Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico

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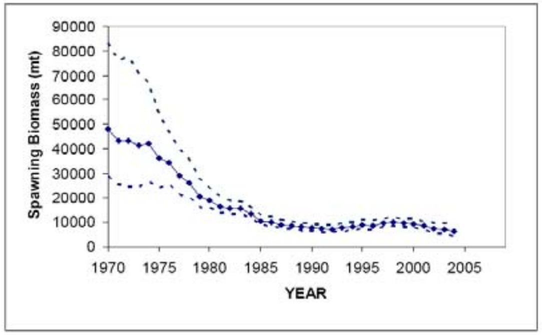
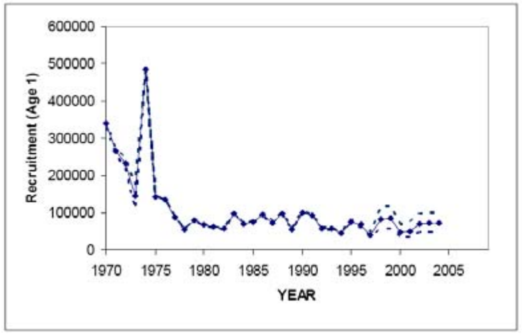
Bluefin tuna biology and life history

- Atlantic Bluefin Tuna (*Thunnus thynnus*) is a large, highly migratory species which ranges throughout the Atlantic ocean
- However the vast majority of spawning occurs only in the Gulf of Mexico, and Mediterranean Sea
- Exploitation has been historically high, and stocks declined steeply in the 1970s (ICCAT)

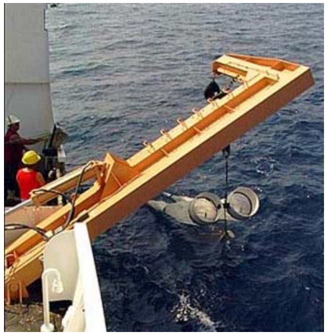


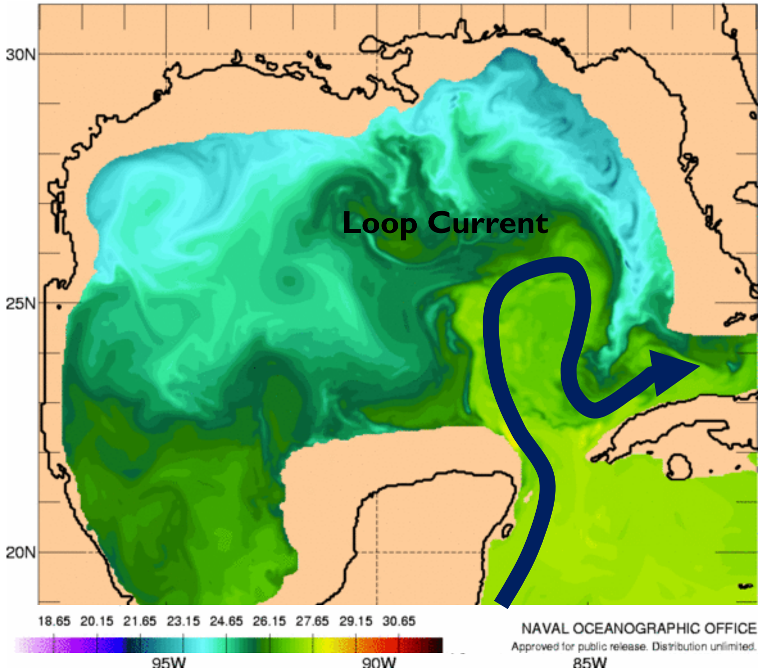


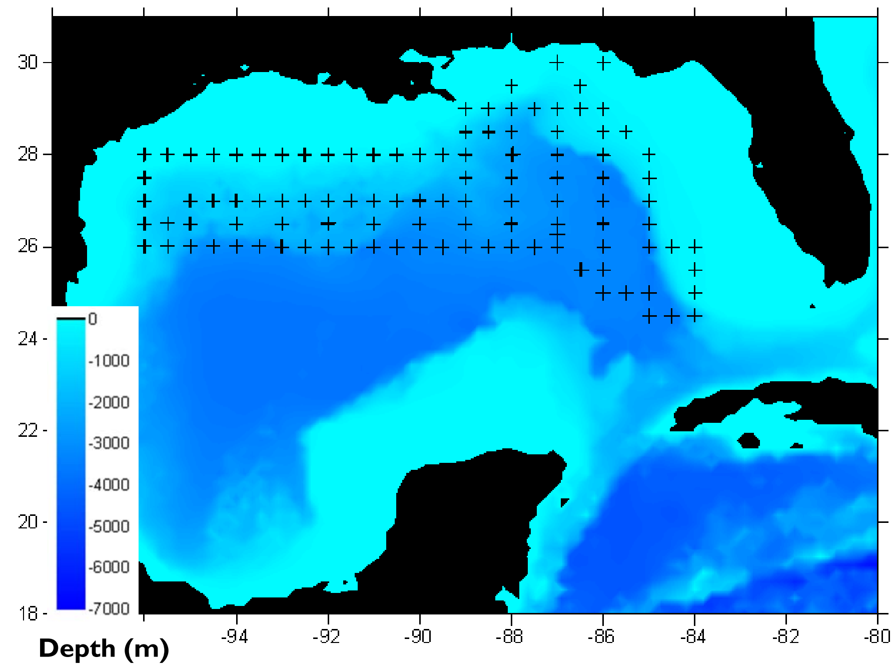
Western Atlantic Bluefin Tuna: Median estimates of spawning biomass and recruitment (ICCAT)

Sampling for bluefin tuna larvae

- Current information on spawning habitat is partially obtained from larval distributions
- Annual spring (April – June) plankton surveys targeting bluefin tuna larvae have been completed across the northern Gulf of Mexico since 1977
- Sampling methods included bongo net tows, neuston net tows, and CTD casts for environmental data

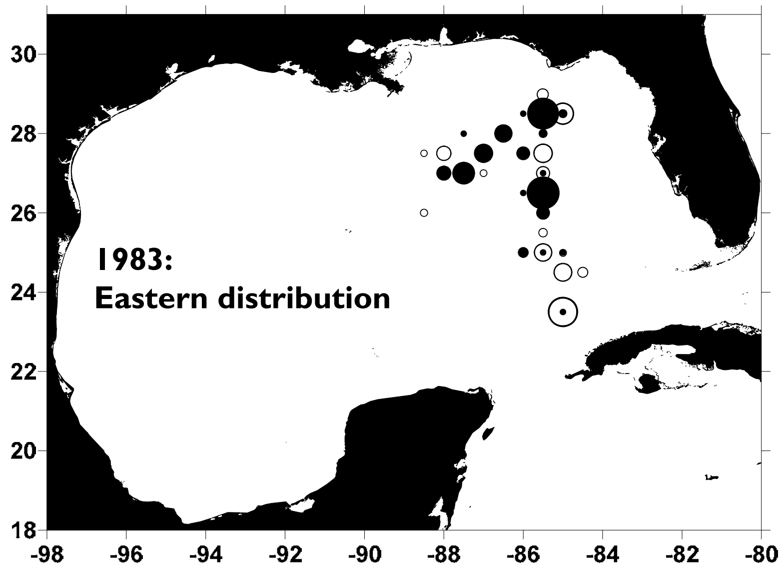


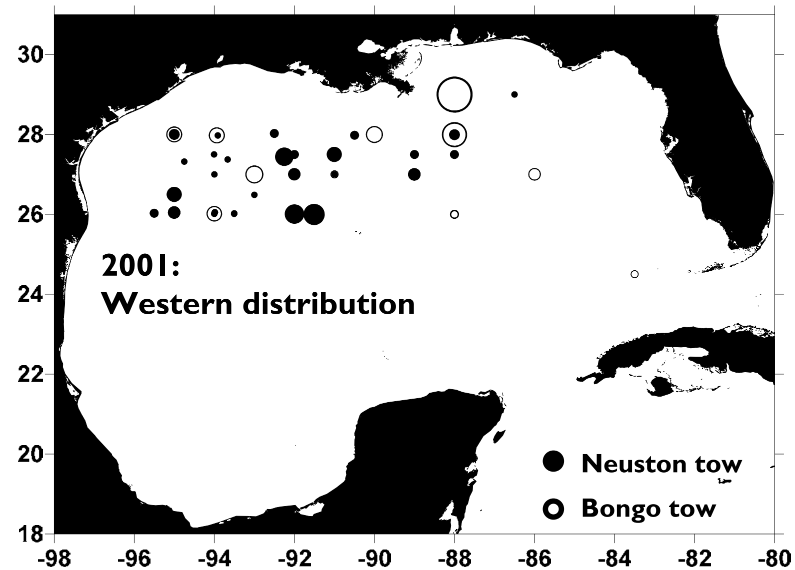




Spawning biomass and larval abundance

- Bluefin larval abundance and distributions in the Gulf of Mexico have been highly variable spatially and temporally over the past 30 years



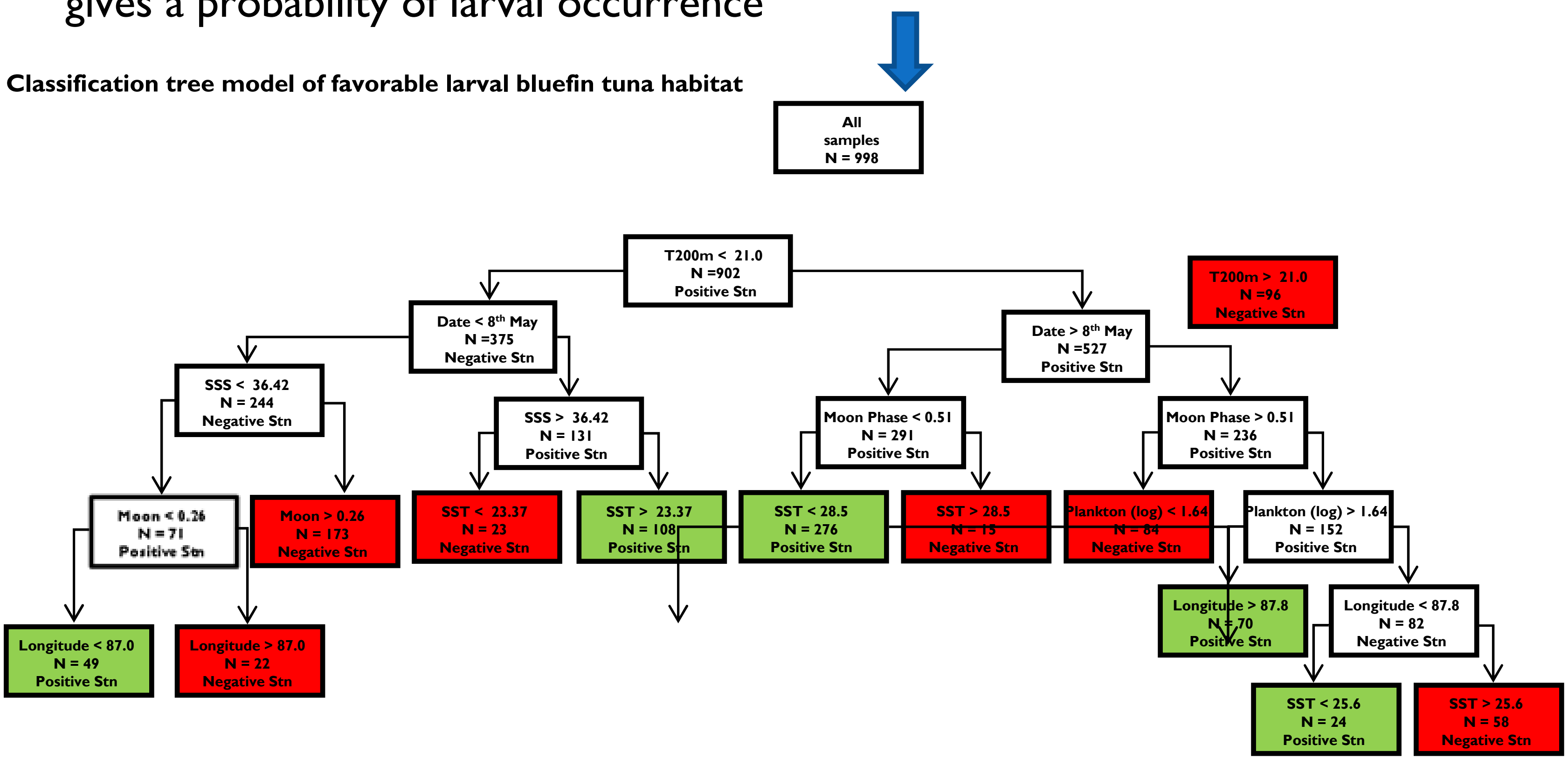


- Much of this variability can be accounted for by interannual variation in the strength and position of oceanographic features, such as the Loop Current, warm Loop Current eddies and low salinity river plumes
- A simple modeling approach was used to identify oceanographic habitats of low, and high, favorability for the collection of bluefin tuna larvae

Classification tree modeling

- Algorithms sequentially split the dataset into two groups using environmental variables
- Each split attempts to separate conditions which are favorable, and unfavorable, for larval bluefin tuna occurrence
- Each station sampled can be classified into one of the terminal nodes, which gives a probability of larval occurrence

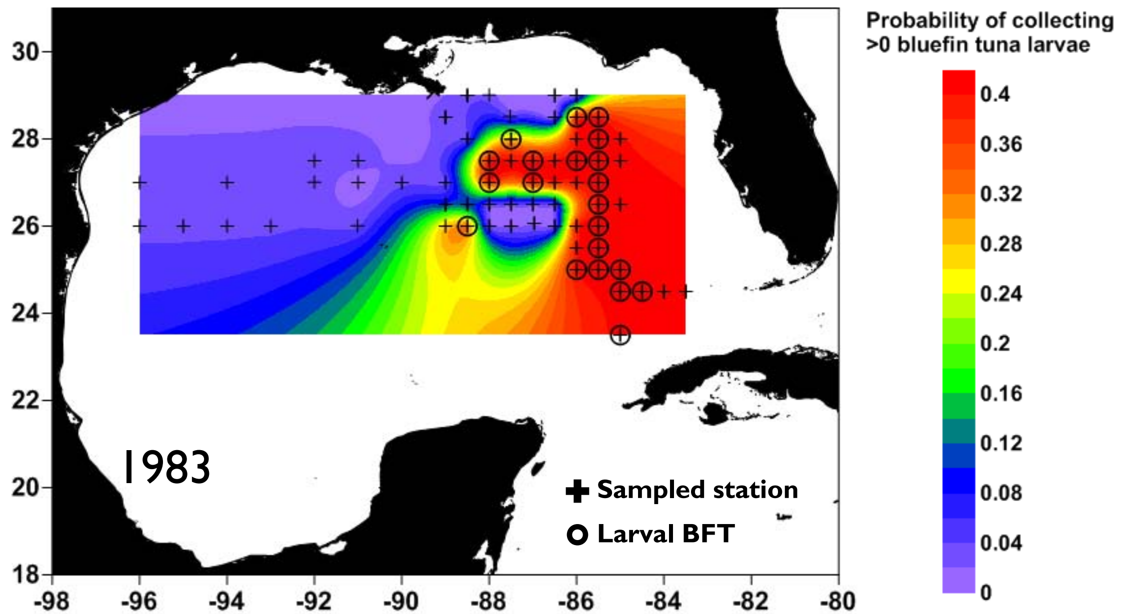
Classification tree model of favorable larval bluefin tuna habitat



(Muhling *et al.*, submitted)

Habitat modeling results

- A variety of variables defined the habitat model, however most bluefin tuna larvae were collected at surface temperatures from ~ 23.5 to 28.5°C, and cooler temperatures at 200m depth
- Although well adapted to survive cold water on feeding grounds, adult bluefin tuna are less well adapted to very warm waters (Blank *et al*., 2004)
- Adult bluefin tuna during spawning season in the Gulf of Mexico may prefer areas where surface temperatures are ~ 24 – 27°C (Teo *et al*., 2007). Water of ~25°C may best favor larval development (Miyashita et al., 2000)
- *How might this species respond to climate change conditions?*



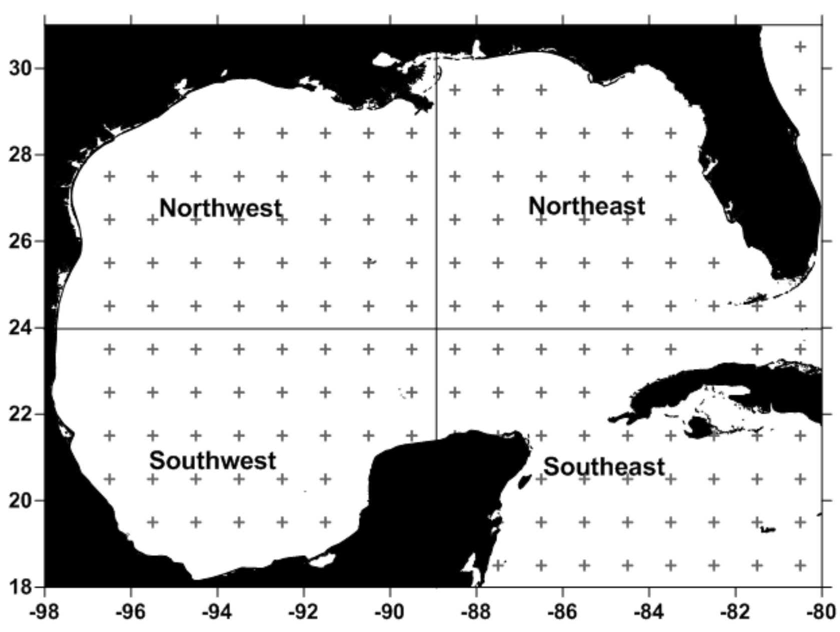
Predicted favorable habitat for larval bluefin tuna in 1983, and larval catch locations

Downscaled climate models

- Climate-related effects on bluefin tuna spawning in the Gulf of Mexico are likely to be related to temperature and salinity changes, and physical oceanographic regimes
- To assess the climate-related changes in regional physical oceanographic features, we will use a high-resolution (10km) regional ocean model constrained with boundary conditions obtained from the IPCC models under three CO_2 emission scenarios
- The regional ocean model will be initialized and integrated for 1970 to 2000 using the IPCC models under the climate of the 20th century scenario. Then, the same model will be further integrated between 2000 and 2100 under the three CO_2 emission scenarios
- Once the model down-scaling has been completed, we will assess the effects of a range of climate change scenarios on bluefin tuna spawning patterns, and on the GOM ecosystem

Initial data exploration

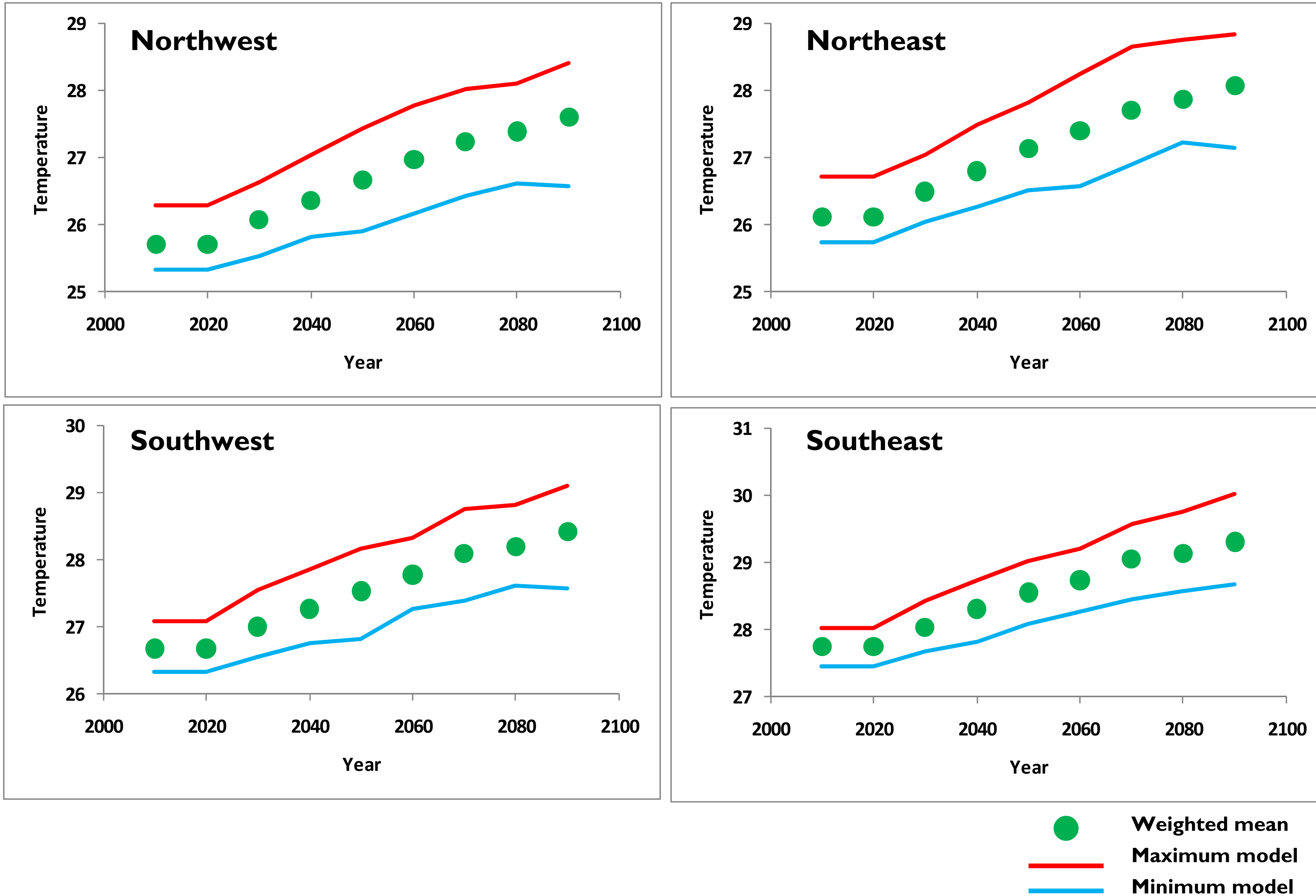
- Model downscaling has not yet been completed
- However, we used temperature predictions from a suite of IPCC models under scenario SRES A1B to make preliminary assessments on potential changes in spawning habitat
- We first ranked, and weighted, each model on its ability to hindcast temperature in each of the four zones of the Gulf of Mexico for the last 30 years of the 20th century, compared to recorded observations
- Models were assessed on their ability to replicate the mean, and variance, of temperature at the surface, 100m depth and 200m depth for the months of April, May and June



Model	Model Ranking	Model Weight
ingv_echam4	1	0.88
bccr_bcm2_0	2	0.82
miroc3_2_medres	3	0.76
gfdl_cm2_1	4	0.76
iap_fgoals1_0_g	5	0.62
mri_cgcm2_3_2a	6	0.59
csiro_mk3_0	7	0.53
ncar_ccsm3_0	8	0.53
csiro_mk3_5	9	0.50
cnrm_cm3	10	0.38
cccma_cgcm3_1_t63	11	0.38
miub_echo_g	12	0.32
giss_aom	13	0.26
mpi_echam5	14	0.26
gfdl_cm2_0	15	0.24
giss_model_e_h	16	0.09
ncar_pcm1	17	0.06
giss_model_e_r	18	0.00
ipsl_cm4	19	0.00

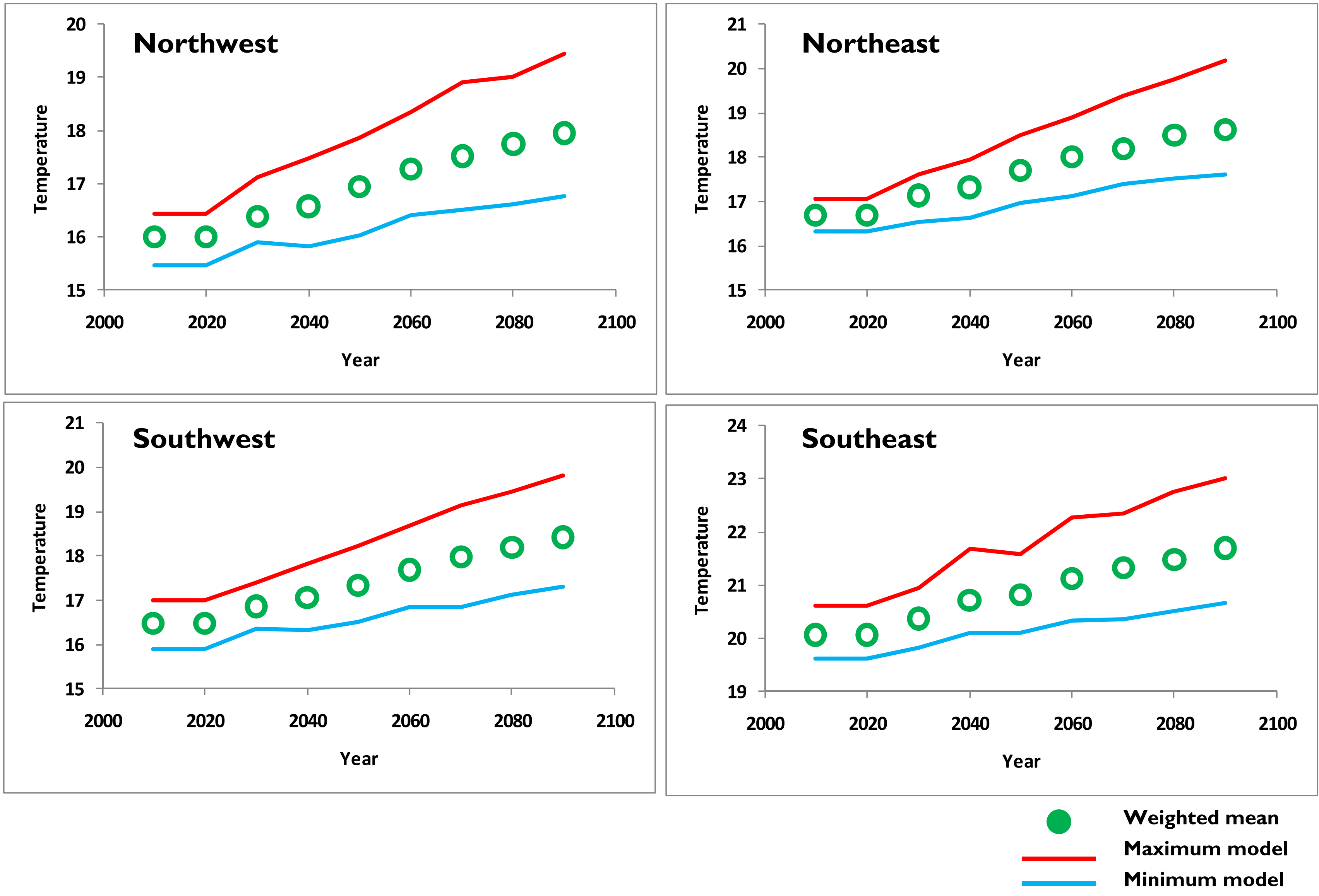
Predicted surface temperature

- May surface temperatures are predicted to increase between ~ 1.5 and 2.0°C



Predicted temperature at 200m

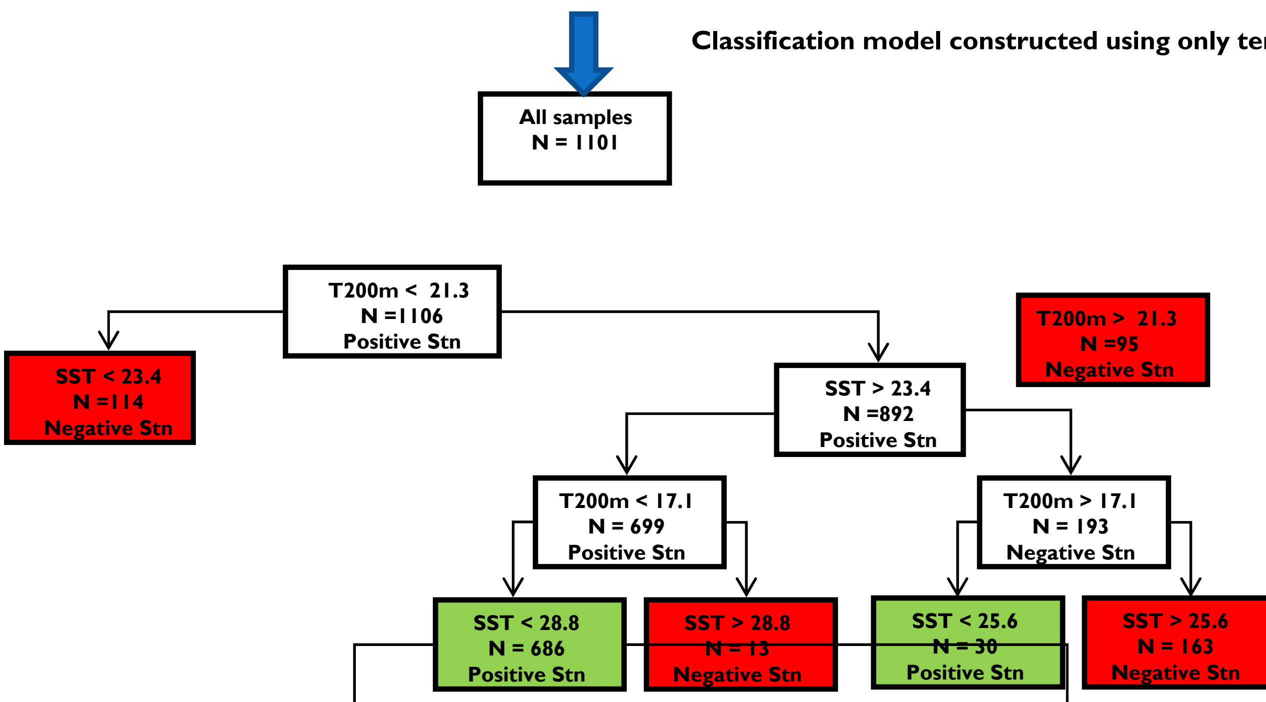
- May temperatures at 200m are predicted to increase ~ 1.5 °C



Predicting habitat extent

- The classification model was re-run to include only temperature at the surface, and at 200m depth
- The projected temperature conditions in the Gulf of Mexico from IPCC models were run through the classification model
- Changes in theoretically favorable habitat for larval bluefin tuna was then assessed

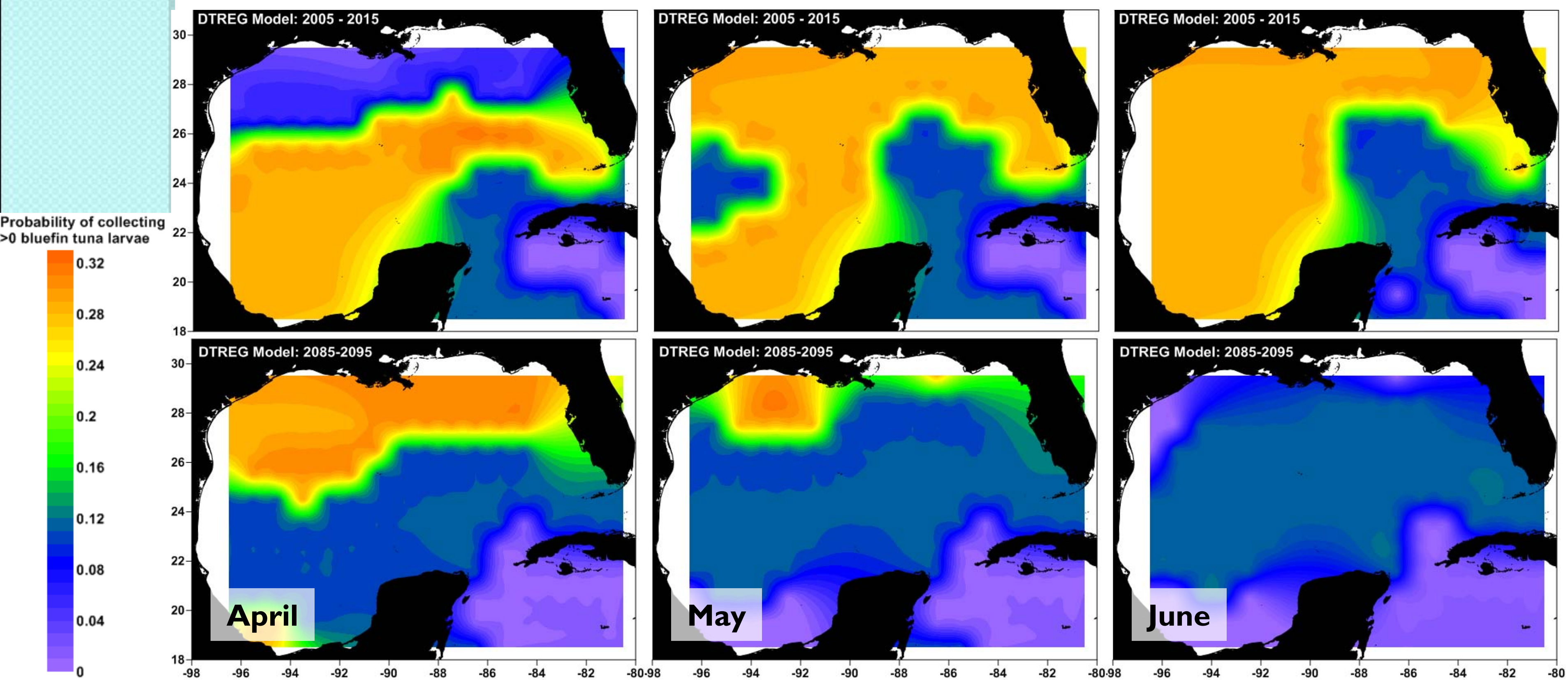
Classification model constructed using only temperature



Habitat extent under climate change conditions

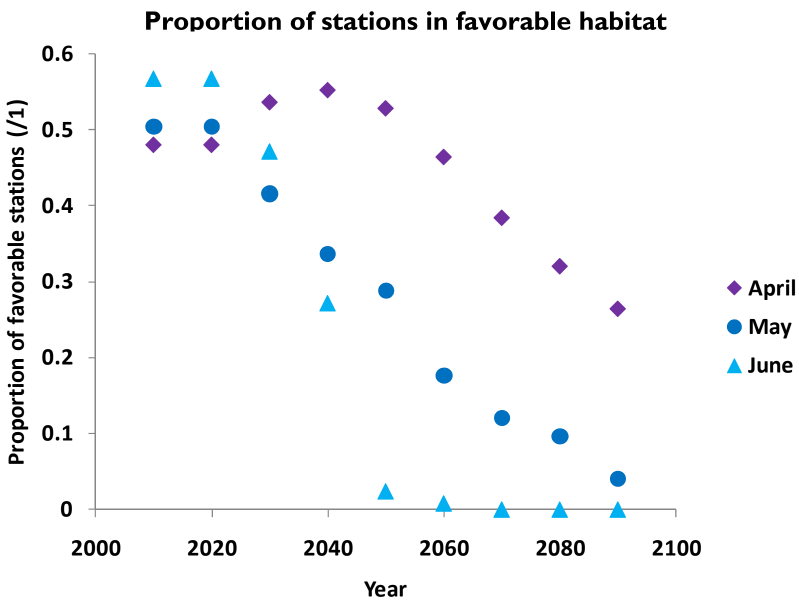
- **April**: Good habitat moves further north, as northern shelf is no longer prohibitively cool
- **May**: Good habitat across US EEZ is largely lost. Some habitat remains in the northwest
- **June**: Habitat is largely lost, across the Gulf of Mexico

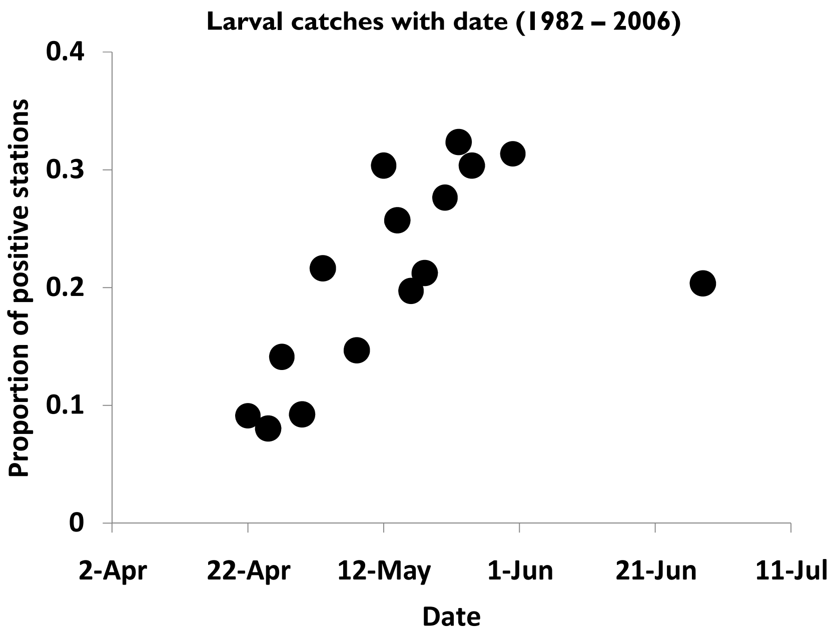
Projected changes in favorable habitat extent between the present, and 2085 - 2095



Changes in favorable larval habitat

- The proportion of grid points that were classified as likely to contain larvae showed a decrease over time, with decreases in May and June more pronounced than in April
- The probability of collecting larvae currently peaks at the end of May
- Although spawning tends to occur at temperatures above 24C, triggers for adult bluefin tuna spawning are not well known

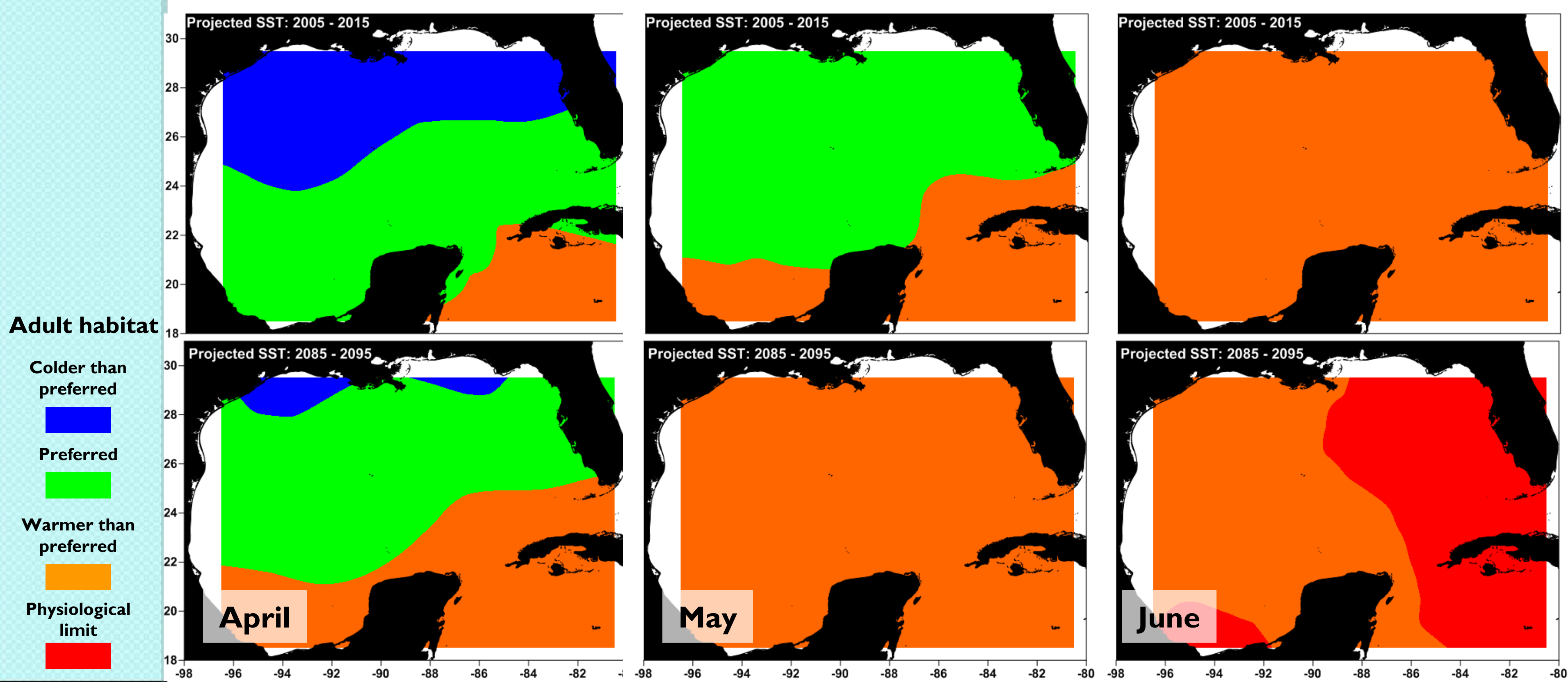




Predicted range of adult bluefin tuna

- Distributions of larvae are ultimately determined by adult spawning locations. However, little is known about the preferred spawning habitat of adult bluefin tuna
- Tagging data suggest that areas with surface temperatures of ~ 24 – 27°C may be preferred (Teo *et al.*, 2007). Temperatures of > 30°C are likely to be highly unfavorable
- Distributions of these ranges under projected temperature conditions were examined

Projected changes in theoretical adult bluefin tuna habitat extent between the present, and 2085 - 2095



Conclusions

- A suite of climate models predict substantial temperature increases in the Gulf of Mexico through the 21st century. Changes will occur at the surface, and at depth
- Spawning habitat for bluefin tuna may be reduced in size, and favorable conditions may occur earlier in the season
- Downscaling climate models will enable us to examine the projected behavior of mesoscale oceanographic features, such as the Loop Current, and eddies
- Future work will also examine potential effects of changes in salinity on spawning habitat
- Further work is needed on adult bluefin tuna spawning habitat preferences

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