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Governance challenges for tropical nations losing fish species due to climate change

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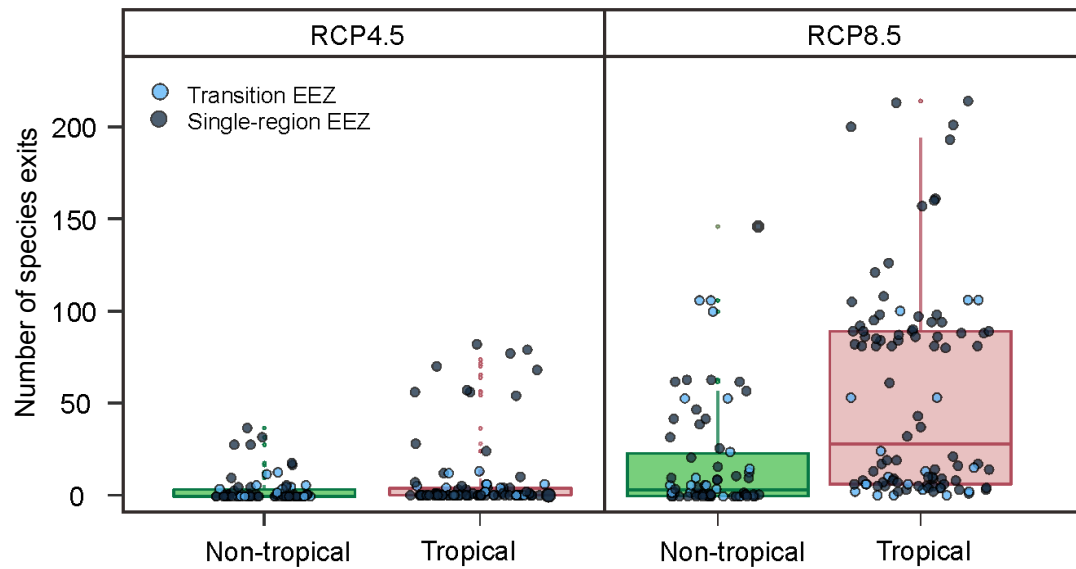
Supplementary Information

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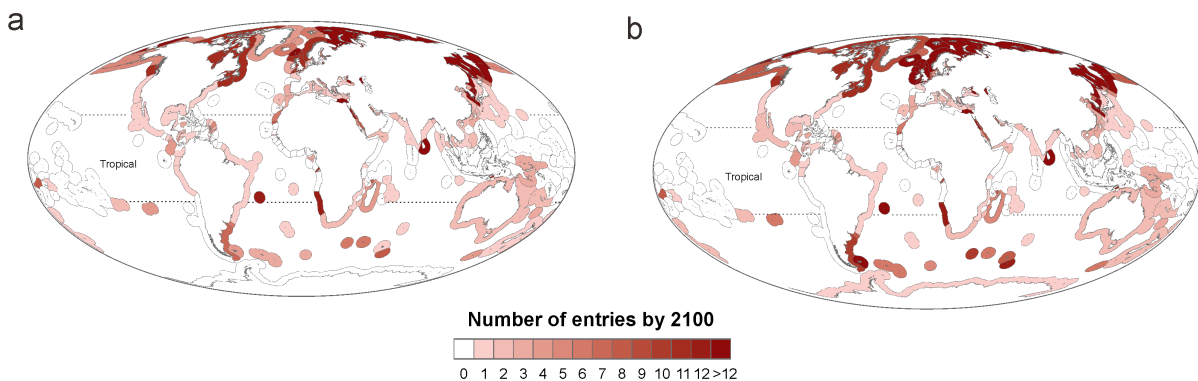
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Supplementary Figures



Supplementary Figure 1. Median loss of species by EEZ over the period 2012-2100 with interquartile range shown. Blue dots represent EEZs that straddle the tropical and non-tropical regions. Grey dots show EEZs that are either fully in the tropics or non-tropical region as delineated by Figure 1 in the main text.



Supplementary Figure 2. Number of new species shifting into each EEZ by 2100 under (a) RCP 4.5 and (b) RCP 8.5.

Supplementary Methods: Exit analysis

List of tropical exclusive economic zones used in exit analysis (Fig. 2a and Fig. 2b)

These EEZ boundaries are completely within the geographic tropical zone, defined as being between 23°26'12.5" (or 23.4368°) N and 23°26'12.5" (or 23.4368°) S.

Central American and Caribbean

- Bahamas
- Turks and Caicos Islands
- Cuba
- Cayman Islands
- Haiti
- Dominican Republic
- British Virgin Islands
- Anguilla
- Saint Kitts and Nevis
- Antigua and Barbuda
- Montserrat
- Saint Lucia
- Dominica
- Barbados
- Grenada
- Trinidad and Tabago
- Saint Vincent and the Grenadines
- Panama
- Costa Rica
- Nicaragua
- Honduras
- El Salvador
- Mexico
- Guatemala
- Belize
- Jamaica
- Curaçao
- Sint-Maarten
- Northern Saint-Martin
- Bonaire
- Saba
- Sint-Eusasius
- Aruba
- Martinique
- Guadeloupe
- Puerto Rico
- Virgin Islands

East Africa

- Comoro Islands
- Mayotte
- Seychelles
- Reunion
- Mauritius
- Mozambique
- Madagascar
- Kenya
- Somalia
- Eritrea
- Djibouti
- Sudan
- Republique du Congo
- Equatorial Guinea
- Cameroon
- Gabon
- Democratic Republic of the Congo
- Angola
- Tanzania

Northwest Africa

- Mauritania
- Gambia
- Senegal
- Saint Helena
- Sierra Leone
- Liberia
- Togo
- Benin
- Sao Tome and Principe
- Ghana
- Guinea Bissau
- Guinea
- Ivory Coast
- Nigeria
- Nigeria – Sao Tome and Principe (Join Regime)

South America

- Brazil
- Colombia
- Quitasueño (Colombia)
- Serrara (Colombia)

- Ecuador
- French Guiana
- Galapagos Islands
- Guyana
- Peru
- Suriname
- Trindade
- Venezuela

South Asia

- India

South Pacific

- Fiji
- Kiribati
- Marshall Islands
- Micronesia
- Nauru
- New Caledonia
- Northern Mariana Islands and Guam
- Palau
- Papua New Guinea
- Solomon Islands
- Vanuatu
- Wake Island

Southeast Asia

- Brunei
- Cambodia
- East Timor
- Indonesia
- Malaysia
- Myanmar
- Philippines
- Singapore
- Thailand
- Vietnam

Supplementary Methods: Agreement analysis

Method for collecting international agreements

We collected fishing agreements between exclusive economic zones (EEZs), including agreements from regional fisheries management organizations (RFMOs), regional councils and commissions, and other organizations that regulate fisheries and have the

authority to make international agreements. We first identified Regional Fishery Bodies (RFBs), or groups of states or organizations that are parties to an international fishery arrangement, on FAO's webpage (<http://www.fao.org/fishery/rfb/en>). Available convention texts and agreements as well as other relevant documents were collected for these RFBs and recorded in our database.

Next, we leveraged existing databases to identify existing multilateral and bilateral agreements. These databases include Ecolex (ecolex.org), International Environmental Agreements (IEA) (iea.uoregon.edu), FAOlex (fao.org/faolex), United Nations Treaty Series Online (https://treaties.un.org/Pages/AdvanceSearch.aspx?isBack=true&tab=UNTS&clang=_en), and NOAA's "International agreements concerning living marine resources of interest to NOAA fisheries" booklet (http://www.nmfs.noaa.gov/ia/resources/2014_international_agreements_book.pdf). The majority of agreements that we included in our database is from these sources.

Although these databases are comprehensive, we conducted searches for agreements by EEZ (see list of EEZs included in search below) using Google and government websites for additional publicly available agreements. We specifically targeted government departments that oversee fisheries resources and fisheries policy.

Once all agreements were collected, we completed the following filtering process. We only include multilateral or bilateral fisheries agreements that pertained to the management and sustainability of shared fish resources. Other agreements, such as those pertaining to the sale and purchase of fishing rights, the management of non-fisheries related marine animals, and the delineation of EEZs were excluded from our analysis. Furthermore, to ensure consistency in our findings, we adopt the definition for "international agreement" documented in Ron Mitchell's International Environmental Agreement Database and uses the search terms associated with "agreement," "amendment," "other modification", and "protocol" listed on the database's website to inform our selection process: <https://iea.uoregon.edu/international-environmental-agreements-ieas-defined>). Since we conducted such a broad search for agreements, we collected initial agreement texts, as well as protocols and amendment texts for those same texts. While we consider protocols as separate agreements, amendments to agreements are not considered to be unique agreements. In order to ensure that we did not double count agreements and amendments in our analyses, we assign all documents a "uniqueness" identifier, which links texts of the same agreement.

List of tropical exclusive economic zones used in agreement search (Fig. 2c)
Agreements were not found for all EEZs listed.

Central America/ Caribbean

- Mexico
- Belize
- Costa Rica
- El Salvador

- Guatemala
- Honduras
- Nicaragua
- Panama
- Cuba
- Haiti
- Dominican Republic
- Puerto Rico (USA)
- Jamaica
- Trinidad and Tobago
- Guadeloupe (France)
- Martinique (France)
- Bahamas
- Barbados
- Saint Lucia
- Curaçao (Kingdom of the Netherlands)
- Aruba (Kingdom of the Netherlands)
- Saint Vincent and the Grenadines
- US Virgin Islands (USA)
- Grenada
- Antigua and Barbuda
- Dominica
- Cayman Islands (UK)
- Saint Kitts and Nevis
- Sint Maarten (Kingdom of the Netherlands)
- Turks and Caicos Islands (UK)
- Saint Martin (France)
- British Virgin Islands (UK)
- Caribbean Netherlands (Kingdom of the Netherlands)
- Anguilla (UK)
- Saint Barthelemy (France)
- Montserrat (UK)

Southeast Asia

- Vietnam
- Cambodia
- Thailand
- Myanmar
- Malaysia
- Indonesia
- Singapore
- Philippines
- Timor-Leste
- Brunei

South Asia

- Bangladesh
- Maldives
- India
- Pakistan
- Sri Lanka

Northwestern Africa

- Morocco
- Mauritania
- Cape Verde
- Senegal
- Gambia
- Guinea-Bissau
- Guinea
- Sierra Leone
- Liberia
- Ivory Coast
- Ghana
- Togo
- Benin
- Nigeria
- Cameroon

South Pacific

- Micronesia
- Palau
- Kiribati
- Marshall Islands
- Nauru
- Vanuatu
- Fiji

- Solomon Islands
- Papua New Guinea
- New Caledonia (France)
- Western New Guinea (Indonesia)
- Northern Mariana Islands (United States)
- Guam (United States)
- Wake Island (United States)

Data collection

Once the agreements had been filtered based on the aforementioned criteria, we read and recorded agreements in a database. For each agreement, we recorded the following information:

- Title of the agreement;
- Year in which it was signed;
- Signatories of the agreement;
- Whether or not it is an agreement pertaining to an RFB; and
- If relevant, to which specific stock or species the agreement pertained

In addition, we recorded whether the agreement contained any of the following search terms related to climate driven range shifts: “climate”, “climate change”, “warming”, “global warming”, “cooling”, “global cooling”, “temperature”, “sea-surface temperature”, “SST”, “range shift”, and “shift”. Our team was able to read and populate the database for agreements in English, Spanish, French, and Chinese. We used Google Translate for agreements in other languages, predominantly Russian and Portuguese.

Data processing

For each region in the tropics, we counted the number of unique agreements and calculated the percentage of agreements that contains references to climate driven range shifts.

Limitations

This database has some limitations. There were two main challenges to data collection: 1) the private nature of some agreements and 2) language barriers. First, some countries do not make their agreements publicly available, and thus relevant agreements from these countries are missing from our database. Second, while some of the databases that we used for data collection included agreements in a wide range of languages, we were only able to conduct additional searches for agreements in English and Spanish.