The effect of increasing sea surface temperatures (SSTs) on tropical and temperate fish biodiversity

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Introduction

As sea surface temperatures (SSTs) continue to rise, marine ecosystems are among the most vulnerable to the impacts of global warming. In contrast to terrestrial regions, thermal refugia are less readily available for marine species. As ectotherms, marine fish are highly responsive to changes in temperature, which plays a fundamental role in critical biological processes such as reproduction, growth and metabolism [5]. Biodiversity responses to rising SSTs are expected to be more immediate and severe in marine ecosystems [1]. Tropical marine species are projected to have the highest rates of extirpations because of their narrower temperature tolerances [1]. Rising SSTs will force these species to exist closer to their critical thermal limits (CTmax) where motor function becomes deregulated [9].

Our study intends to investigate how rising SSTs in the northern hemisphere influence biodiversity rates of marine fish species across temperate and tropical regions, given their current thermal tolerances. We hypothesize that in the northern hemisphere, rising SSTs in temperate and tropical regions will drive marine fish species to operate closer to their CTmax leading to latitude-dependent shifts in biodiversity rates. From this hypothesis, we predict: 1) In tropical regions, rising SSTs will lead to a decrease in species richness as more species approach or exceed their CTmax, resulting in extirpations. 2) Species richness in temperate regions will increase as tropical species shift poleward. 3) Across latitudes, rising SSTs will cause marine fish species with lower relative thermal tolerance to experience more pronounced declines in abundance over time.

Methods

We will merge three global datasets to create a new working dataframe. *BioTime* is a global dataset comprised of 30 studies from 1874 to 2016 that quantifies biodiversity change across time with over 951,566 entries of 4080 fish species from the temperate shelf and tropical seas. [6]. We are using the NOAA SSTs data source to extract SSTs from the temperate (23.5°N - 66.5°N) and tropical (0°N - 23.5°N) latitudes. We will match environmental temperatures to the data from *BioTime*. The SSTs were obtained from the *Optimum Interpolation Sea Surface Temperatures* V2 (OI SST V2), which collects long term climate data in situ and from satellites from 1990 to 2023 [8]. We will convert the spatial data to a rectangular dataframe of average SSTs in the tropical and temperate coordinates over time, resulting in a dataframe with monthly mean temperatures. Finally, we will use *globTherm*, a database on thermal tolerances for aquatic and terrestrial organisms [2]. From this dataset, we will use the information on temperate and tropical fish CTmax/CTmin and temperature preference (tPref) to analyze how species are moving relative to these metrics over time. This will be done to each dataframe before taxonomic harmonization, which is necessary to merge all the data sets by the correct taxon.

Using this new dataframe, we will perform a linear regression analysis to analyze the changes in biodiversity over time in both climate zones. Biodiversity will be measured as species richness, using the abundance data from BioTime to count the number of species present per year to calculate species richness. We will then calculate the changes in $\boldsymbol{\beta}$-diversity to assess potential range shifts related to changing SSTs over time. Finally we will complete Tukey's post hoc tests to compare thermal performance of species over time with the SSTs and species richness, and to infer if species are getting closer to the CTmax over time.

Anticipated Results & Significance

We anticipate that species richness trends will be strongly tied to sea surface temperature changes over time and to limitations imposed by species specific CTmax temperatures (Fig 1). Additionally, we expect to see the $\boldsymbol{\beta}$-diversity of the two regions become more similar over time as tropical species move into temperate regions.

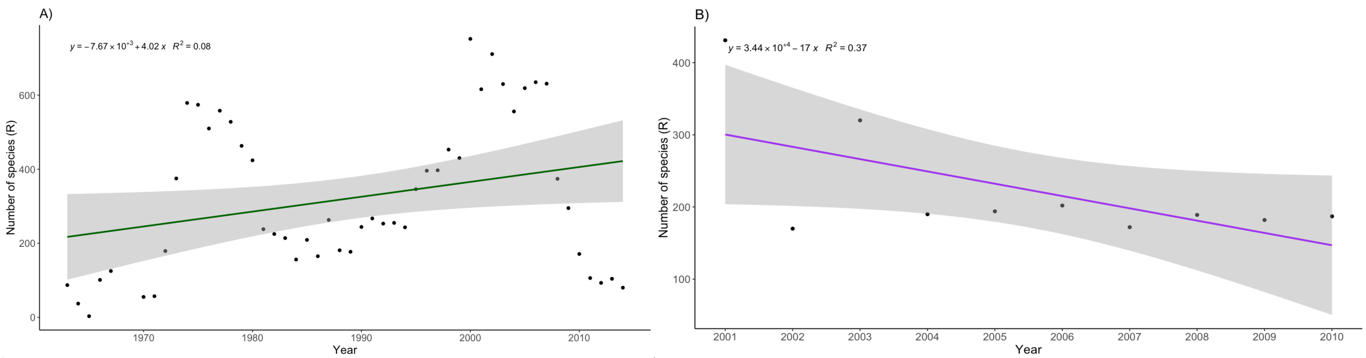

Figure 1; (a) Temperate fish species richness (R), and (b) tropical fish species richness in the Northern hemisphere over time. Scatter plots showing the observed species richness per year from 1964 to 2014 for temperate fish, and 2001 to 2010 for tropical fish. Linear models are fit to the data and equations are displayed on the plots. Species richness in temperate latitudes (23.5°N - 66.5°N) show a positive trend over time and species richness in tropical latitudes (0°N - 23.5°N) shows a negative trend over time.

The effect of biodiversity on ecosystem function is severely understudied in most areas of the world. Only 13% of studies are tropic-centric, and they largely focus on the northwestern hemisphere and Costa Rica, leaving much of the world underrepresented in the literature [4]. Warming SSTs are therefore likely to cause unexpected impacts in understudied regions. Decreases in biodiversity are also associated with nutrient deficiencies in people with a significant portion of wild fish in their diets. This puts approximately 2 billion people at risk, especially in the tropics, where we expect to see the greatest biodiversity loss [7]. Warming SSTs are also expected to cause range shifts, resulting in increases in temperate biodiversity as tropical fish migrate polewards (Fig. 1). In fast-shifting species (defined by range shifts polewards of ≥17 km per year) populations decrease by 50% on average and are as high as 92.7% in some species [3]. This will inevitably lead to population & fishery collapses, increased extinction rates and even greater biodiversity loss.

Citations

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