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Climate change impacts on spawning grounds of Atlantic tunas in the northern Gulf of Mexico

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Introduction

Atlantic bluefin tuna (*Thunnus thynnus*) is a wide-ranging species found throughout the Atlantic Ocean. However, within the western North Atlantic, significant spawning activity has not been recorded outside the Gulf of Mexico. While bluefin tuna can tolerate colder waters than other tunas, they are adversely affected by warm waters. Conditions within the Gulf of Mexico during the spring spawning season often approach the upper limits of tolerance for this species. A predictive habitat model for bluefin tuna larvae in the Gulf of Mexico has been produced using historical data (Muhling *et al.*, 2010). Larvae were primarily collected between early May and mid June, within a defined temperature range, suggesting a limited spawning window. Because of these preferences, and their reproductive biology, bluefin tuna populations show high vulnerability to the projected warming effects of climate change. In contrast, although yellowfin tuna (*T. albacares*), blackfin tuna (*T. atlanticus*) and skipjack tuna (*Katsuwonus pelamis*) also initiate spawning in the Gulf of Mexico during spring, these species increase their spawning activity with water temperature, without a defined upper limit.

Methodology

As a first step in determining climate change impacts on tuna spawning in the Gulf of Mexico during spring, we applied future predictions of water temperature at the surface and at 200m depth to existing spawning habitat models. Separate models were constructed for bluefin tuna, skipjack tuna and yellowfin/blackfin tuna, using artificial neural networks. The latter two species were combined, as they are not possible to distinguish visually at early larval stages. Temperature predictions were sourced from a dynamically downscaled climate model for the Gulf of Mexico and Caribbean, projected under CO_2 emission scenario SRES A1B (720 ppm stabilization). Potential temporal and spatial changes in spawning habitat for bluefin, yellowfin/blackfin and skipjack tunas in the Gulf of Mexico were then quantified for the middle and end of the 21st century, for the months of March, April, May and June.

Results and Discussion

Spring spawning grounds for bluefin tuna were predicted to increase slightly in March, and decrease through April, May and June (Fig. 1). By 2090, there was predicted to be little suitable spawning habitat for bluefin tuna in the Gulf of Mexico. In contrast, spawning grounds of tropical tunas were predicted to increase (Fig. 2).

Mean monthly probabilities of occurrence for both yellowfin/blackfin tuna and skipjack tuna in the Gulf of Mexico were predicted to increase approximately 10-20% during all spring months, between the late 20th and 21st centuries (Fig. 3). Mean probabilities of occurrence for bluefin tuna larvae were not predicted to change markedly between the late 20th and 21st centuries during March and April, however losses in spawning habitat were predicted for May and June.

This work has significant implications for the future management of highly migratory tunas in the western Atlantic Ocean. Tropical tuna species may be favorably affected by warming water temperatures in the Gulf of Mexico, and may be able

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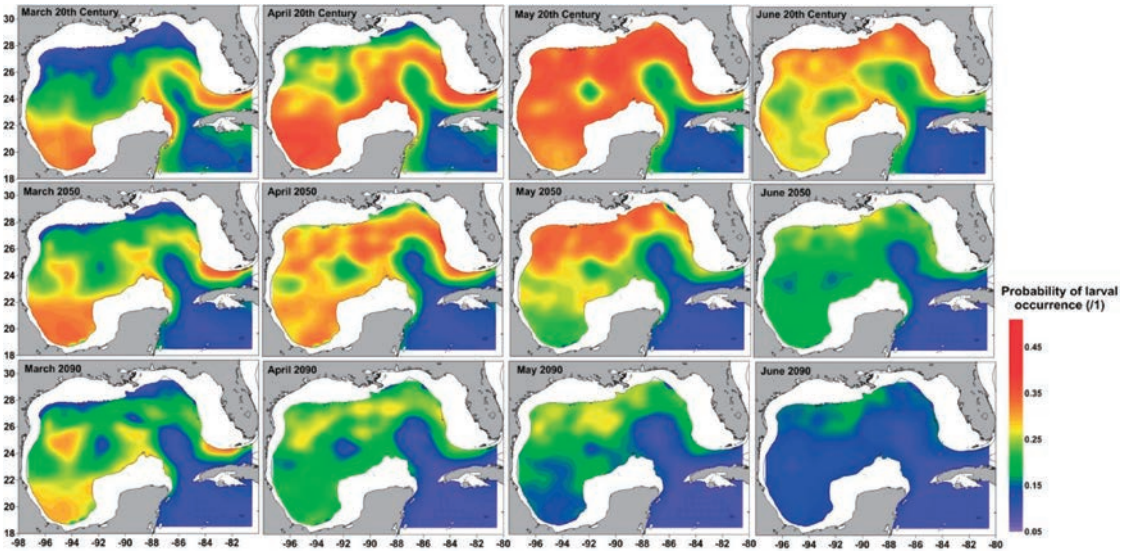

Fig. 1. Prediction of the extent of habitat suitable for the occurrence of larval bluefin tuna in the Gulf of Mexico under late 20th century conditions (1971 to 1999), and projected conditions in 2050, and 2090, for the months of March, April, May and June. The probability of occurrence (%) is shown, based on output from the artificial neural network model using weighted mean temperature values.

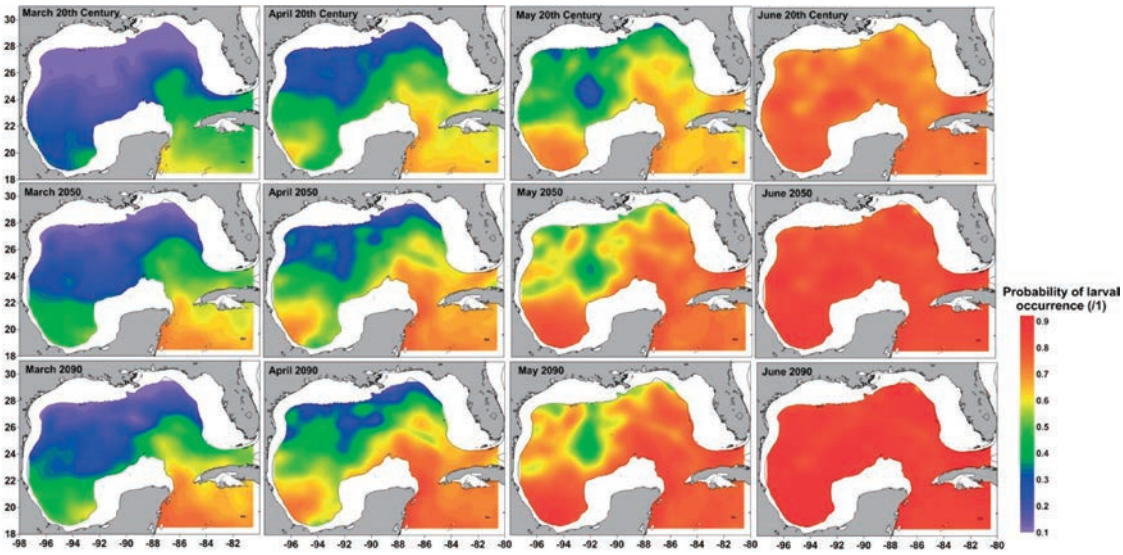

Fig. 2. Prediction of the extent of habitat suitable for the occurrence of larval yellowfin/blackfin tuna in the Gulf of Mexico under late 20th century conditions (1971 to 1999), and projected conditions in 2050, and 2090, for the months of March, April, May and June. The probability of occurrence (%) is shown, based on output from the artificial neural network model using weighted mean temperature values.

to commence spawning earlier in the year. In contrast, the spawning season of bluefin tuna may be shifted or truncated, largely due to the physiological tolerances of adult fish. Bluefin tuna migrate long distances to reach their Gulf of Mexico spawning grounds, and their ability to adapt spawning strategies to a changing environment remains largely unknown. The potential impacts of climate change may thus be significant and unfavorable for this species.

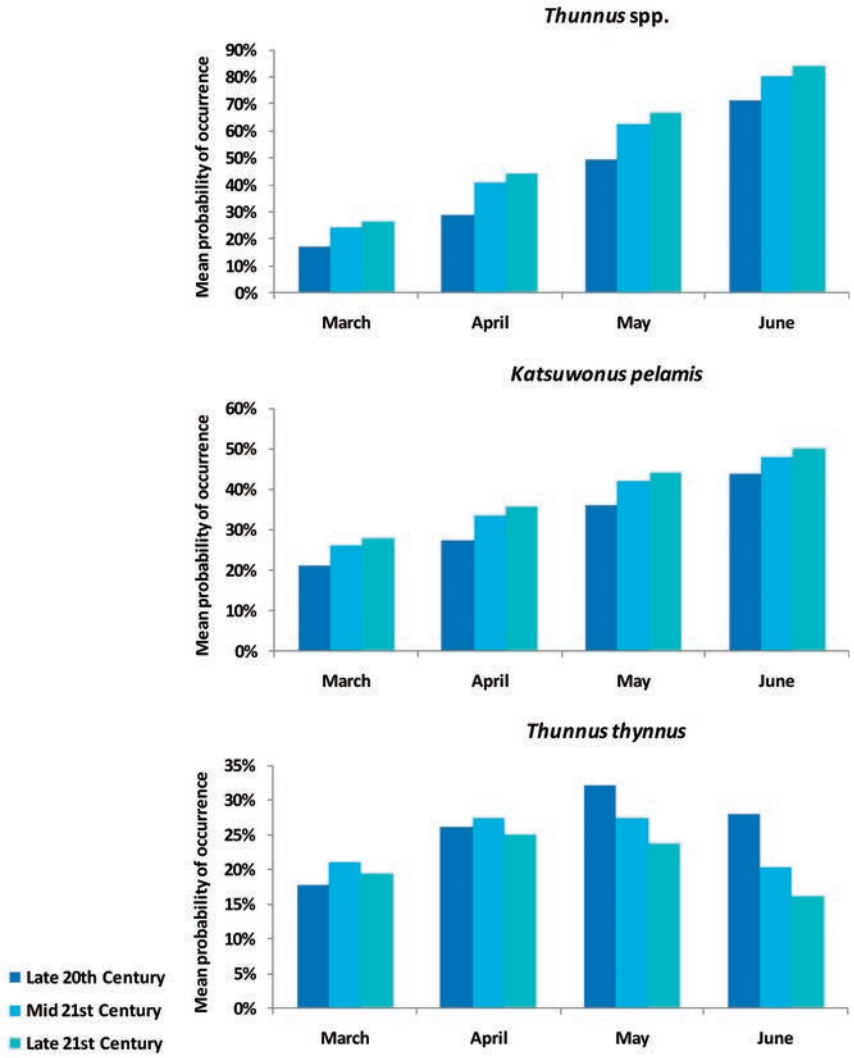

Fig. 3. Mean probability of occurrence by month for larval yellowfin/blackfin tuna (top), skipjack tuna (middle) and bluefin tuna (bottom) during the late 20th century, mid 21st century, and end 21st century. Probabilities are shown for the months of March, April, May and June.

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