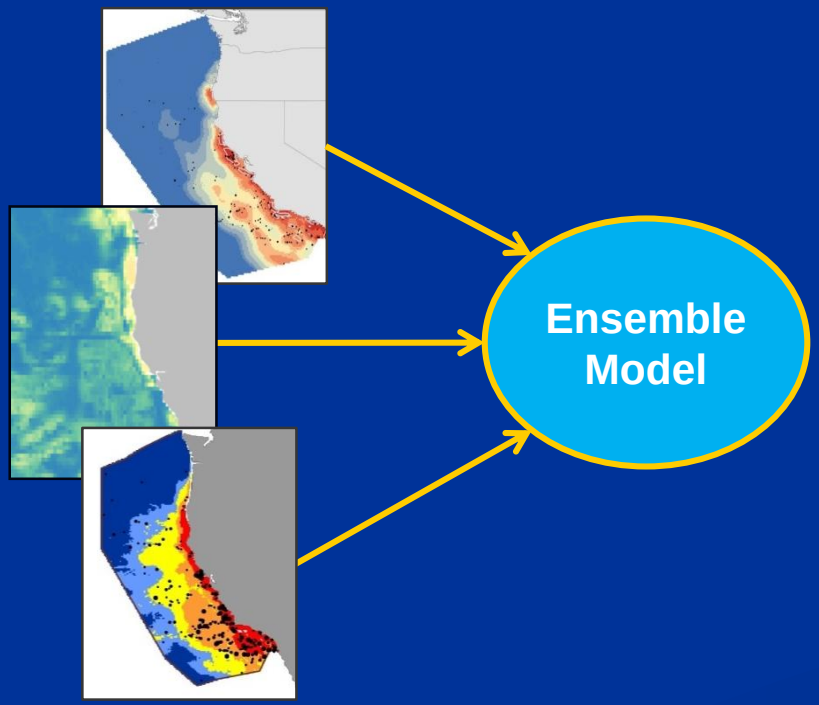
NMFS Protected Species Toolbox Mini-Symposium II
March 1-2, 2018
Alaska Fisheries Science Center, Seattle WA

eSDM: An ensemble tool for species distribution models (*Spatial Analysis Theme)*



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with contributions from
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Daniel Palacios (Oregon State Univ)
Monica DeAngelis (US Navy)

For questions, please contact
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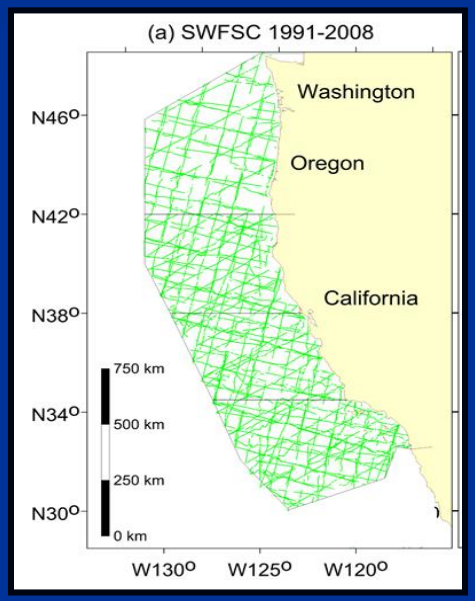
Why Ensemble Modeling?

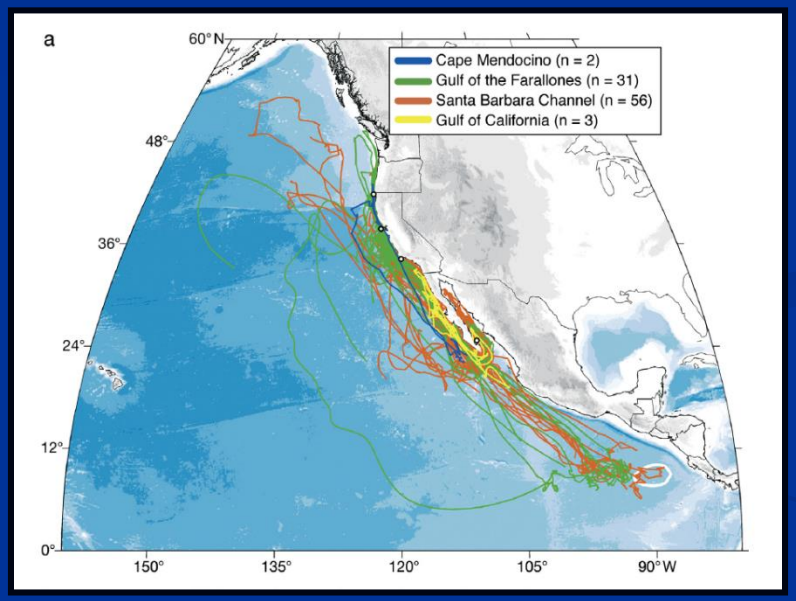
- A variety of sampling techniques have been used to develop species distribution models, with varying strengths & limitations.

Systematic surveys



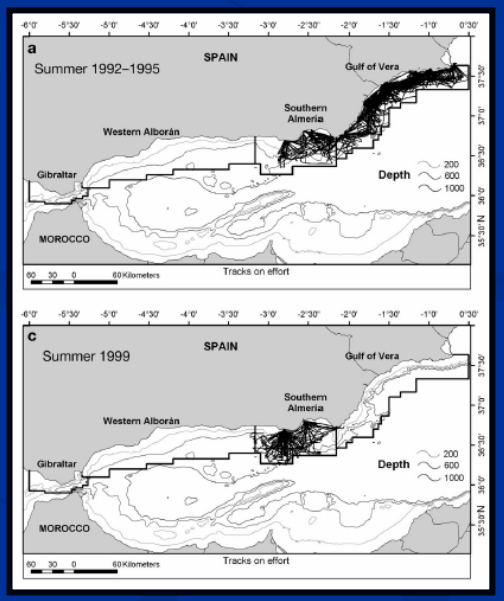
Becker et al. 2016

Telemetry studies



Bailey et al. 2009

Opportunistic surveys



Cañadas and Hammond 2006

- No single model is correct at all times, in all areas and at all scales

Example: West Coast blue whales

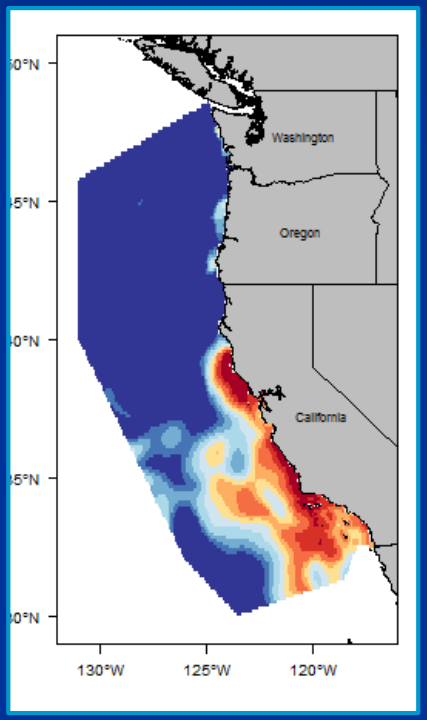
NMFS Large Whale Workshop (September 2014)

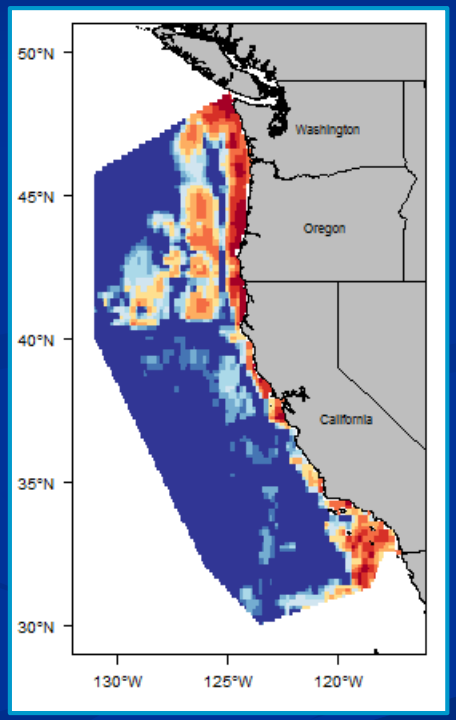
Organized by Monica DeAngelis (formerly NOAA West Coast Region) to look at the availability of large whale models off U.S west coast

Source	Data	Model type	Region
Pardo et al. 2015	SWFSC LT (CCE & ETP)	Bayesian hierarchical	CCE/ETP
Becker et al. 2016	SWFSC LT (CCE)	GAM	CCE
Hazen et al. 2016	Tagging	GAMM/BRT	ENP
Redfern et al. 2017	SWFSC LT (CCE & CCE/ETP)	GAM	CCE
Dransfield et al. 2014	ACCESS LT	Neg. Bin. Regression	Central CA
Irvine et al. 2014	Tagging	Kernel density	US EEZ
Širović et al.	Passive acoustics	GAM	SCB
Monnahan et al.	Passive acoustics	GAMLSS	ENP

West Coast blue whales

Multiple, published blue whale models off the U.S. West Coast created challenges for management and assessment of local risks (e.g. entanglements, ship strikes).





May 2015: Joint NMFS-IWC workshop to examine blue whale models and develop a plan for evaluating/combining diverse models

How can we combine information from multiple studies to get a better spatial model?

OPTION 1: Integrate diverse data within a single analysis framework (e.g. Bayesian hierarchical models).

Challenges can include…

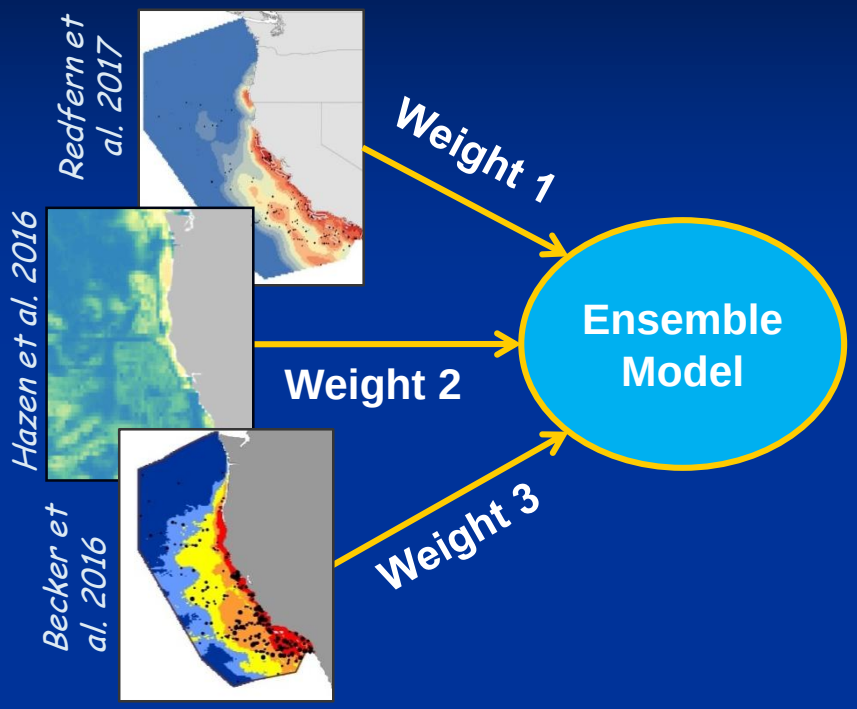
… data ownership

… computational limitations

… analytical expertise required

OPTION 2: Combine model *outputs* to create a single ensemble model

Ensemble Modeling



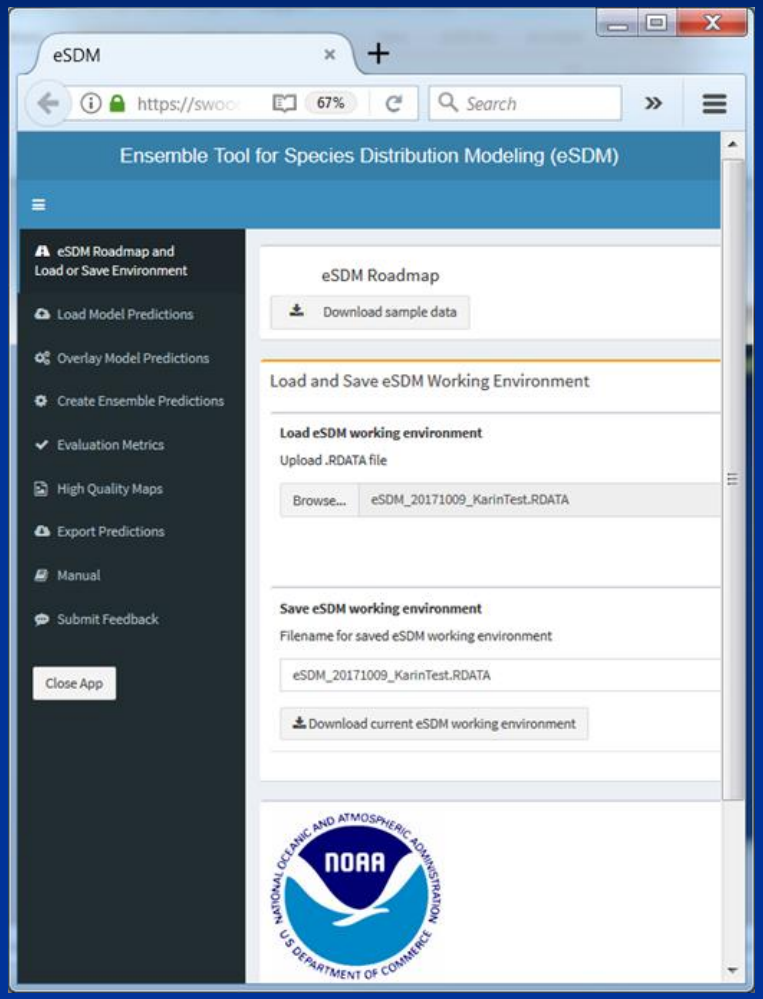
Predictions from a set ('ensemble') of models often yield more robust predictions and allow evaluation of uncertainties.

Wintle et al. 2003,
Johnson and Omland 2004,
Araújo and New 2007,
Thuiller et al. 2008,
Gritti et al. 2013

Advantages:

- Requires only model outputs (not original data)
- Computationally more straightforward
- Can be done by end-users/resource managers

NOAA Fisheries Science & Technology
Protected Species Spatial Toolbox Project: ***eSDM***

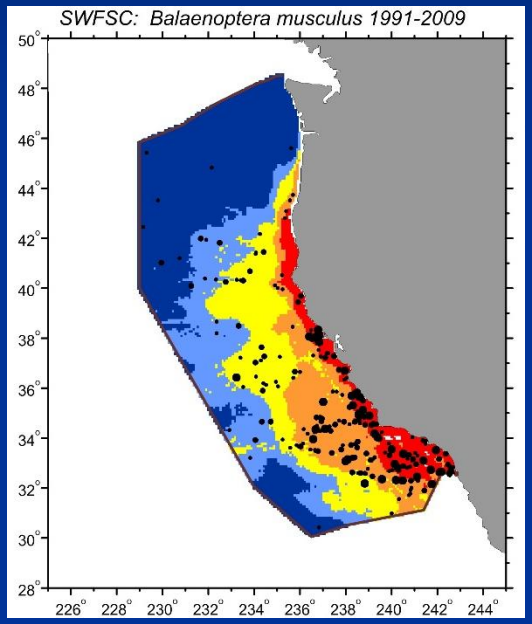


- Goal: Develop a user-friendly R tool (***eSDM***) for creating and exploring ensemble models from *existing* spatial models (e.g. provided in GIS or CSV files).
- Purpose: Enhance and facilitate management decision-making
- Approach: Use published blue whale models as a case study to explore ensembling methods; solicit input from Science Centers, Regions and other end-users during development and testing.
- Today's presentation: Provide overview of this project and introduce the draft ('beta version') of ***eSDM***.
- Tomorrow: Hands-on demo for anyone interested in trying the ***eSDM***

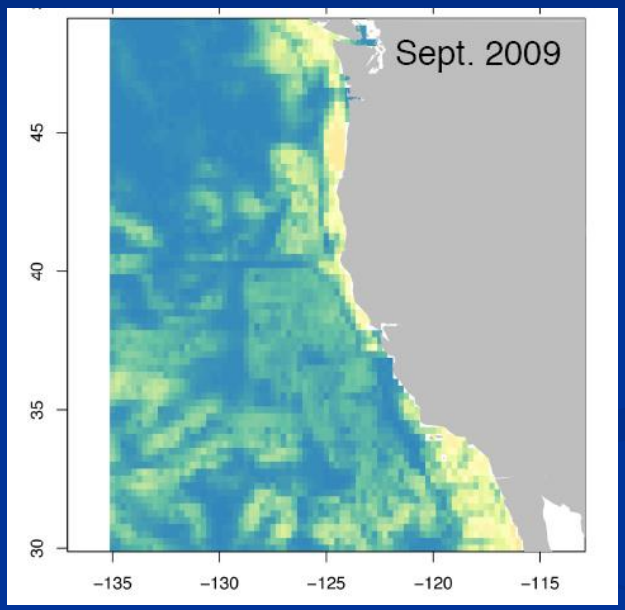
Blue Whale Case Study

Initially focused on three models of absolute density for the entire California Current Ecosystem study area

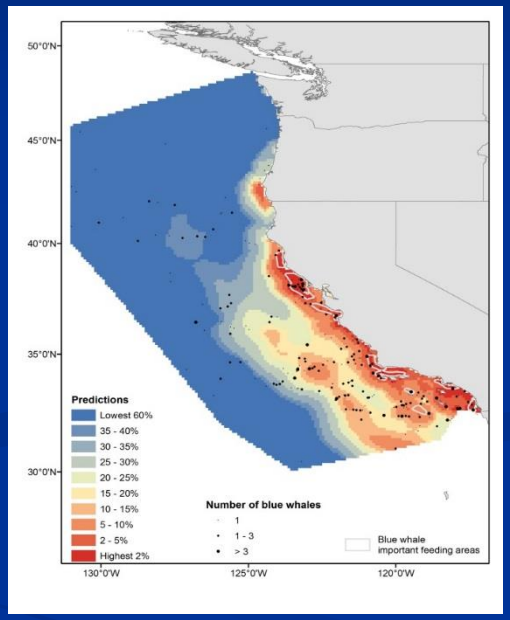
Becker et al. 2016



Hazen et al. 2016



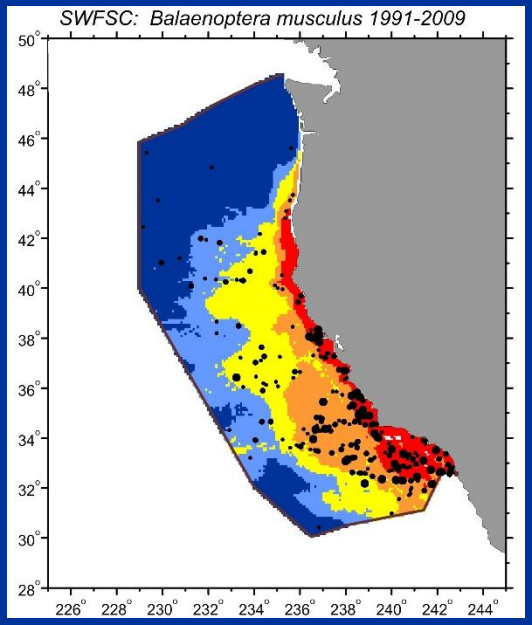
Redfern et al. 2017



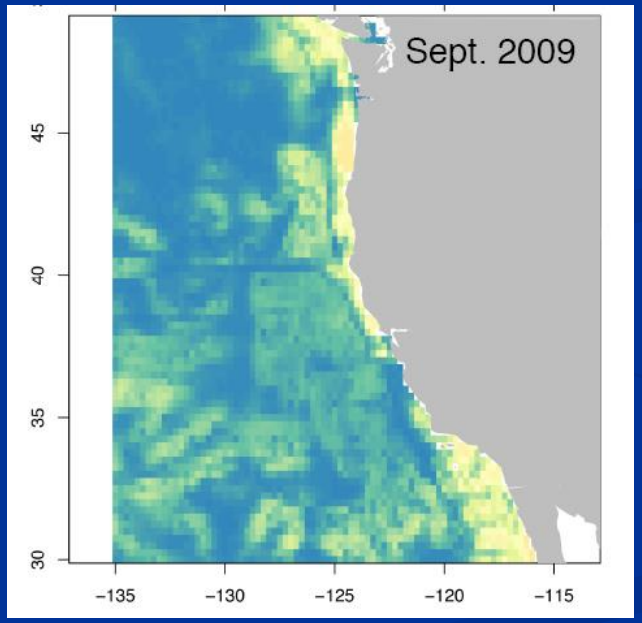
1991-2009 shipboard line-transect survey	1994-2008 blue whale satellite telemetry data	1991-2009 shipboard line-transect survey
Contemporaneous 8-day ROMS covariates	Contemporaneous satellite-derived covariates	Climatological SODA covariates
~10 x 10 km prediction grid	~25 x 25 km prediction grid	10 x 10 km prediction grid

Creating a common grid

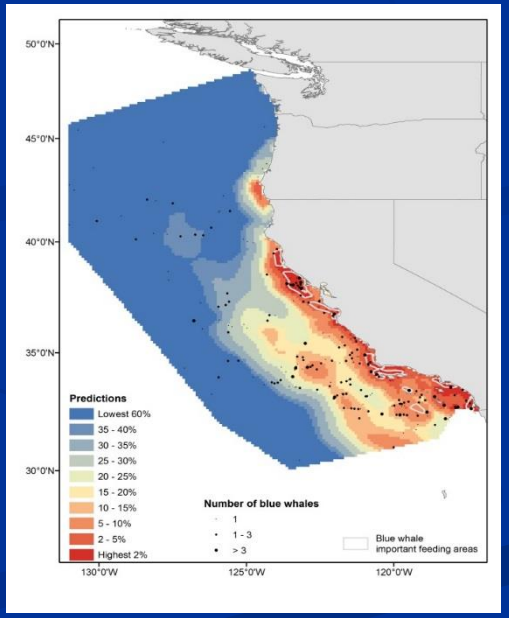
- Models predictions were made using different spatial resolutions and grid patterns (equal area vs. equal degrees), etc.
- Models need to be re-scaled to a common unit if they are not all the same data types (absolute/relative animal density, probability of occurrence, etc).



Becker et al. 2016

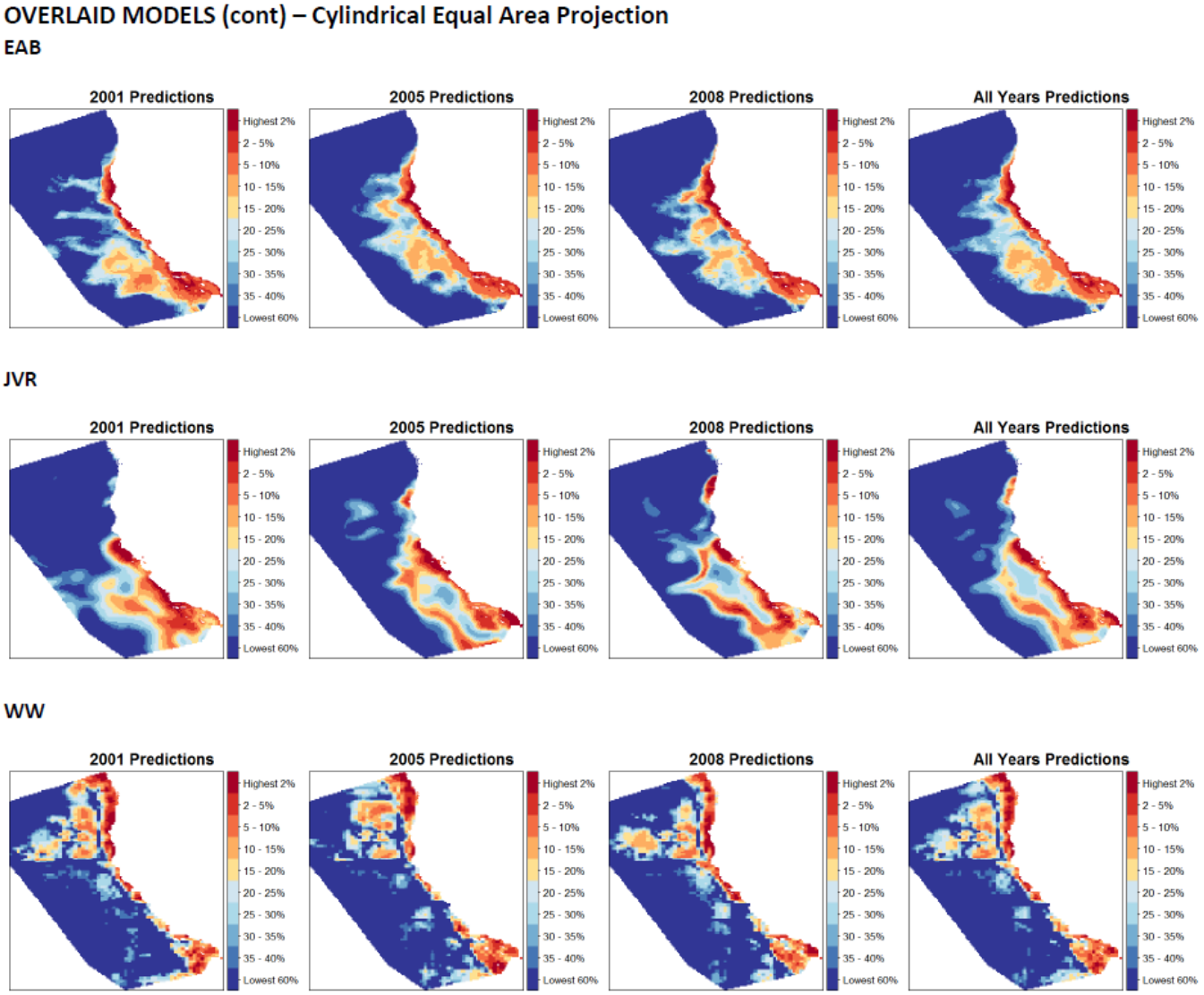


Hazen et al. 2016



Redfern et al. 2017

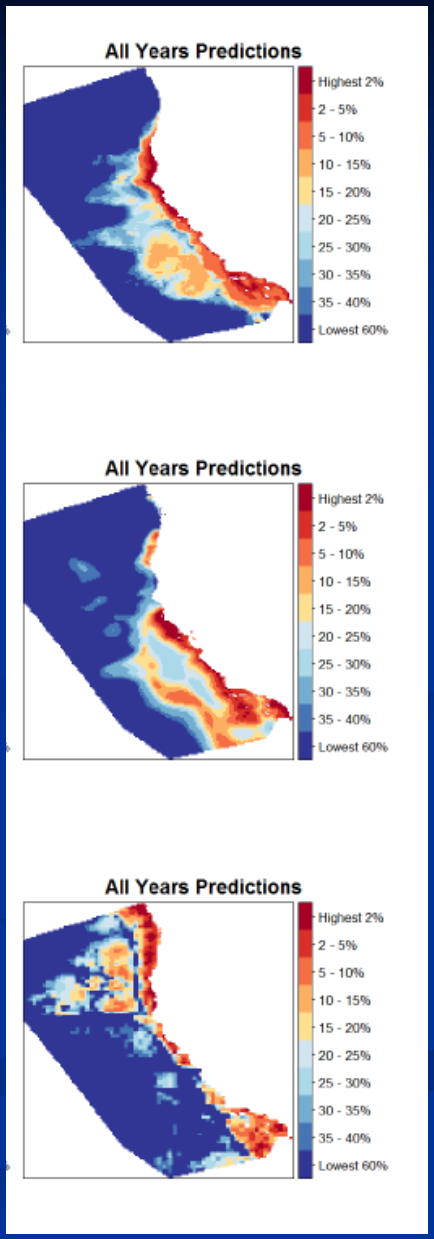
Estimates for summer/fall, 2001, 2005, and 2008



Redfern et al. in prep.

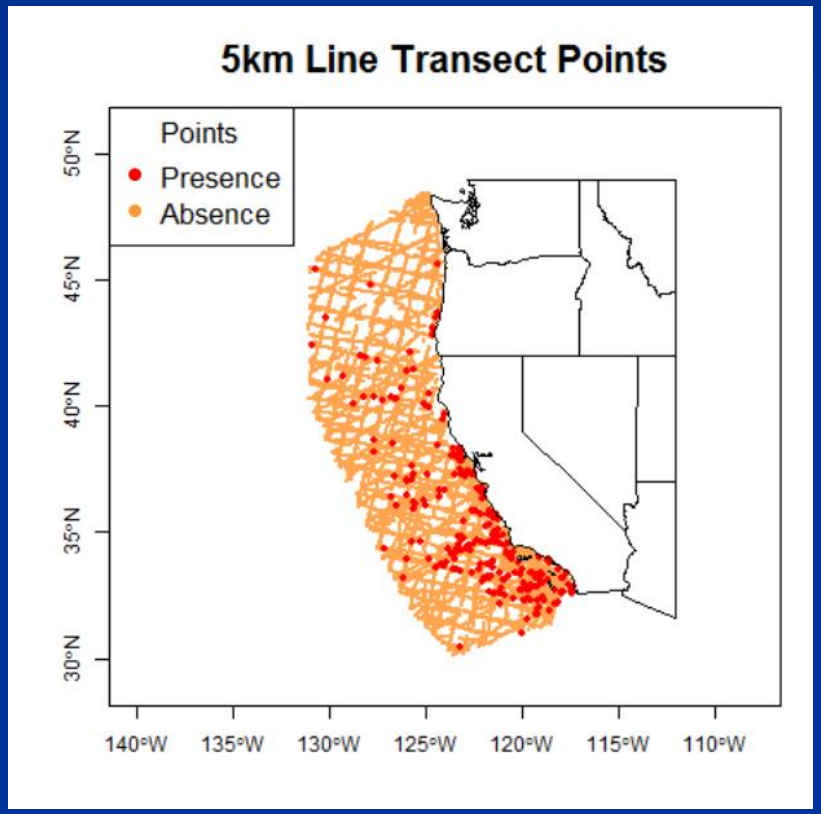
Evaluation and Weighting of Models

- Evaluation of model performance relative to validation data sets:
  - AUC: Receiver operating characteristic curve *(Fawcett 2006)*
  - TSS: true skill statistic *(Allouche et al. 2006)*
  - RMSE: Root mean squared error
- Development of weighting schemes:
  - User-provided errors/weights
  - Performance-based weights (e.g. AUC)
  - Regional/global weights?
  - Down-weighting for models based on same underlying data?



Validation data sets for blue whale case study

We used presence and absence points based on 5-km survey segments from NOAA/SWFSC cruises, home range areas from blue whale telemetry study, and both combined.



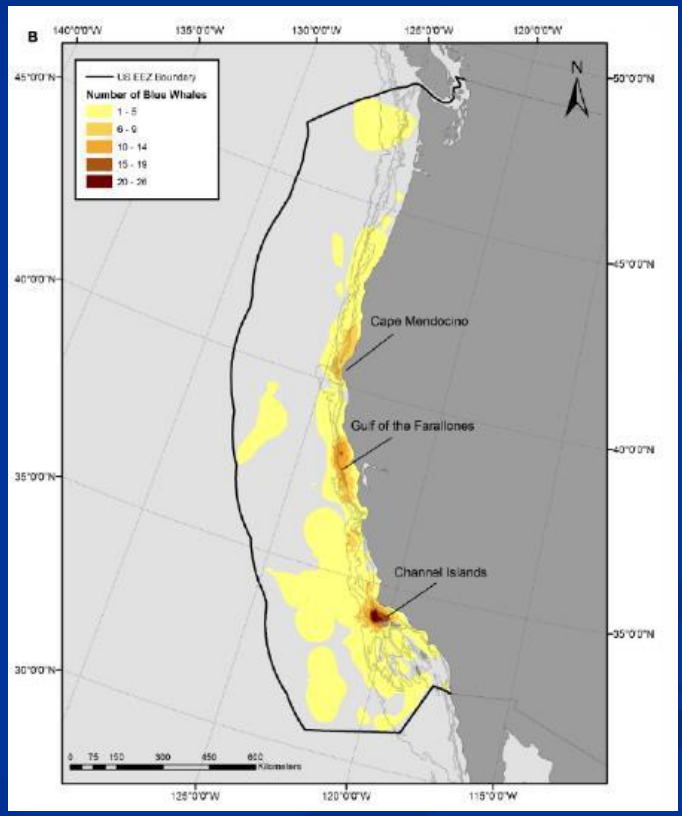
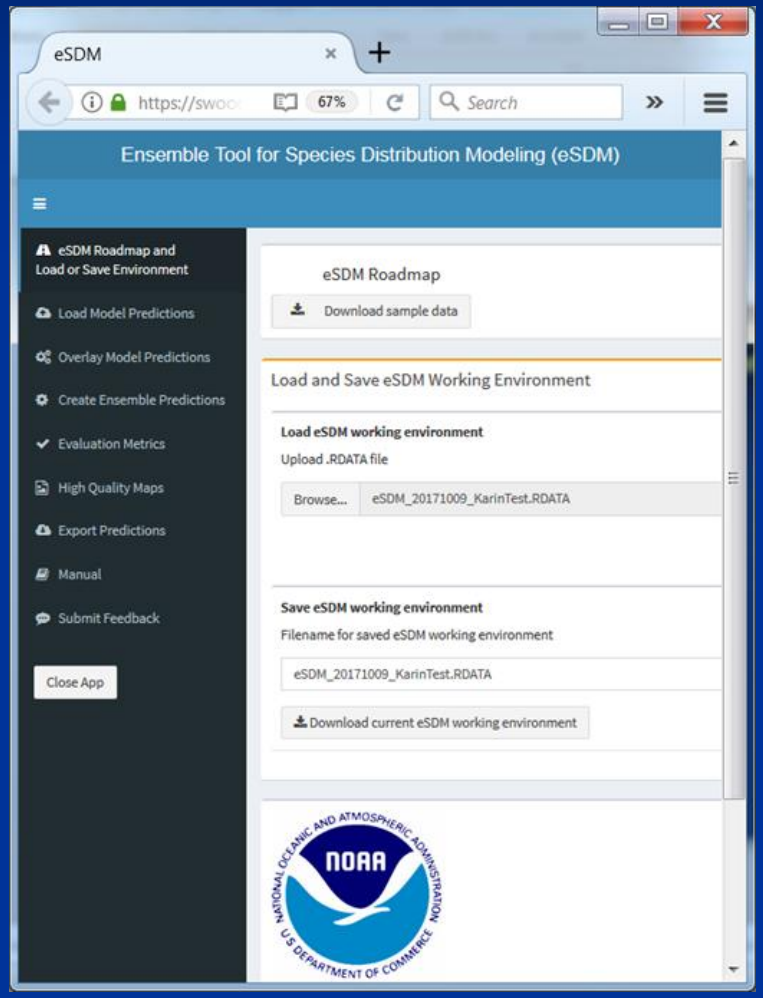


Figure 2b from Irvine et al. (2014)

eSDM Ensemble Tool

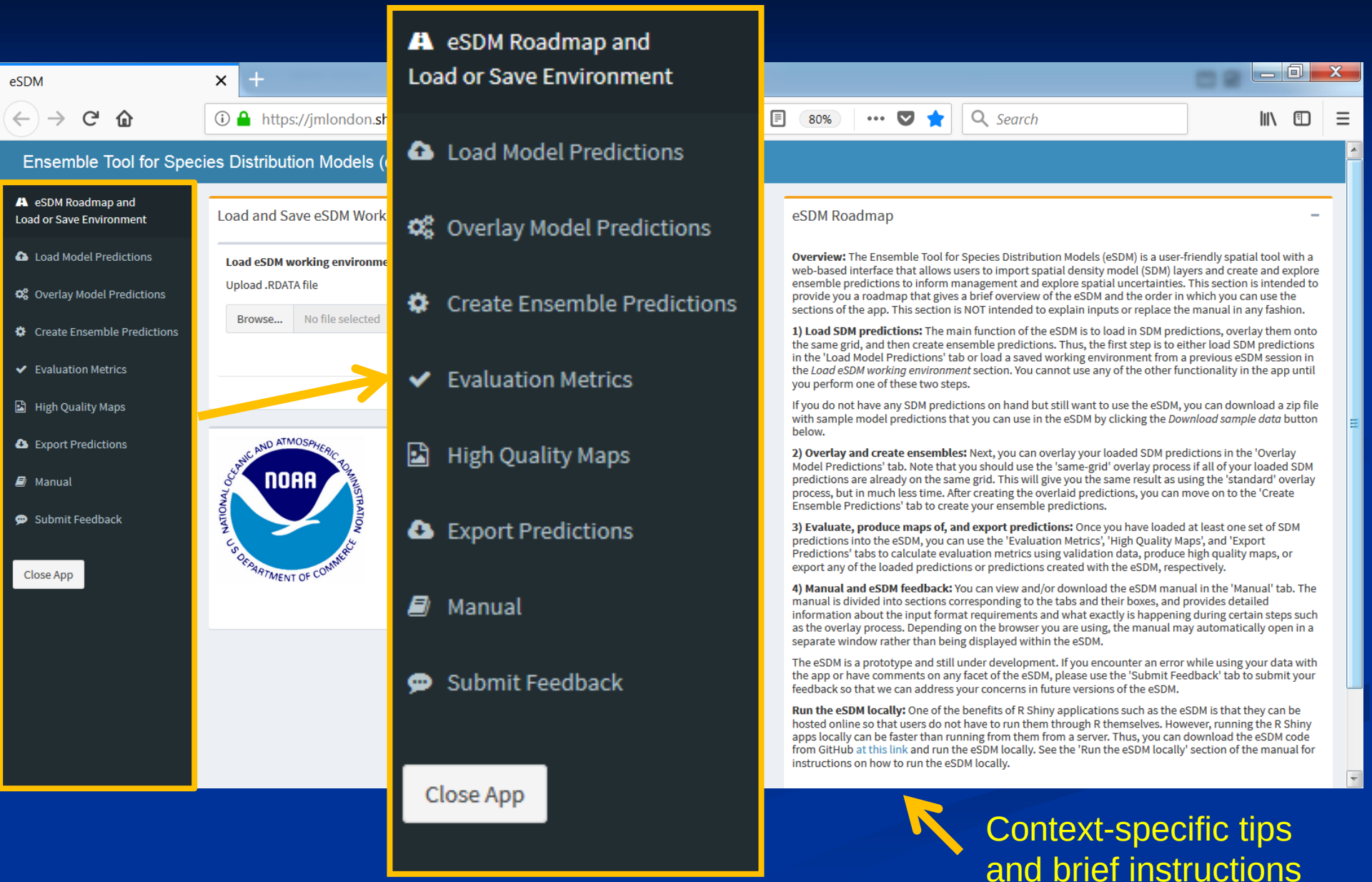
https:https://jmlondon.shinyapps.io/eSDM/



Draft tool includes features that were explored and determined to be useful for blue whale case study (*Redfern et al., in prep*):

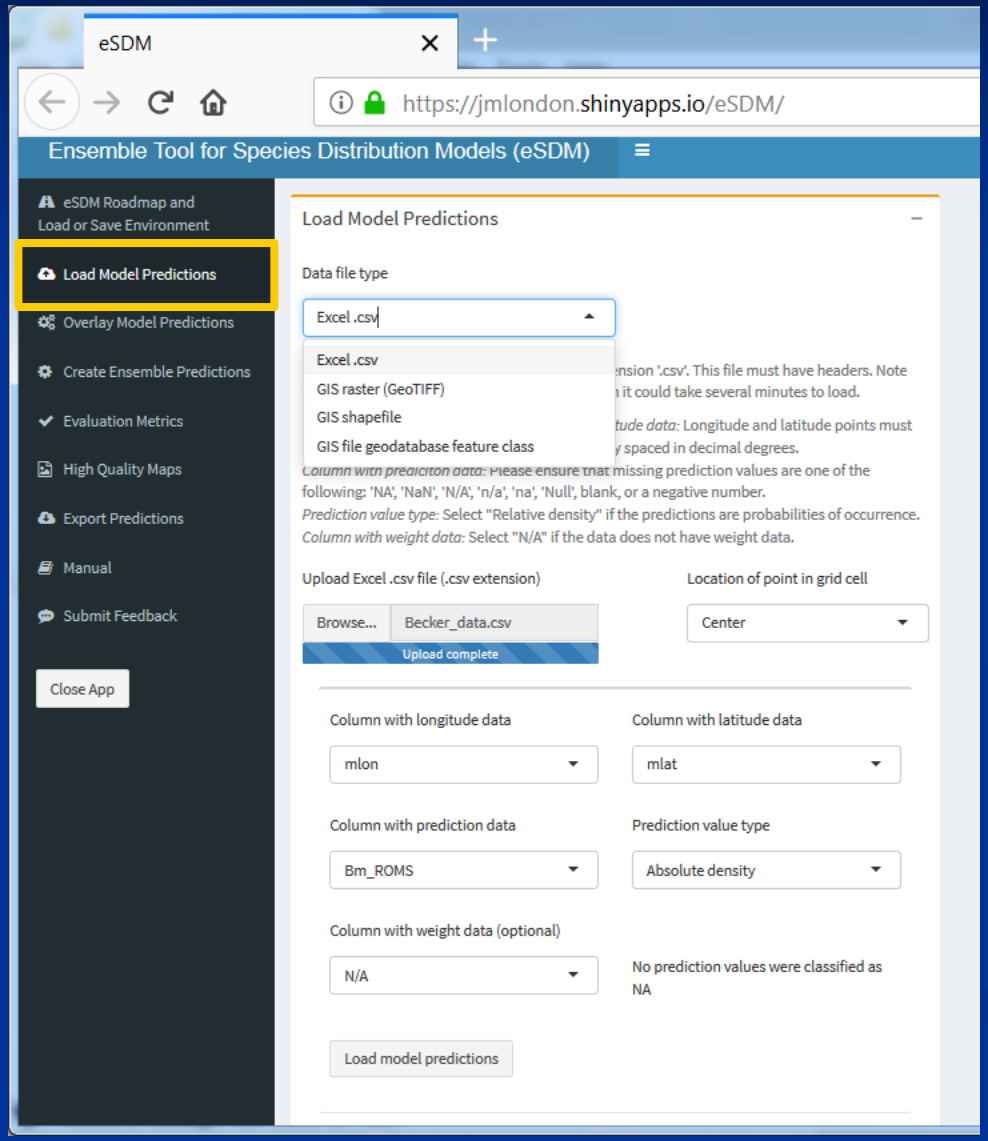
- Import options for .CSV and GIS files
- User-specified weights (for whole model, regions, individual pixels)
- AUC & TSS evaluation and weighting
- Scaling to absolute abundance or relative densities
- Validation of individual and ensemble models with external data sets
- Plotting tools
- Model export capabilities

eSDM Overview: Tabs for each step of ensembling process



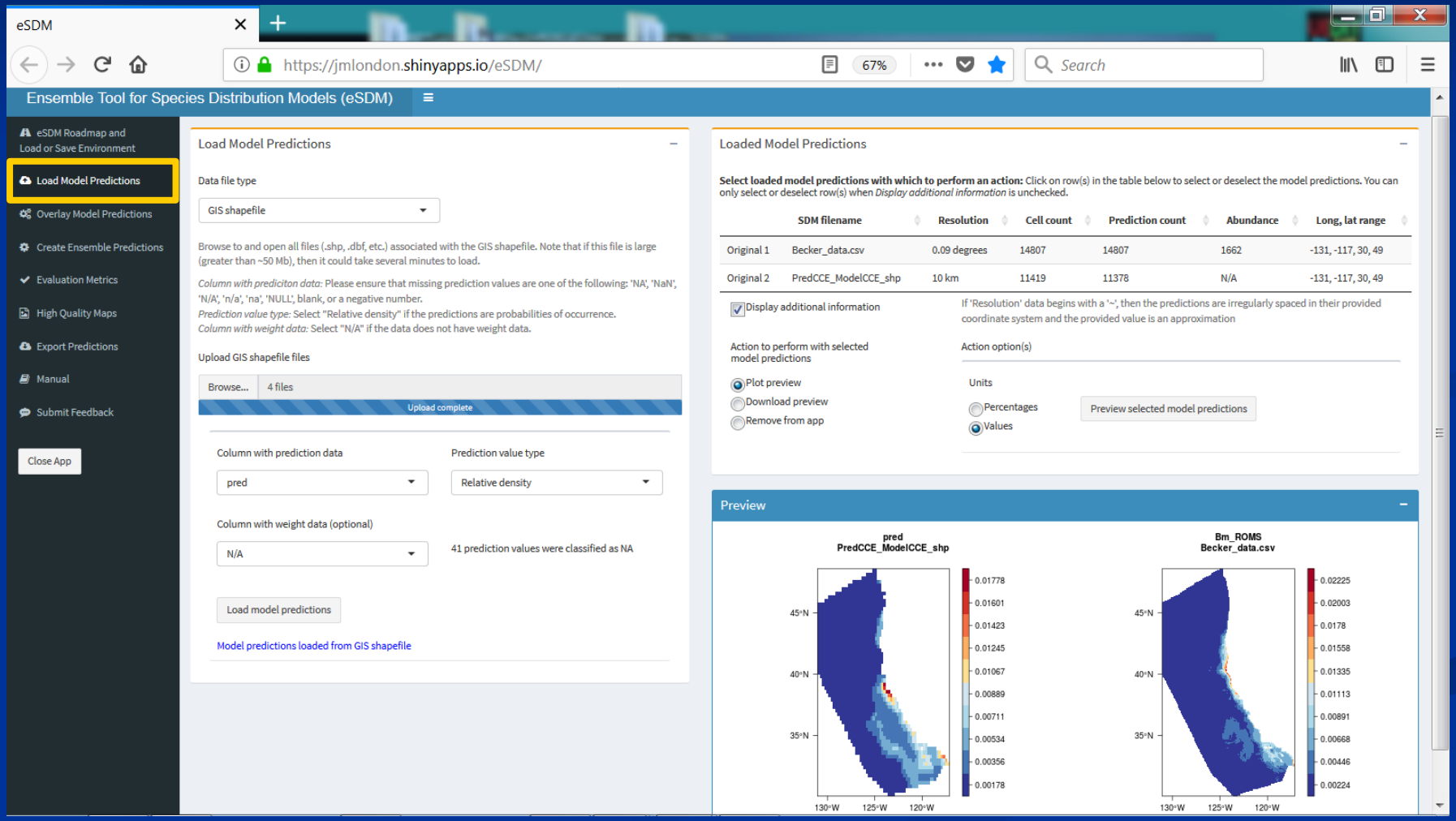
Context-specific tips and brief instructions

eSDM Overview: Load Model Predictions



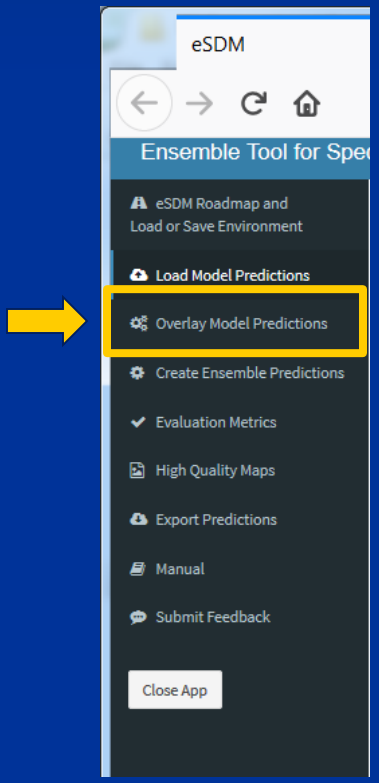
- Import options for .CSV and GIS files
- Can specify pixel-specific weights during loading
- Allows for absolute density or relative density values

eSDM Overview: Load Model Predictions
Model summary stats and preview



eSDM Overview: Overlay Model Predictions

The overlay process is the backbone of this tool, as it allows you to create ensemble models for grids developed with different coordinate systems and/or spatial resolutions.



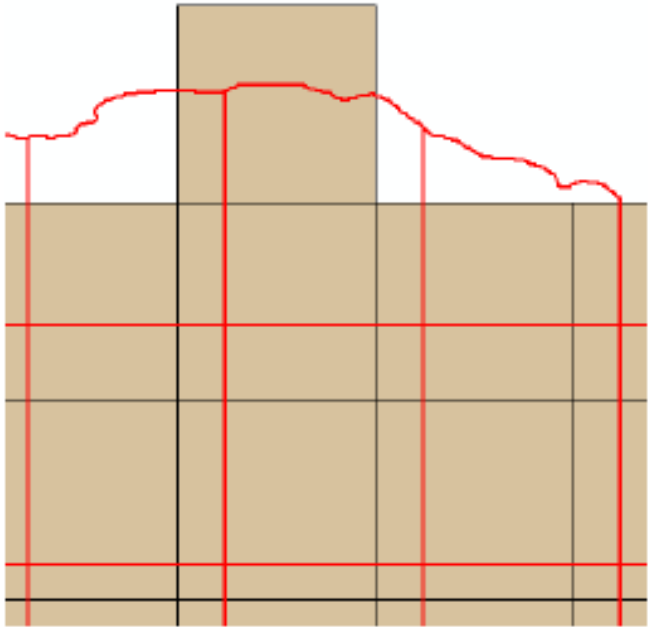


Figure 1

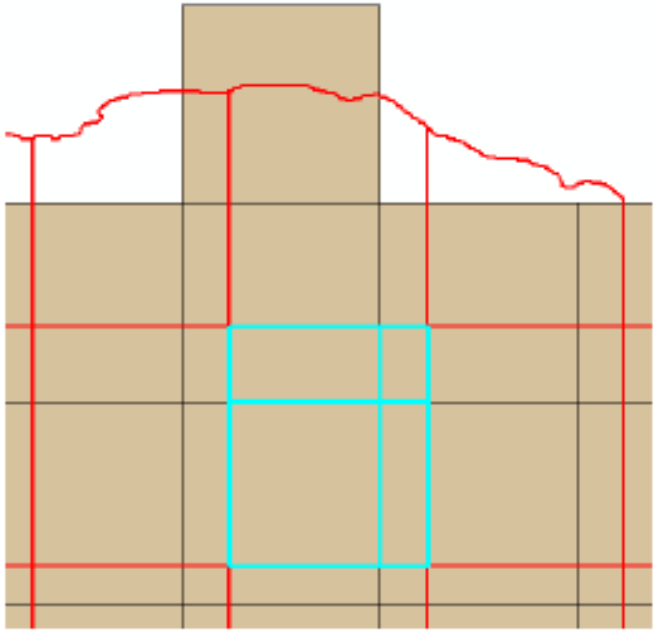
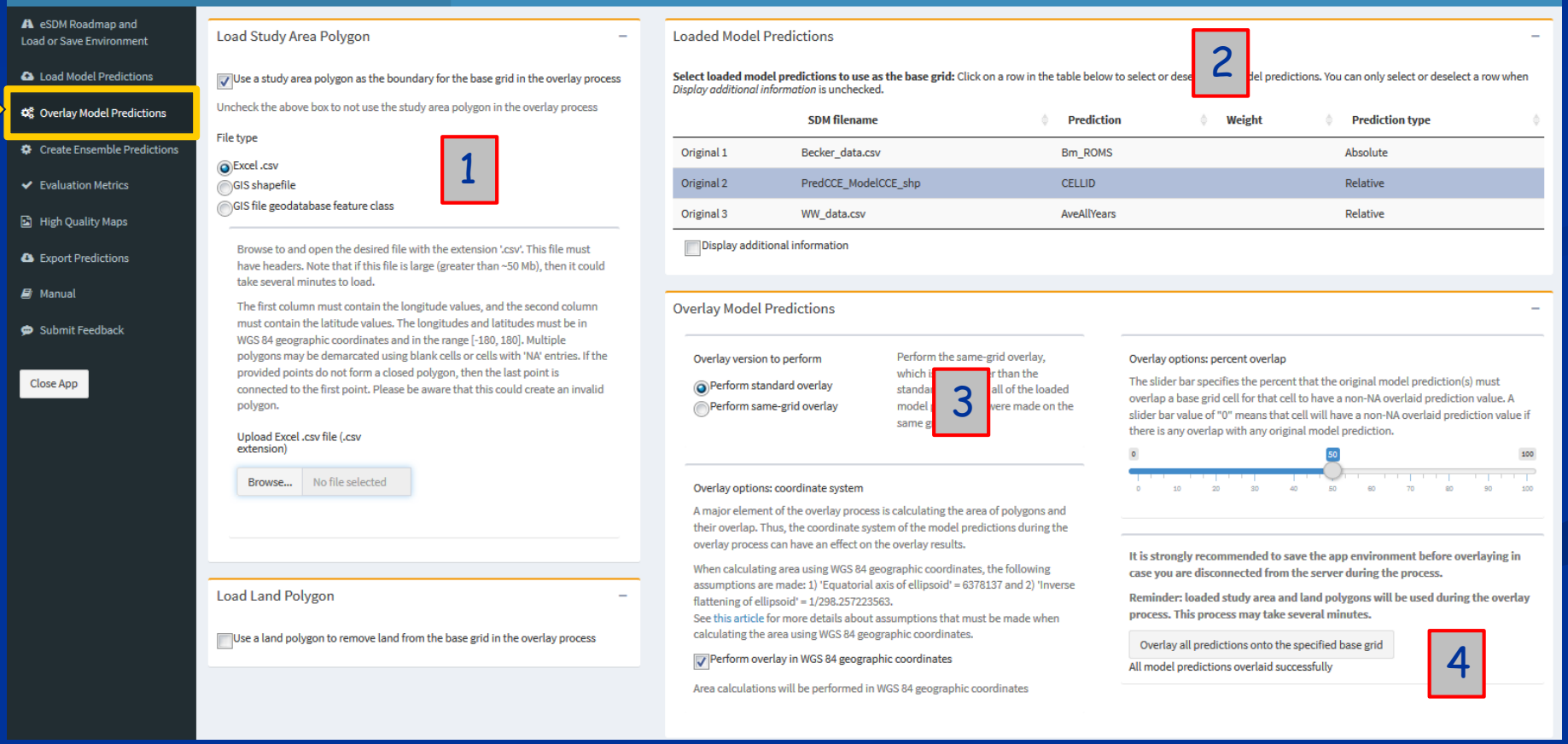


Figure 2

Woodman 2017 (eSDM User Manual)

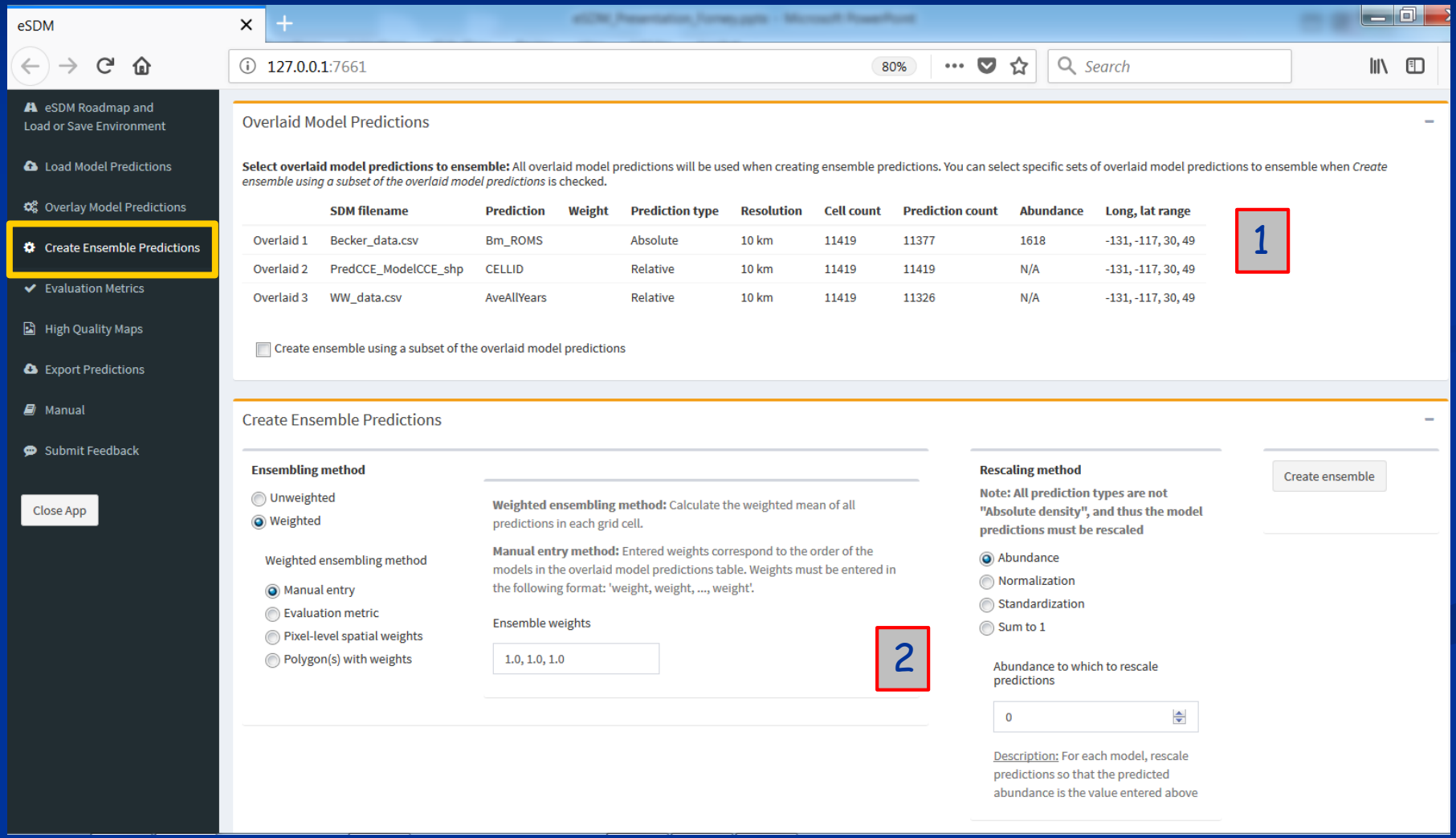
eSDM Overview: Overlay Model Predictions

1. Load any land or other study area polgygons (e.g. to clip model to smaller area)
2. Select the model to use as the base grid
3. Choose *Perform standard overlay* (or *Perform same grid overlay* if grids same)
4. Click on Overlay predictions onto specified base grid (can take a while)



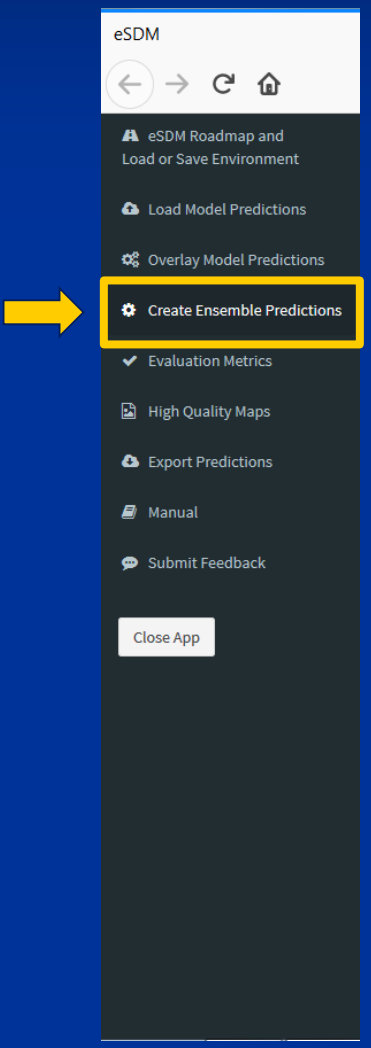
eSDM Overview: Create Ensemble Predictions

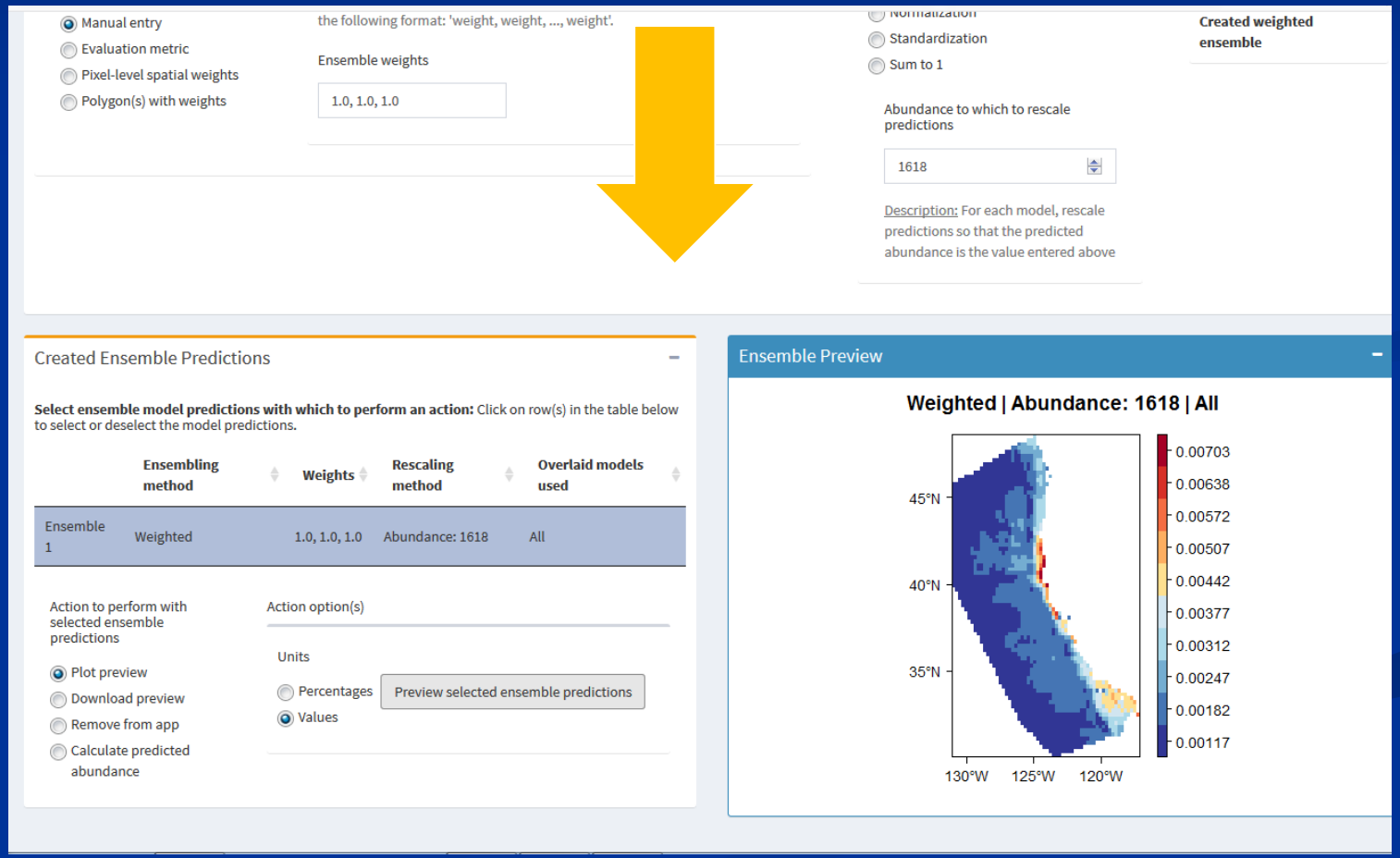
1. Select models to combine in ensemble (default is All)
2. Choose options for weighting and re-scaling



eSDM Overview: Create Ensemble Predictions

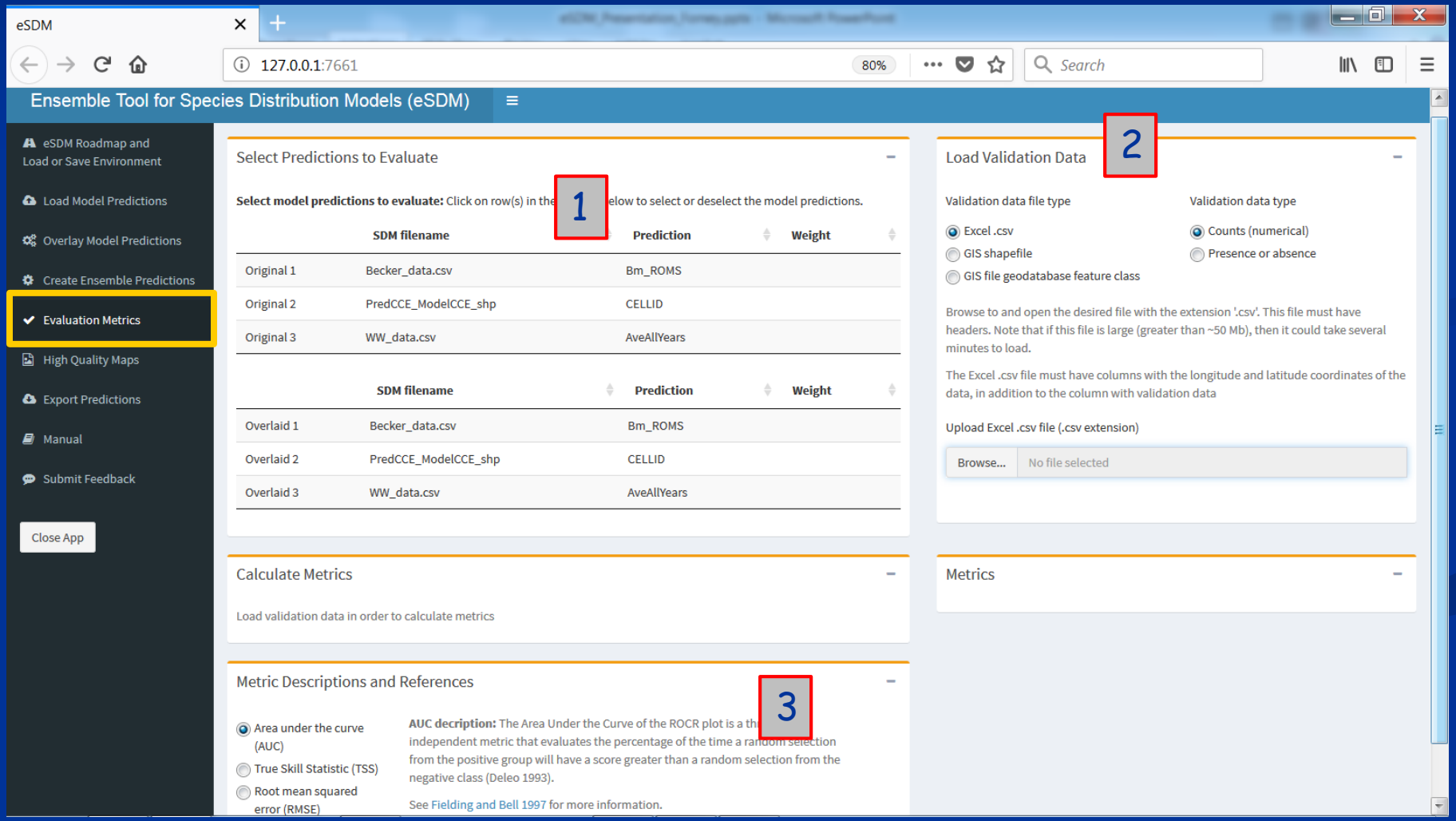
After creating ensemble model(s), scroll down to select and preview individual ensemble models





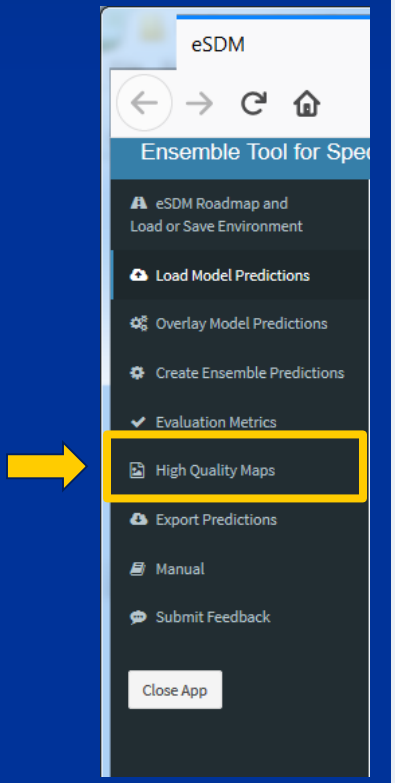
eSDM Overview: Evaluation Metrics

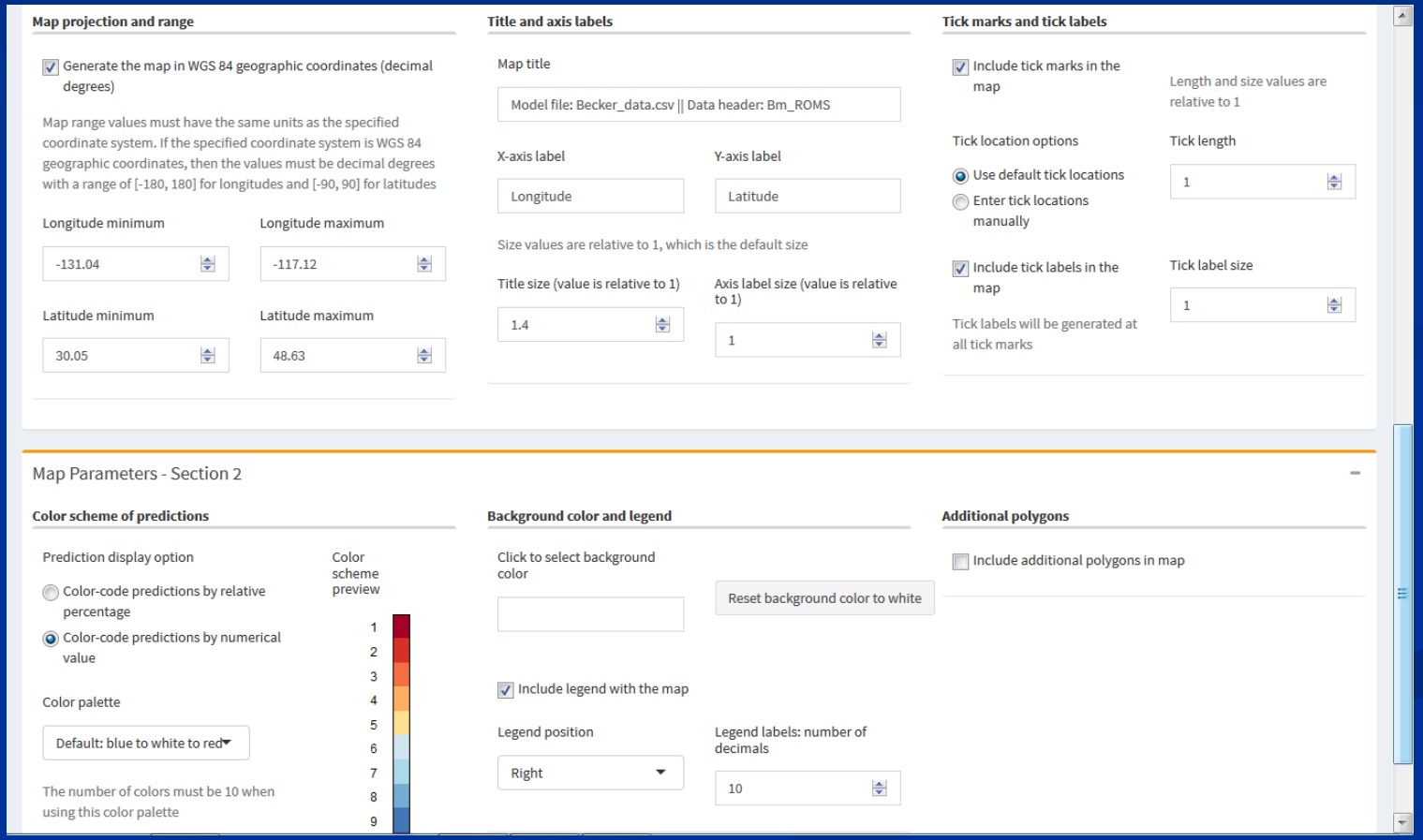
1. Select original models or overlaid models created previously
2. Load external validation data sets (if desired)
3. Select AUC, TSS, RMSE (can then be applied as weights)



eSDM Overview: High Quality Maps

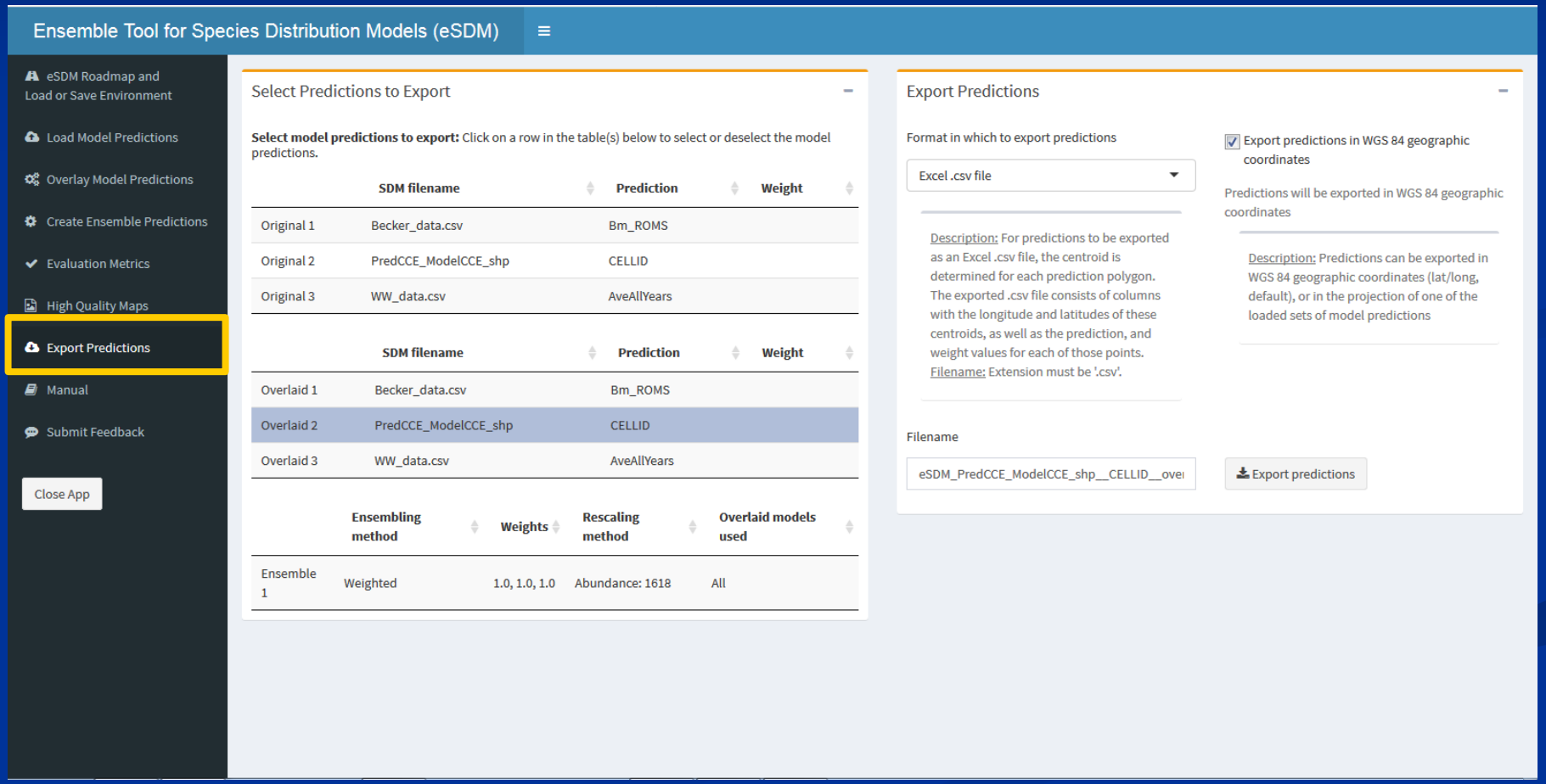
Can customize map dimensions, colors, and plotting options to create a high-resolution map (e.g. for publications)



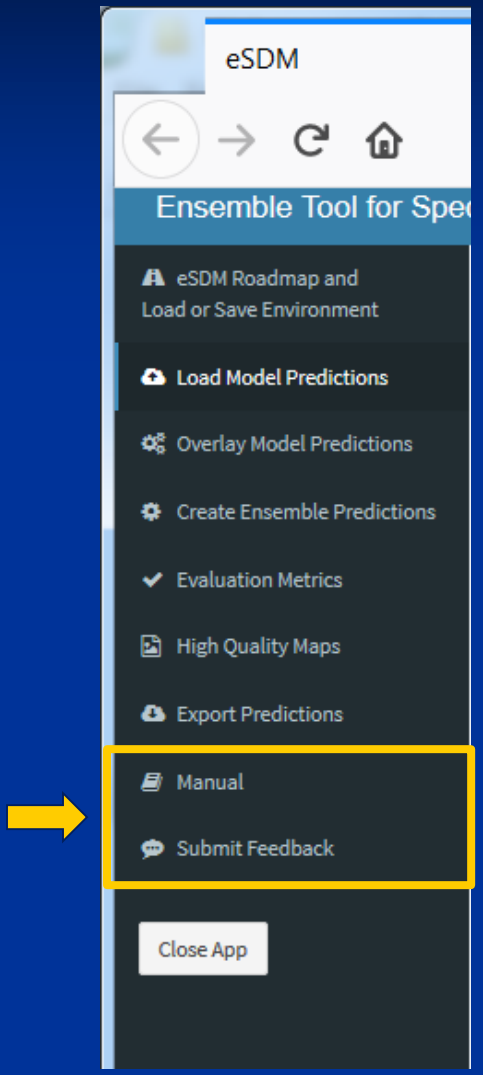


eSDM Overview: Export Predictions

All models in the eSDM can be exported as .CSV files, GIS shapefiles or as Google Earth .KML or KMZ files



eSDM Overview: User Manual, Feedback, Next Steps



- Each page has dynamic tips and instructions, but there is also a full user manual (PDF), which loads automatically when the *eSDM* opens. It can also be accessed via the 'Manual' tab
- Below this tab, there is a link to submit feedback and report bugs (Please!?!)
- Sam Woodman will return from the field at the end of April 2018 and will make fixes, improvements, and release the revised *eSDM* tool and a supporting paper (target date: September 2018).
- We hope that the *eSDM* will be broadly useful to scientists and managers to explore models, model uncertainty, and inform future management decisions.

Acknowledgments

- NOAA National Marine Fisheries Service:
  - Office of Science and Technology
    (esp. Mridula Srinivasan, Amber Bellamy, Jeanette Davis)
  - Southwest Fisheries Science Center
  - Eric Ward, (NWFSC, as co-Lead for Protected Species Spatial Team)
  - Josh London (AFSC/MML, for hosting the *eSDM* ShinyApp)

- U.S. Navy
- International Whaling Commission

- All the colleagues who have provided support and feedback to date, esp. Monica DeAngelis, Elliott Hazen, Kristin Mabry, Daniel Palacios, Debra Palka, Penny Ruvelas, Doug Sigourney, Mridula Srinivasan

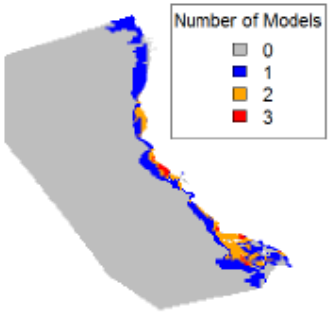
THANK YOU!

Delta plots

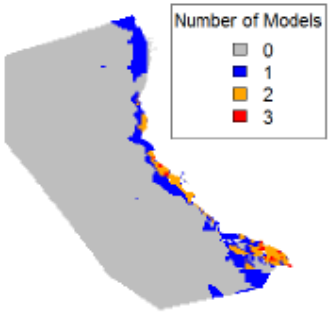
This PDF was later amended to make the document 508 compliant.

Overlap of highest 5% of predictions

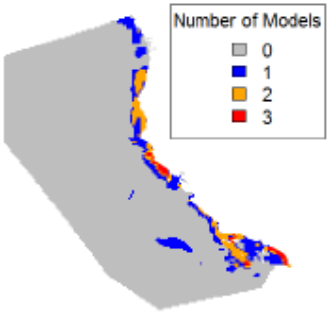
2001 Delta 0.05



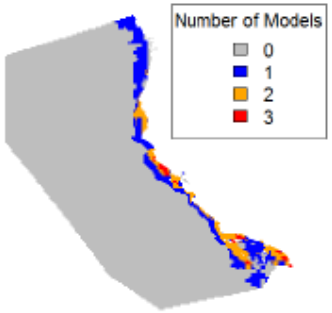
2005 Delta 0.05



2008 Delta 0.05

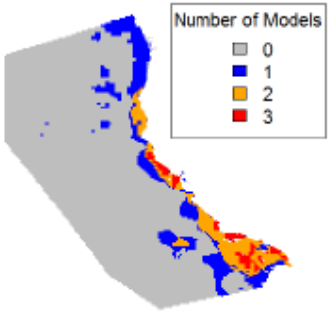


All Years Delta 0.05

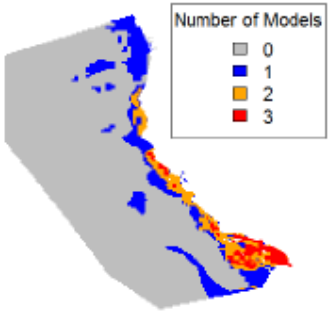


Overlap of highest 10% of predictions

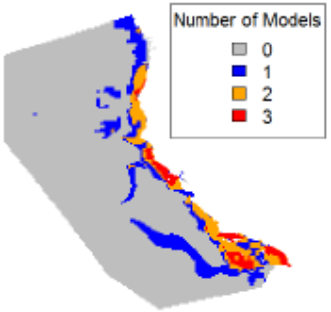
2001 Delta 0.10



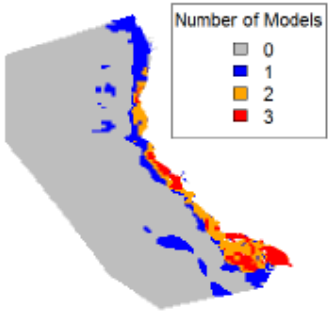
2005 Delta 0.10



2008 Delta 0.10



All Years Delta 0.10



Only one model has high predicted densities north of 40° latitude – suggests we need an objective method of evaluating and weighting models geographically