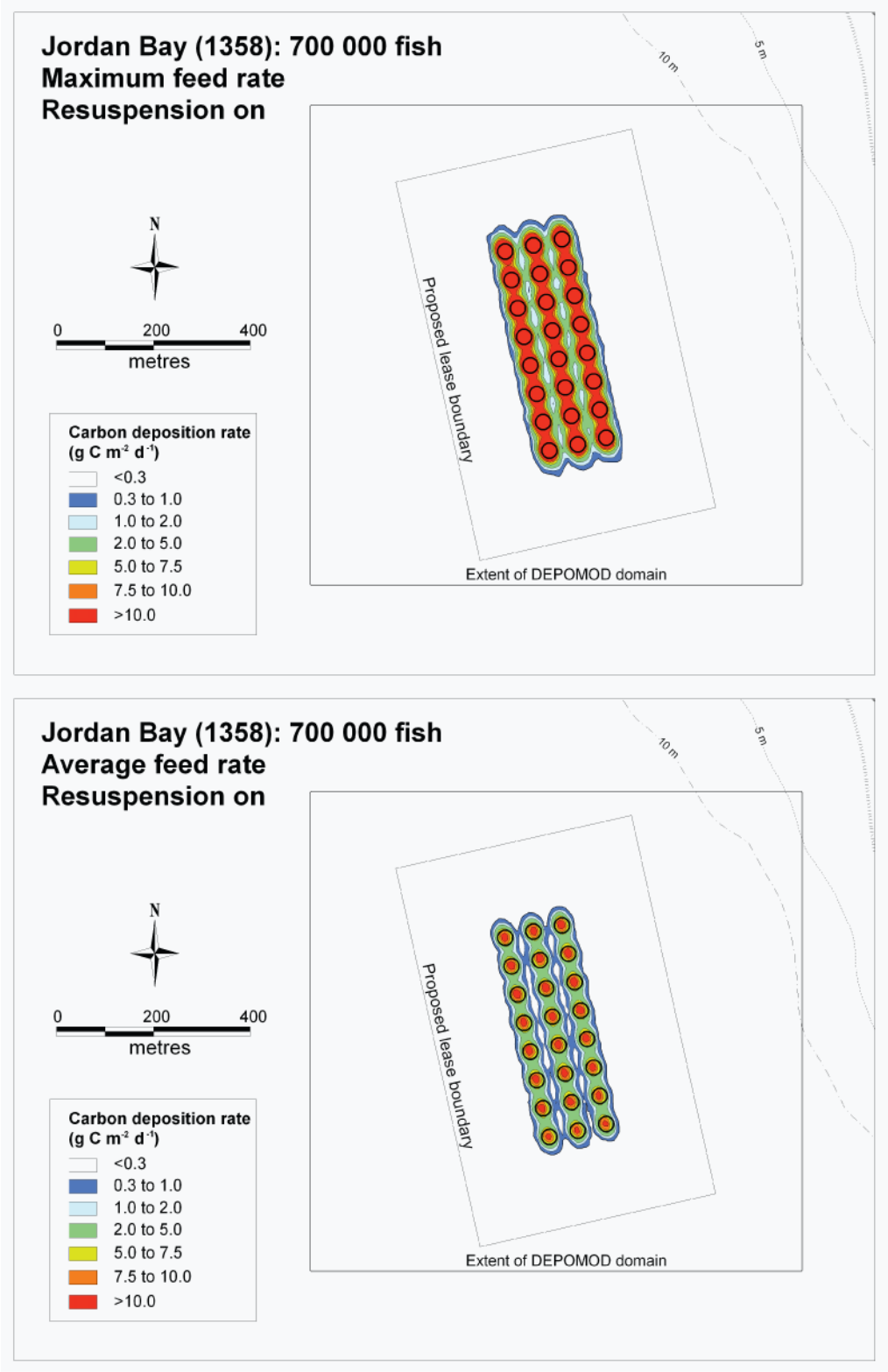

Figure 5c. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Jordan Bay salmon farm (site 1358), with a total of 700,000 fish in 24 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension on.

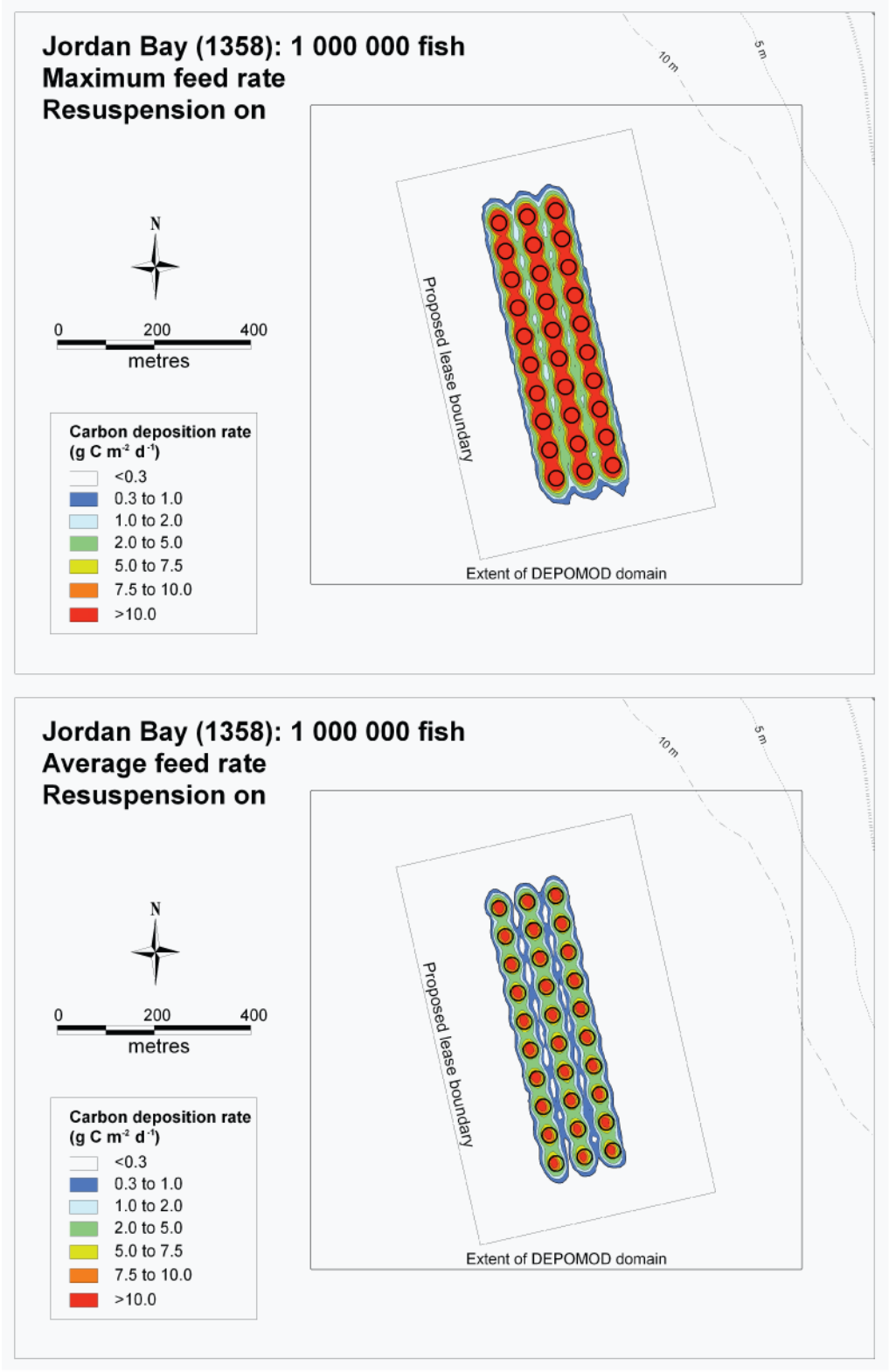

Figure 5d. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Jordan Bay salmon farm (site 1358), with a total of 1,000,000 fish in 30 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension on.

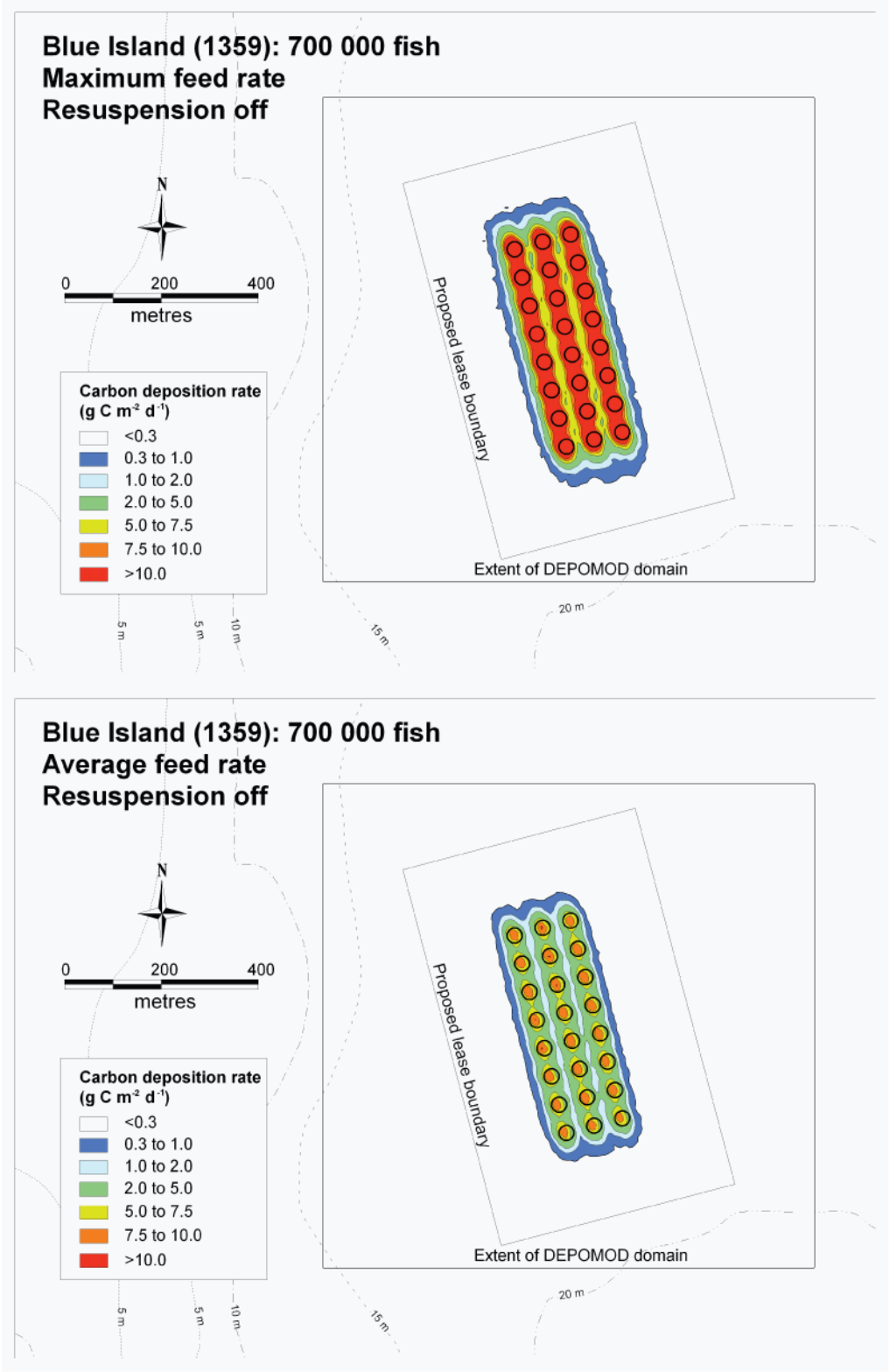

Figure 6a. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Blue Island salmon farm (site 1359), with a total of 700,000 fish in 24 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension off.

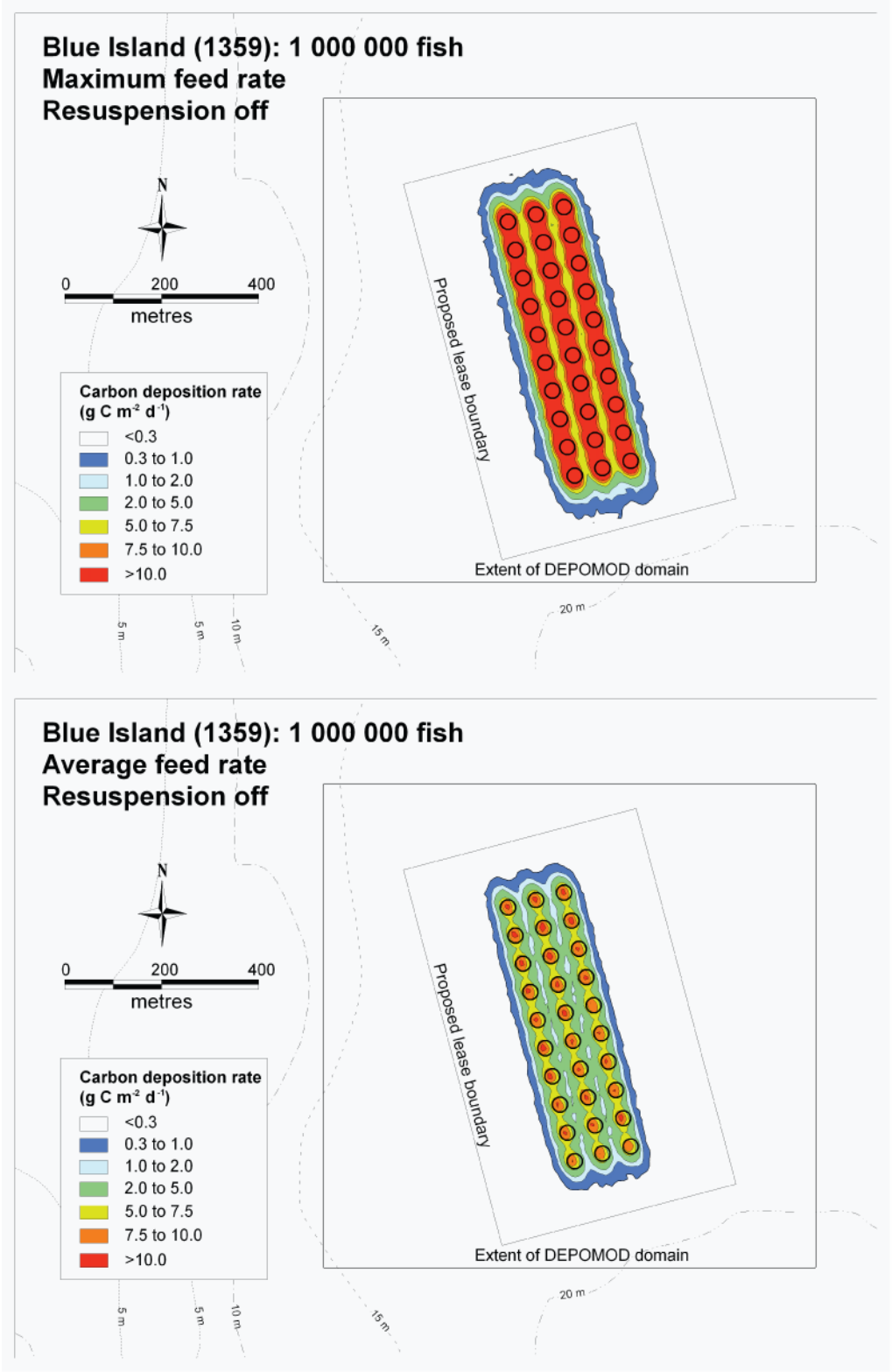

Figure 6b. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Blue Island salmon farm (site 1359), with a total of 1,000,000 fish in 30 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension off.

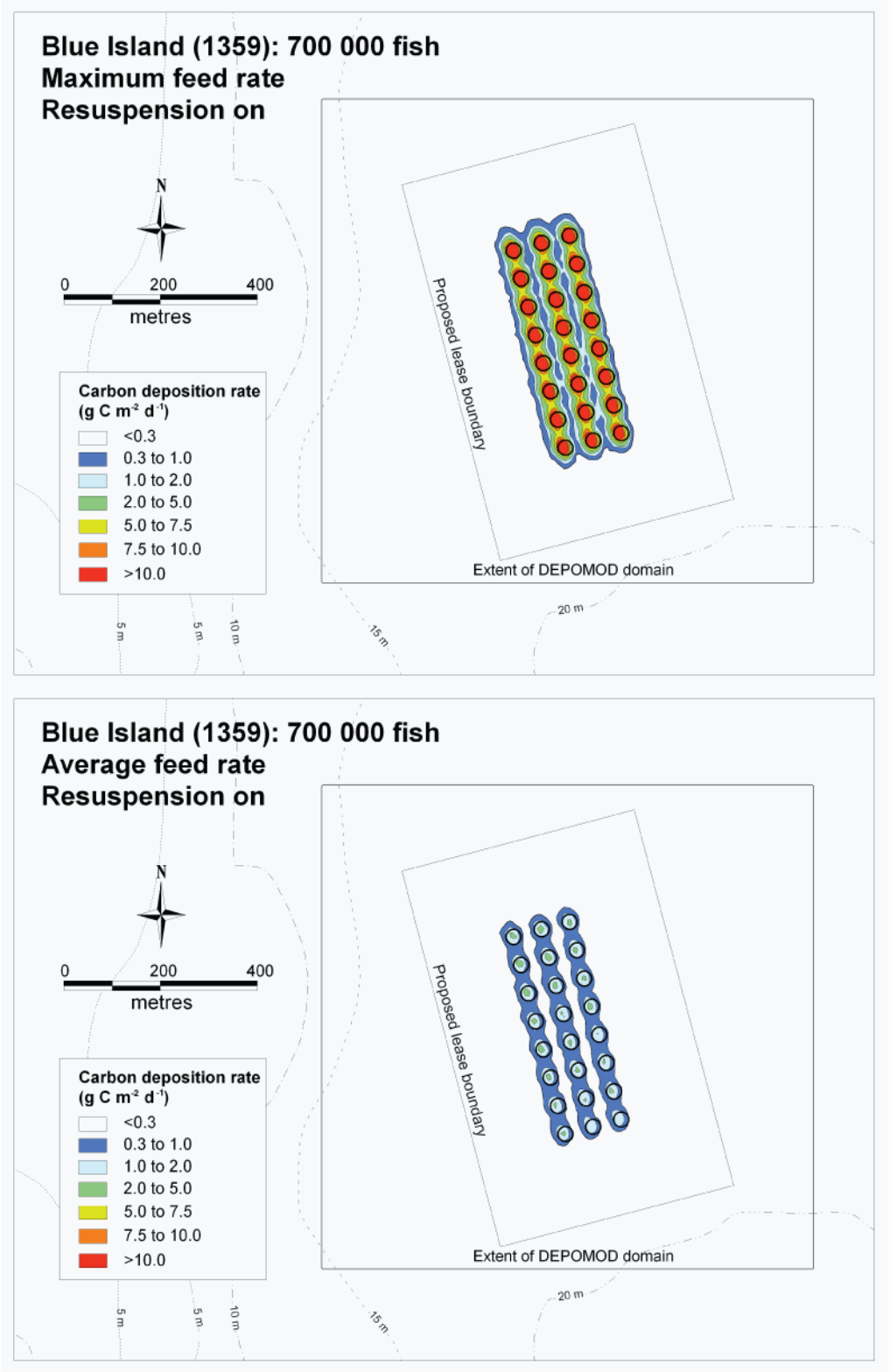

Figure 6c. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Blue Island salmon farm (site 1359), with a total of 700,000 fish in 24 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension on.

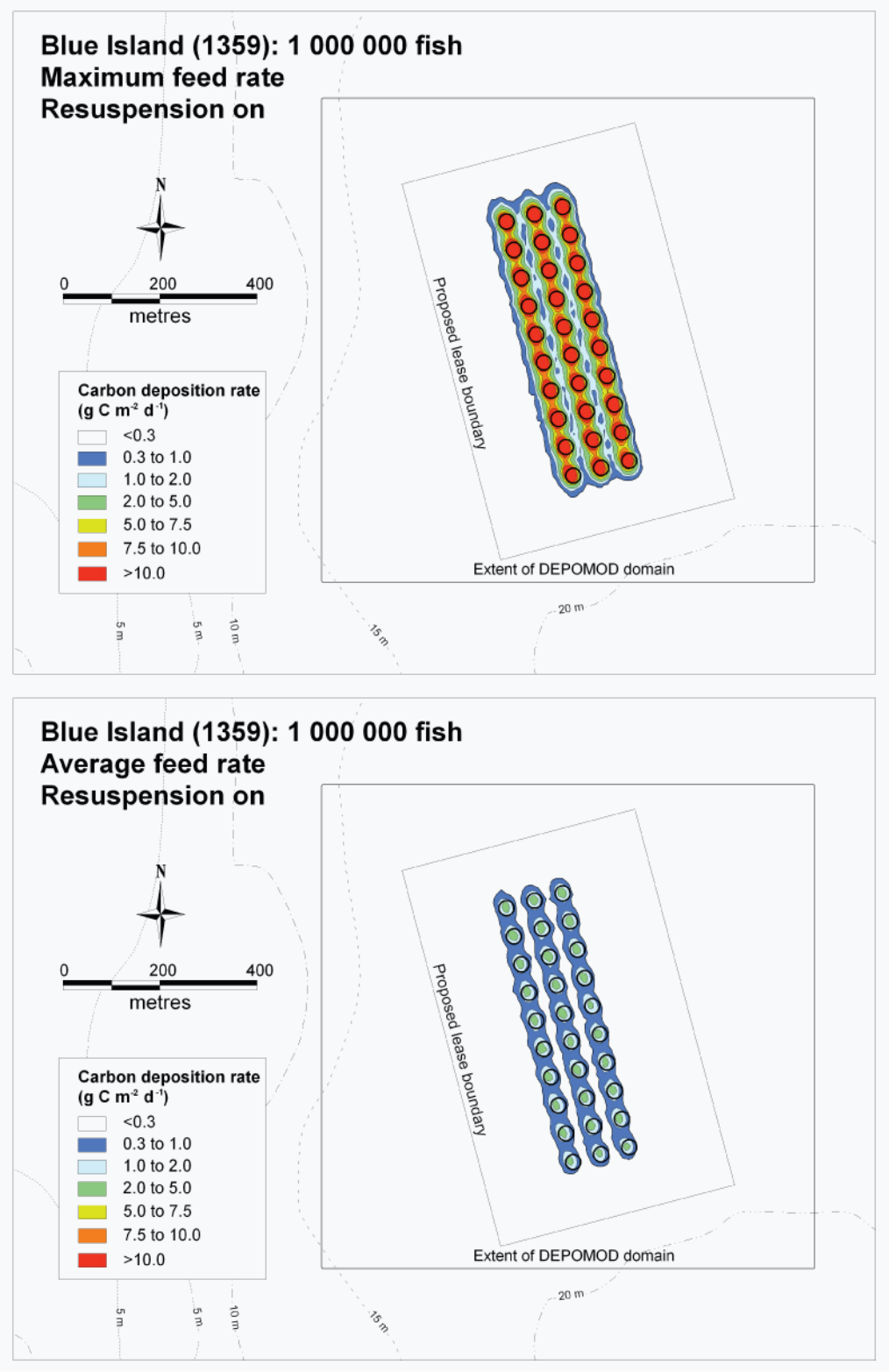

Figure 6d. Contour plots of DEPOMOD predicted carbon deposition rates at the proposed Blue Island salmon farm (site 1359), with a total of 1,000,000 fish in 30 cages, using proposed maximum (top) and average (bottom) feed rates, with resuspension on.

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Fisheries and Oceans Canada
PO Box 1006, Station B203
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Canada, B2Y 4A2

Telephone: 902-426-7070
Fax: 902-426-5435
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