



## Ecosystem Status Report for the U.S. Caribbean



U.S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
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February 2024

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# **1. Executive Summary**

Here is where we will paste the executive summary

## **2. Introduction**

### **2.1. About this report**

This report is for the Caribbean Fishery Management Council (CFMC). The purpose of this report is to synthesize ecosystem and socioeconomic information to help the CFMC better meet fishery management objectives. This report relied on both previously identified proposed indicators as well as expert vetting to select a suite of indicators that best address the fishery management plan (FMP) objectives for the U.S. Caribbean. Information in this report is organized into two sections: tracking performance toward fishery management objectives and potential risks to meeting fishery management objectives. The style of this report is based on the 2023 State of the Ecosystem Reports for the Northeast U.S. Shelf.

### **2.2. Report structure**

The CFMC's Science and Statistical Committee, as well as the region's Ecosystem-Based Fishery Management Technical Advisory Panel (EBFM TAP), recently completed a series of conceptual models linking key components of the ecosystem and human activities related to fishing. This report used these conceptual models as a starting list of proposed indicators and matched the indicators to answer FMP objectives when possible. For those objectives that did not have an immediate conceptual model-identified indicator, this report used a decision matrix process for expert vetting (Figure 1).

This decision matrix was composed of a list of proposed indicators compiled from the conceptual models as well as proposed indicators provided via expert input. These potential indicators were vetted and edited by expert small working groups, who then scored a decision matrix (Figure 2) of potential indicators against the following decision criteria: long term data availability, measurability, sensitivity to environmental changes, specificity, spatial and temporal scalability, relevance to specific FMP objectives, and responsiveness to management actions.

## Process for Caribbean ESR

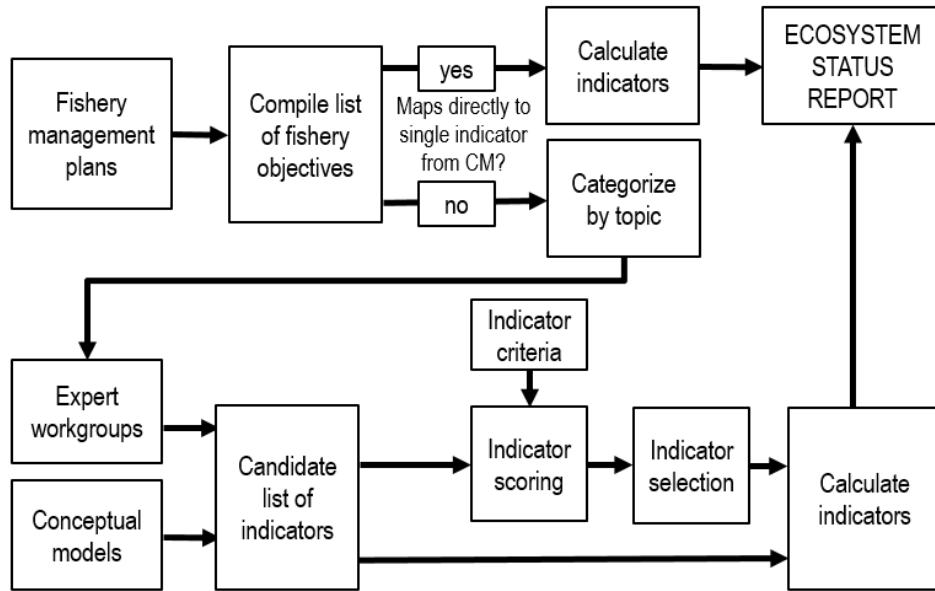


Figure 1: Process for selecting indicators for the U.S. Caribbean Ecosystem Status Report

### 2.2 Notes on interpreting time series figures

Time series data are plotted in a standardized format for ease of interpretation (e.g., Figure 2). The x-axis represents the temporal dimension, which may be monthly, yearly, or irregular time steps, and the y-axis represents the indicator value in units specified in the axis label. The dashed horizontal line represents the mean indicator value across the entire time series, and the solid horizontal lines denote the mean plus or minus one standard deviation. Red shaded areas and green shaded areas show years for which the indicator value is below or above one standard deviation from the mean, respectively. The blue vertical shaded box highlights the last five years of indicator values, over which additional metrics are calculated. Black circles to the right of each figure indicate whether the indicator values over the last five years are greater (plus sign), less than (minus sign), or within (solid circle) one standard deviation from the mean of the overall time series. Arrows to the right of each figure indicate whether the least squares linear fit through the last five years of data produces a positive or negative slope that is greater than one standard deviation (upward or downward arrows respectively), or less than one standard deviation (left-right arrow).

## 2. Introduction

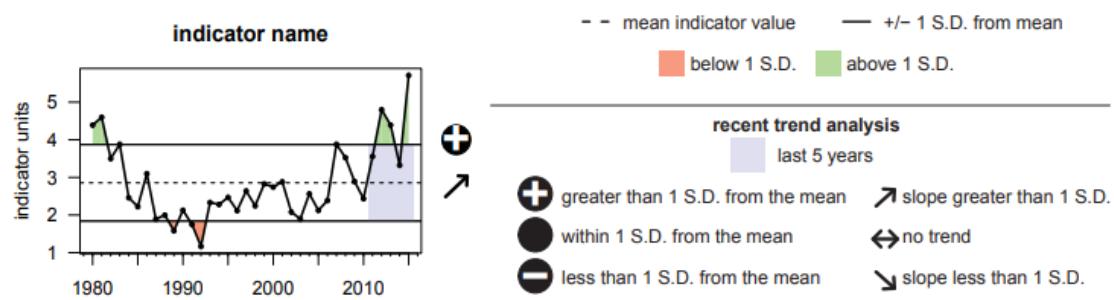


Figure 2: Example time series plot, showing an indicator plotted with its mean and standard deviation, and trend analysis for the most recent five years of data. See text for more detailed description of specific calculations.

### **3. Fishery management plan objectives and conceptual models**

This report's indicator selection process sought to select indicators that corresponded to the island based fishery management plan (FMP) objectives in order to track performance, and also selected indicators related to risks to meeting these management objectives. The following figure shows indicators selected per FMP objective. Indicators were also sourced and considered from the conceptual model exercise completed by the Council's Science and Statistical Committee and District Advisory panels, which began in 2019. Top scored connections in ecosystem components were considered in the ESR indicator suite as well (Rivera et al, in publication).

### 3. Fishery management plan objectives and conceptual models

FMP Objective	Col2	Col3	Col4	Col5	Col6
Objective 1: Provide for long-term sustainable use of fisheries resources within the limits of local ecosystem production using a precautionary, ecosystem-based approach to management that accounts for uncertainty and relevant biological, ecological, economic, and social factors in the fishery, including the benefits of <b>food production, recreational opportunities, and protection of marine ecosystems</b> . Prevent overfishing, rebuild overfished stocks, and achieve OY on a continuing basis.	Total commercial lobster landings, conch landings	Sustainability of economically important reef fish-FID from RVC on mutton, yellowtail, red hind, and queen triggerfish			
Objective 2: Reduce bycatch and waste in the fishery.					
Objective 3: Ensure the metrics upon which OY is based are derived from the best available scientific information and are updated continuously every five years to respond to changing ecological, biological, economic, and social conditions.					
Objective 4: Promote international and domestic cooperation in the management of pan-Caribbean stocks.					

### *3. Fishery management plan objectives and conceptual models*

FMP Objective	Col2	Col3	Col4	Col5	Col6
Objective 5: Minimize conflicts between stakeholders by promoting <b>effective marine spatial planning</b>					
Objective 6: Promote <b>fair and equitable use of fishery resources</b> , recognizing the importance of those resources to fishing communities within the context of differences in local environment, culture, markets, user groups, gears, and seafood preferences.					
Objective 7: Establish resource access permits as necessary and appropriate to facilitate data collection, sustainability, and long-term yield.					
Objective 8: Provide flexibility in the management process which minimizes regulatory delay and allows for rapid adaptation to <b>changing resource abundance, availability, health, or preference</b> , using the best available scientific and socio-economic information.					

### *3. Fishery management plan objectives and conceptual models*

FMP Objective	Col2	Col3	Col4	Col5	Col6
Objective 9: Devise a regulatory framework that maximizes the <b>efficiency and efficacy of enforcement efforts</b> within and across jurisdictional boundaries while promoting the safe conduct of fishing operations.					
Objective 10: Promote awareness of laws and regulations governing marine resource management and the science and social obligations that support that management, and to ensure informed public input into the management process.					
Objective 11: Ensure the <b>socioeconomic health of the fishing communities</b> dependent on federal fishery resources.					
Objective 12: <b>Protect spawning aggregations and, when needed, the habitats</b> supporting those aggregations to ensure the future health of the resource.					

### *3. Fishery management plan objectives and conceptual models*

FMP Objective	Col2	Col3	Col4	Col5	Col6
<b>Objective 13: Describe and identify EFH, adverse impacts on EFH, and other actions to conserve and enhance EFH.</b> Adopt management measures that minimize adverse impacts from fishing on EFH and promote habitat conservation, including designation of specific habitat areas of particular concern within EFH for more focused management action.					
<b>Objective 14: Map, define, and manage habitat</b> upon which the resource depends, with particular emphasis on coral reef resources throughout the region.					
<b>Objective 15: Ensure continued provision of ecosystem services derived from living marine resources</b> , including adequate abundance of forage resources to ensure a healthy and diverse trophic web.					
<b>Objective 16: Account for ecological relationships and functional roles of species in the fishery</b> that contribute to a healthy ecosystem, such as grazers, forage fish, habitat-builders, and top predators.					

*3. Fishery management plan objectives and conceptual models*

FMP Objective	Col2	Col3	Col4	Col5	Col6
Objective 17: Require essential scientific data is gathered and analyzed in advance to guide the development of new fisheries to ensure they are sustainable from the start.					
Objective 18: Promote measures to develop and sustainably manage underutilized marine fishery resources.					

## **4. Risks to meeting fishery management objectives**

In this section, we examine indicators...

### **Coral bleaching stress**

Accumulated heat stress, which can lead to coral bleaching and death, is measured by summing degree heating weeks for the most recent 12-week period from sea surface temperature data (cite). Bleaching stress was generally below average until the mid-2000s, until a sudden bleaching event in 2005 which is now the second most severe event in history. In 2024, an unprecedented bleaching event occurred across the U.S. Caribbean and beyond (fig).

#### 4. Risks to meeting fishery management objectives

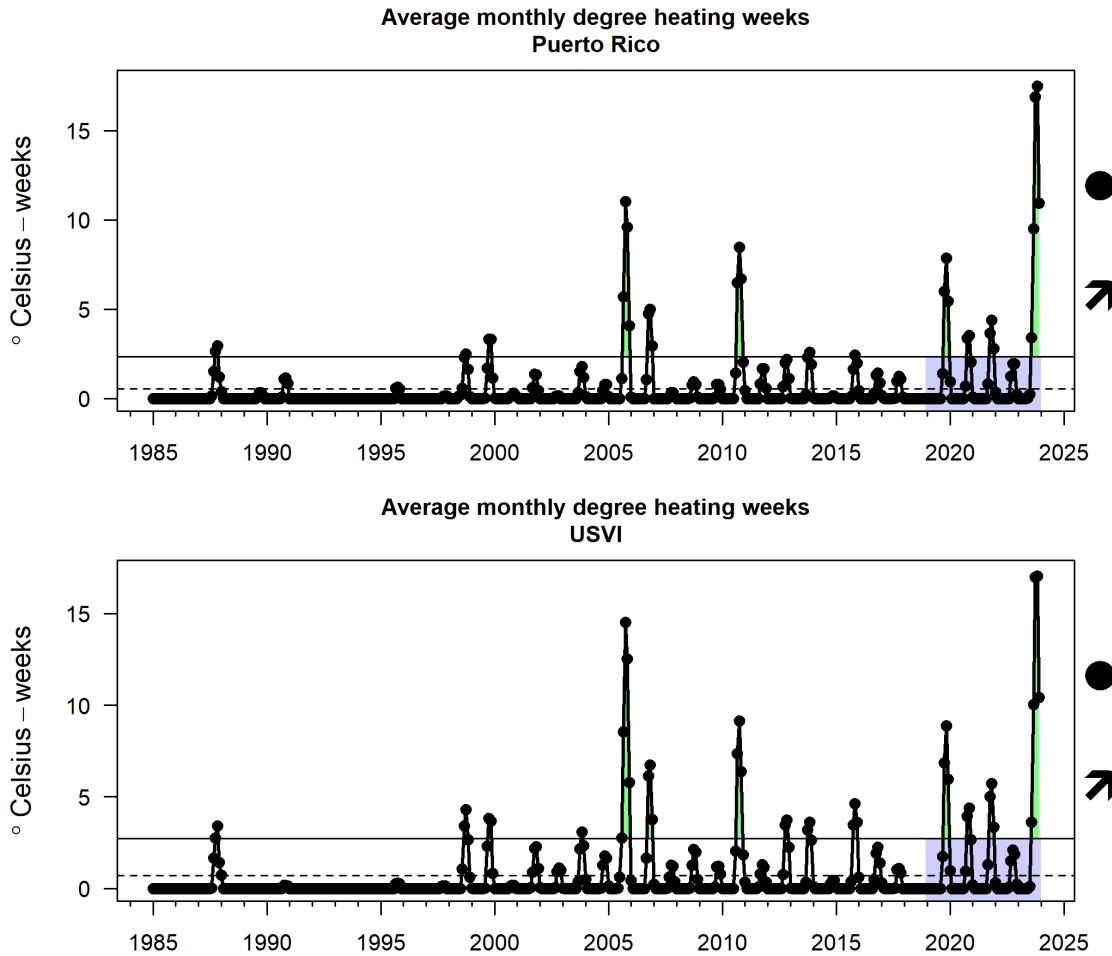


Figure 1: Degree heating weeks plot

#### **Ocean acidification via aragonite saturation state**

Ocean and coastal acidification can impact organisms directly or indirectly; a decrease in aragonite saturation state can weaken the structure of coral reefs and other calcifying organisms. In-situ measurements of aragonite saturation states are scarce and a synoptic, long-term view is only available from modeled products. Aragonite saturation state was derived for the U.S. Caribbean region from the MOM-TOPAZ hindcast (cite). An overall negative trend occurs, with an acceleration of this trend apparent after 2008 (Fig).

#### 4. Risks to meeting fishery management objectives

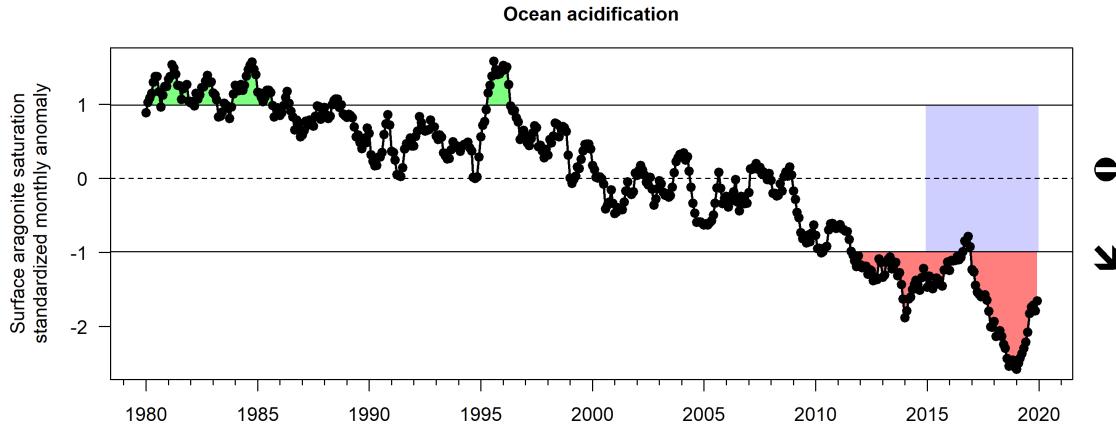


Figure 2: Ocean acidification plot

#### Hurricane activity

Hurricane activity can be captured by the accumulated cyclone energy index which is calculated as the sum of squared wind speeds for storms tracking through the U.S. Caribbean region, as documented by the International Best Track Archive for Climate Stewardship database (cite). The index has fluctuated throughout the past seven decades, with multiple notable peaks (Fig.). The year 2017 hurricane activity was at an unprecedented high, due to two major hurricanes that struck the islands: Irma and Maria.

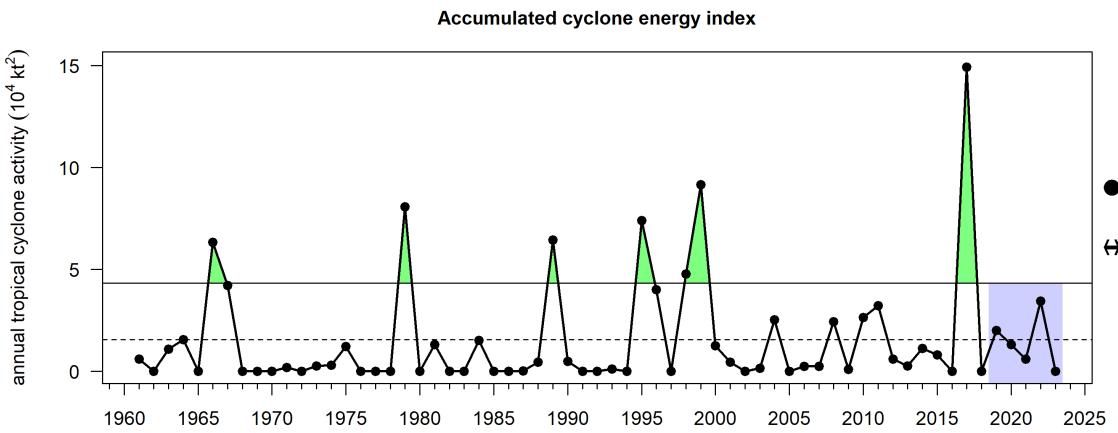


Figure 3: Hurricane activity

#### *4. Risks to meeting fishery management objectives*

##### **Turbidity**

Coastal pollution, runoff, and water quality issues are of major concern to fishing-dependent communities in the U.S. Caribbean (Seara et al. 2024). Water clarity can be measured by the diffuse attenuation coefficient which indicates how strongly light intensity is attenuated within the water column; however, satellite sensors cannot differentiate between organic and inorganic water particles contributing to water clarity. NOAA's Coastwatch program provides estimates of the attenuation coefficient for penetration of light at 490nm (Wang et al. 2009) based on multiple satellite sensors. [sentence on trends]

#### 4. Risks to meeting fishery management objectives

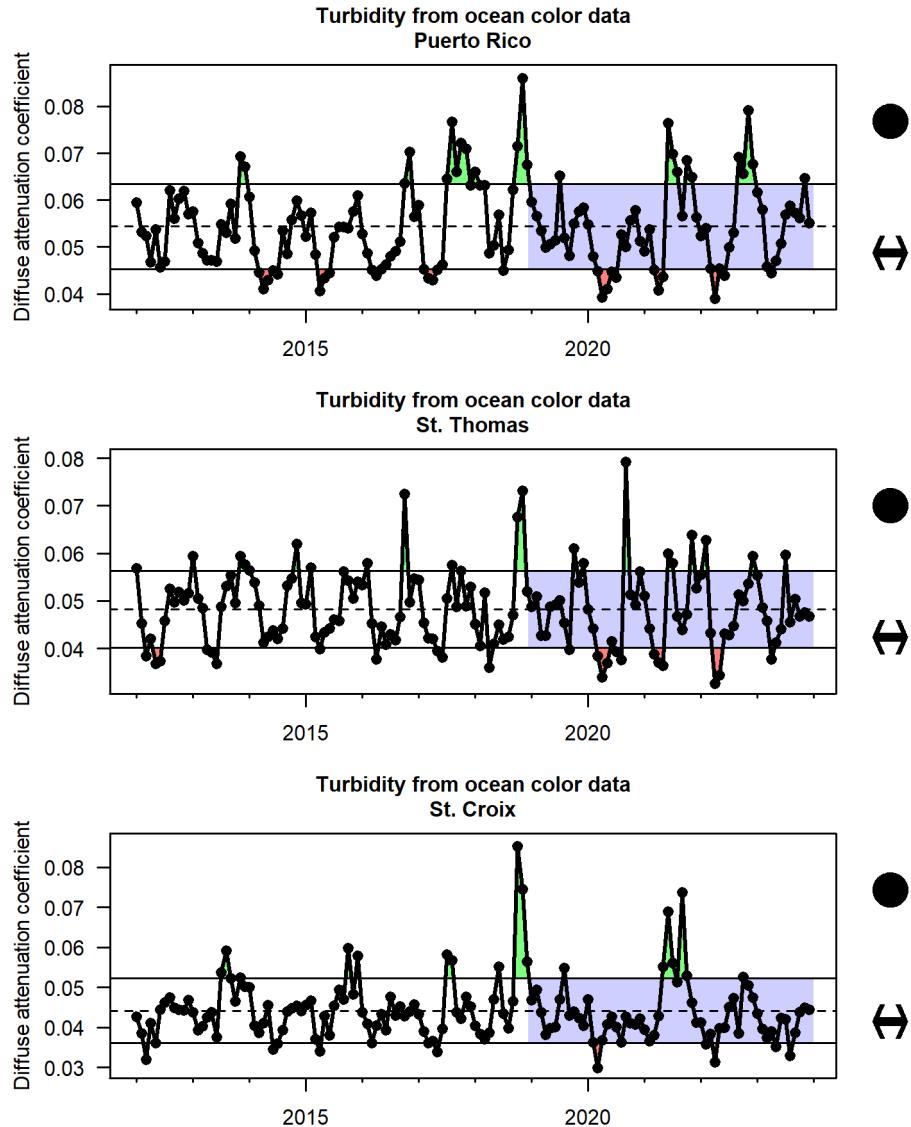


Figure 4: Turbidity plot

#### Sea surface temperature

Ocean temperatures affect species distributions and other aspects of population dynamics and have impacts on habitats such as coral reefs. Monthly mean, minimum, and maximum sea surface temperatures were calculated based on the 1/4 Degree Daily Optimum Interpo-

#### *4. Risks to meeting fishery management objectives*

lation Sea Surface Temperature (OISST) Analysis (cite). Mean temperatures in the U.S. Caribbean region have been increasing at an average rate of 0.25 degrees C per decade. In the last five years, minimum temperatures have been well above average (Fig), while there has been no long-term or recent trend in maximum temperatures experienced.

4. Risks to meeting fishery management objectives

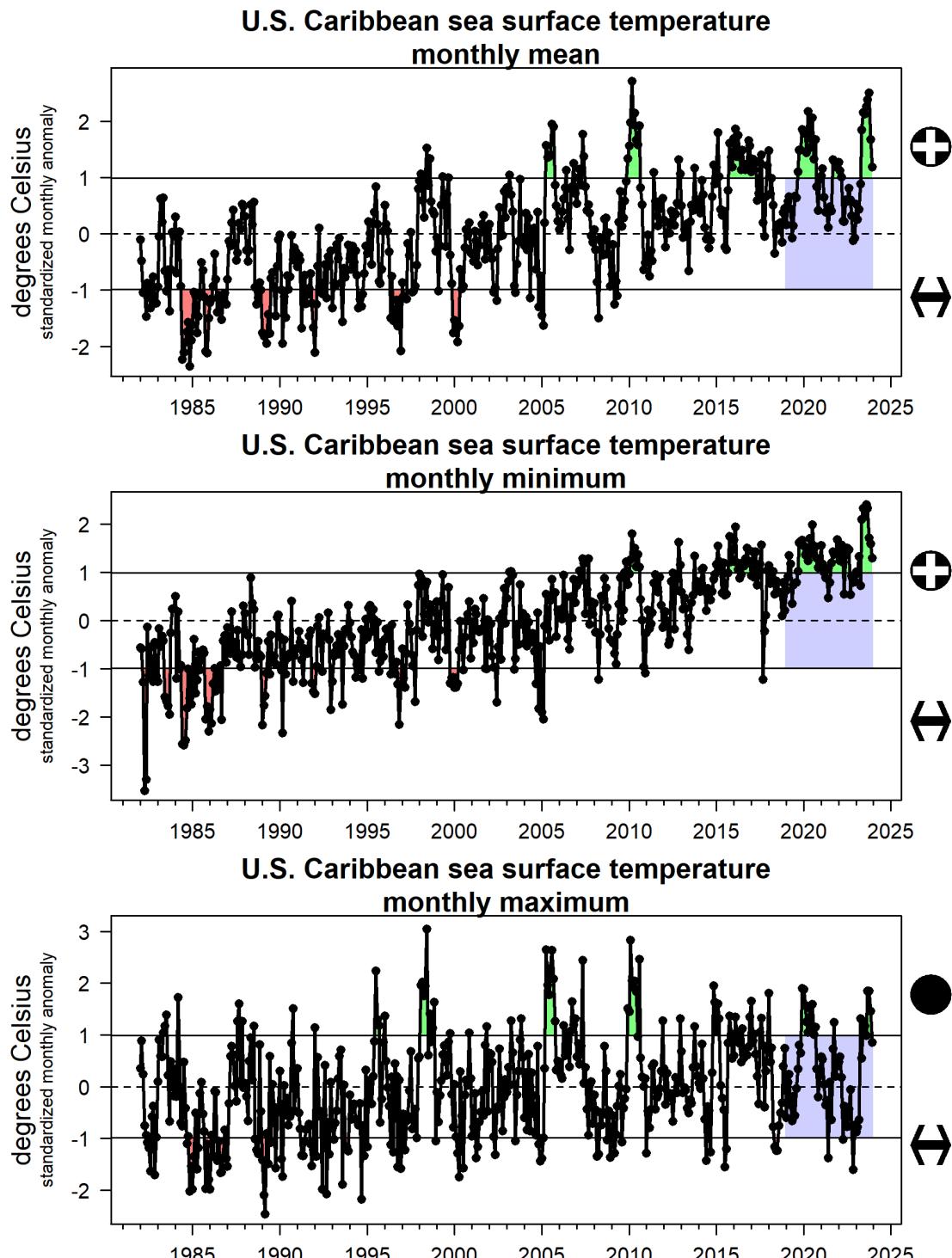


Figure 5: SST plot

#### *4. Risks to meeting fishery management objectives*

##### **Marine debris**

Indicator 6

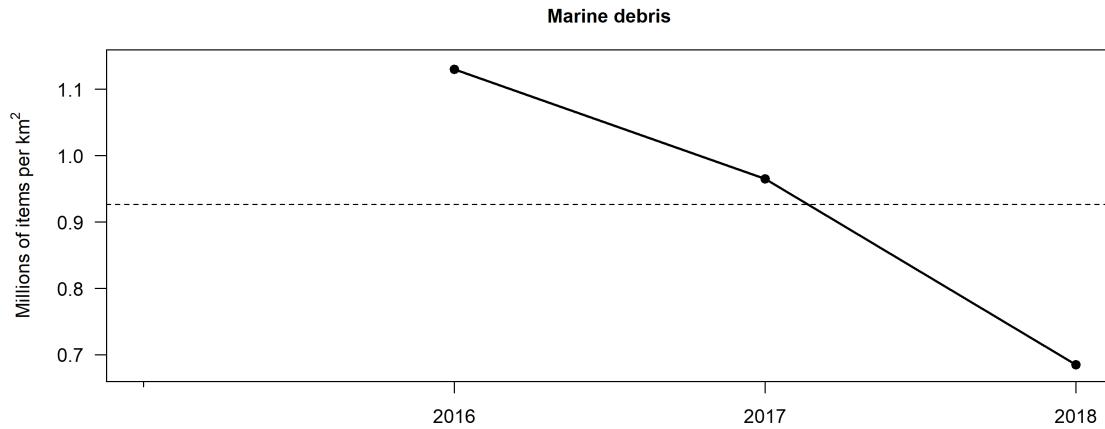


Figure 6: Marine debris plot

##### **Identified point source pollution sites**

Impacts from terrestrial pollution can be captured from several databases maintained by the Environmental Protection Agency, which provide information on companies that have been issued permits to discharge wastewater into rivers, release of toxic chemicals and waste management activities at facilities, and declaration of Superfund sites. The number of pollution sites reported increased in the 2000s, but has decreased slightly in both Puerto Rico and USVI in recent years (Fig.). Note that this indicator does not represent the timing of when pollution was impacting the ecosystem, but rather the timing of political action or attention on the environmental impacts of pollution.

#### 4. Risks to meeting fishery management objectives

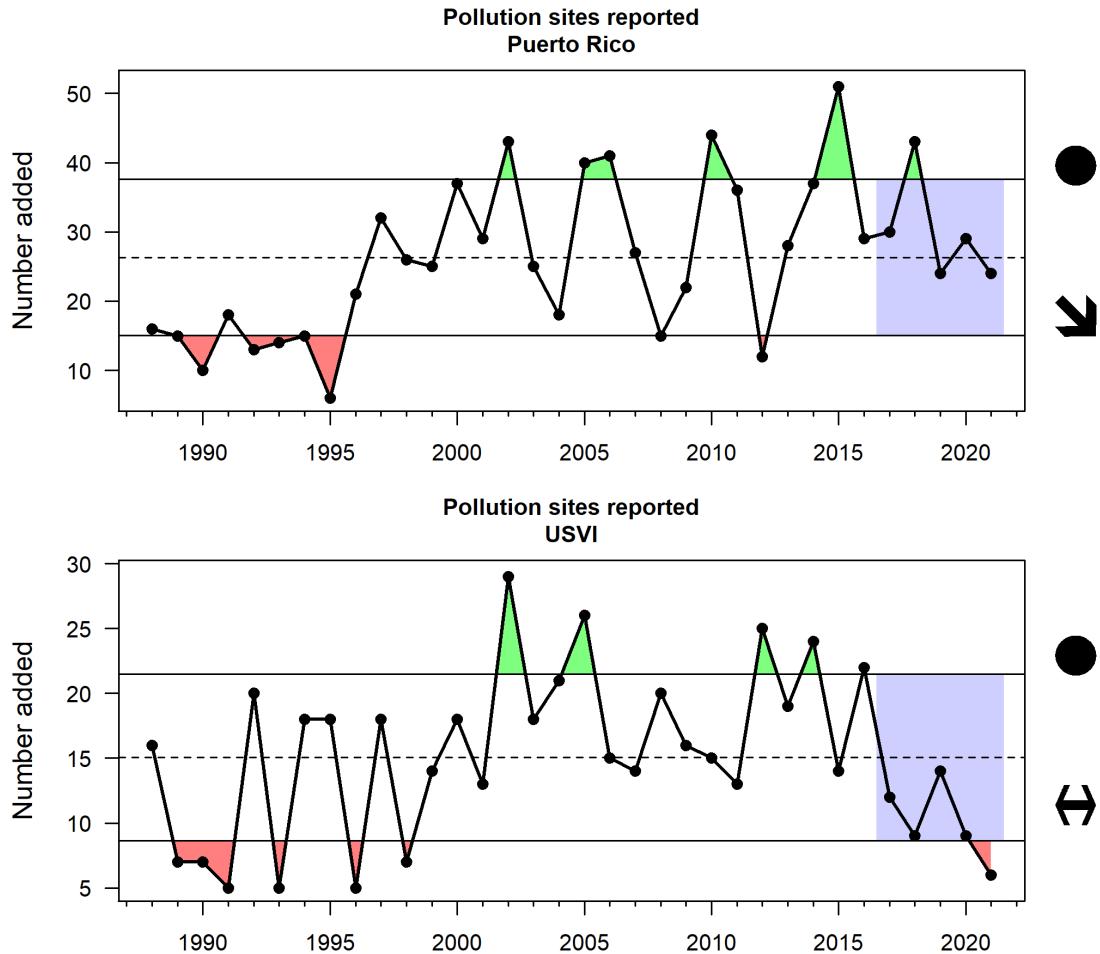


Figure 7: Pollution plot

#### Water quality

Indicator 8 - not done yet

#### Primary productivity via ocean color

Primary productivity is a measure of the total energy available in an ecosystem and is closely correlated with chlorophyll a concentrations. Average chlorophyll a concentrations are derived from the European Space Agency Climate Change Initiative's Ocean Colour

#### 4. Risks to meeting fishery management objectives

product which provides a bias-corrected composite of measurements merged from multiple satellite sensors (cite). Concentrations are plotted as standardized monthly anomalies as there is a seasonal signal that could mask long-term trends. Estimates show a decadal cyclical pattern, with no overall or recent trend apparent (Fig).

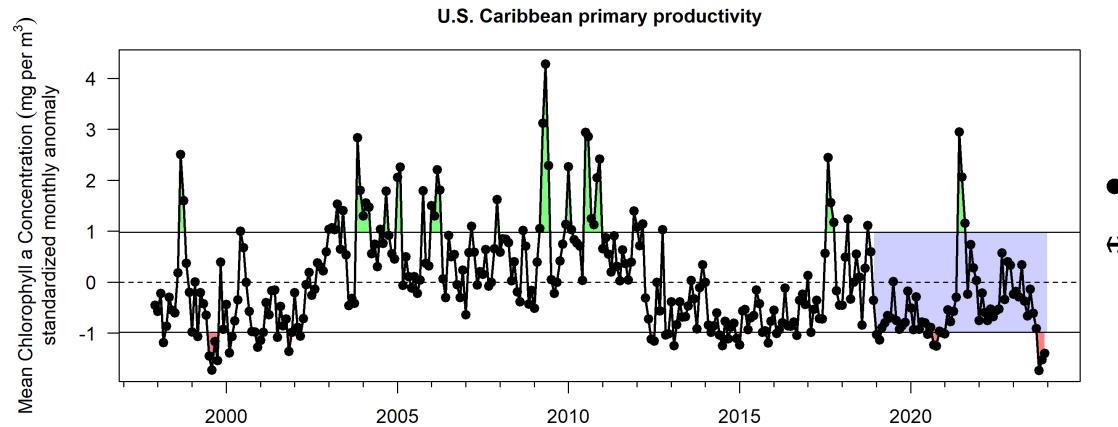
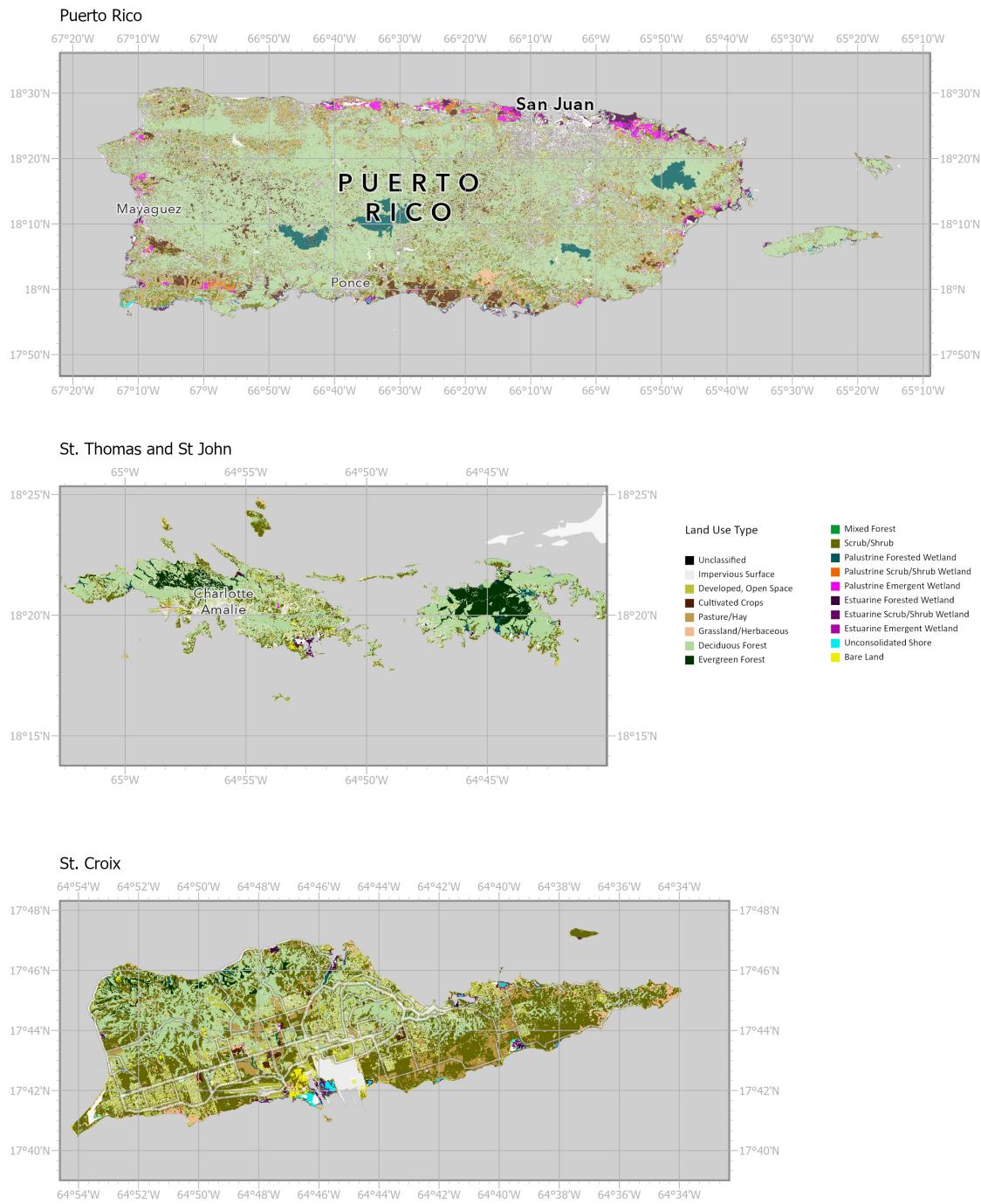


Figure 8: PP plot

#### Coastal development and land use change

Indicator 10

#### 4. Risks to meeting fishery management objectives



#### *4. Risks to meeting fishery management objectives*

##### **Number of major earthquakes**

Earthquakes in Puerto Rico can induce landslides and cause impacts to infrastructure including homes and the electrical grid, and can be a source of stress in the affected human population (Agar et al. 2022 NOAA Technical Memorandum NMFS-SEFSC-759). Seismic events are reported by the USGS in near real-time (cite). A major earthquake swarm occurred in Southwest Puerto Rico in early 2020; in this year there were over 400 events of greater than 3.5 magnitude on the Richter scale (Fig.).

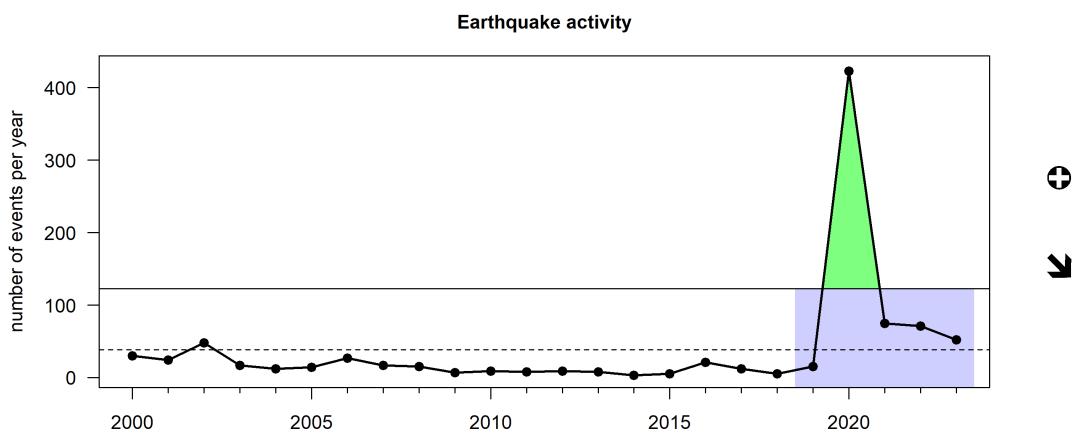


Figure 9: Earthquakes plot

##### **Market disturbances**

Alterations to typical fishing patterns can be quantified by analyzing the seasonality of how fishing activity is distributed throughout the year and detecting deviations from average patterns. A market disturbance indicator was developed by calculating the proportion of landings in each month of the year, and summing the square of deviations between those monthly proportions from the mean proportions across all years. In Puerto Rico there is little trend in the indicator; however there were disturbances in 2005 and 2020-2021. In St. Thomas, the indicator increases throughout time and detects a major disturbance in the 2017-18 fishing season. In St. Croix, disturbance levels were high in 2017-18 and also 2019-20.

4. Risks to meeting fishery management objectives

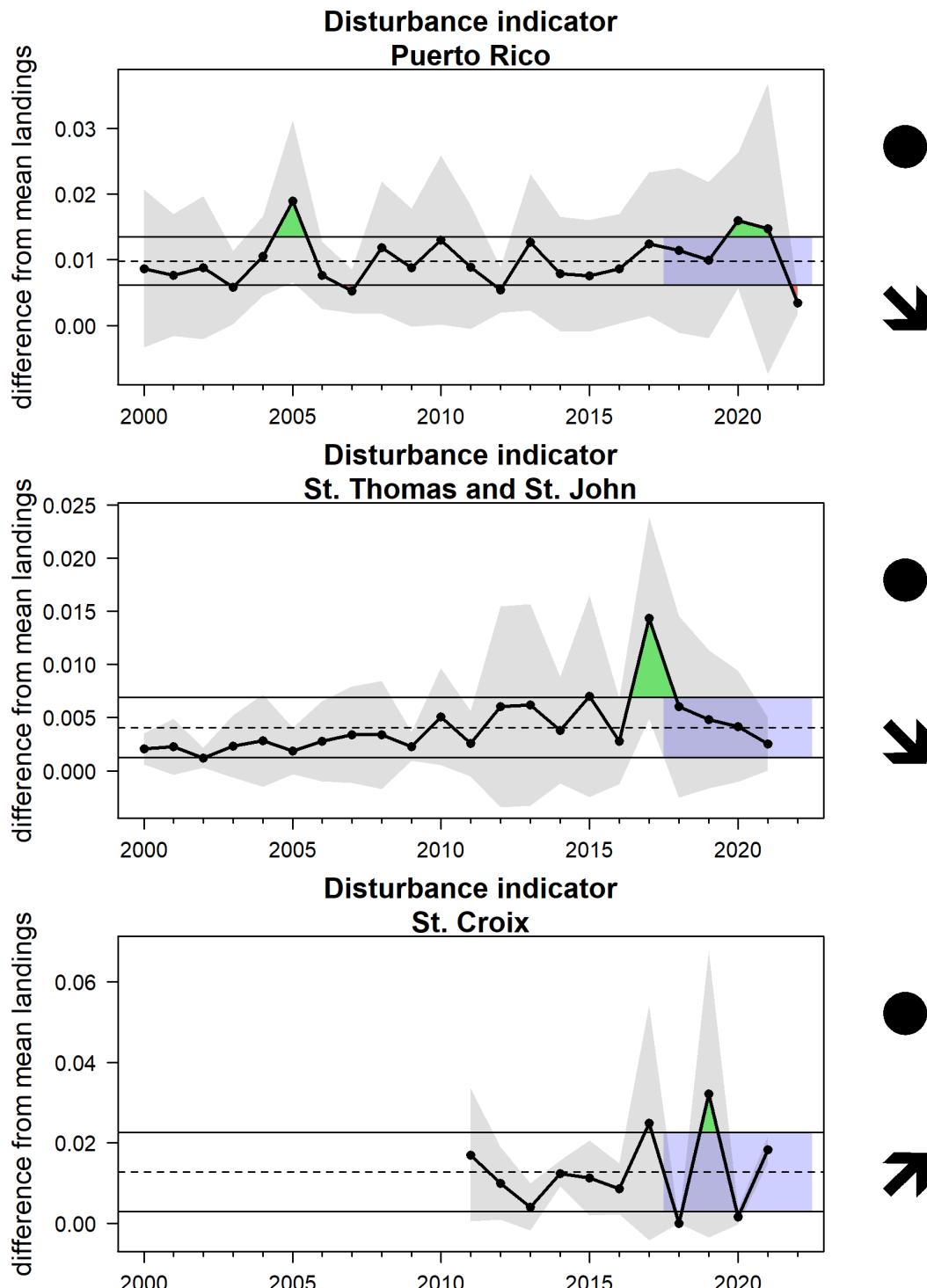


Figure 10: Disturbance plot

#### 4. Risks to meeting fishery management objectives

##### Sargassum inundation

Sargassum (brown macroalgae *S. Fluitains* and *S. natans*) is a designated essential fish habitat important for many pelagic fish and protected species; however, when large blooms collect in nearshore environments the mats can reduce oxygen, suffocate beaches and have detrimental impacts on marine species. Mean monthly Sargassum wet biomass is estimated from satellite measurements using the algorithm of Wang et al. (2018). Sargassum blooms were largely absent from the U.S. Caribbean prior to 2011, but bloom activity has been generally increasing since that year (Fig.). Major inundation events occurred in 2018 and 2021.

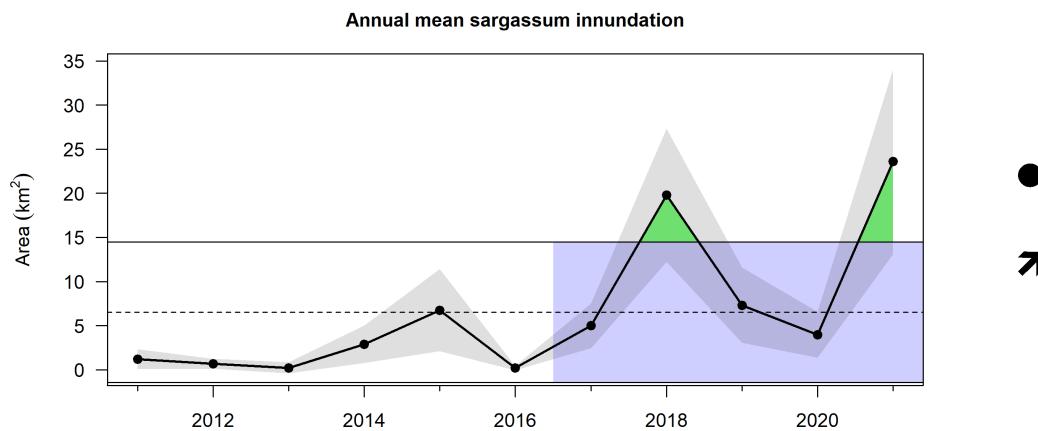


Figure 11: Sargassum plot

##### Tourism (air arrivals and cruise passengers)

Human activity has an impact on the marine ecosystem indirectly through its influence on coastal development and pollution, as well as directly through marine tourism, fishing and demand for seafood. Human activity is exerted by the local population as well as the extensive tourism industry that exists in the U.S. Caribbean. Total population estimates are reported by the U.S. Census (??) and tourism activity can be measured through hotel occupancy rates (cite) and the number of cruise passengers (cite). Human population in the U.S. Caribbean has been declining gradually since 2000. Tourism was relatively stable until recent years, with major decreases in 2017 and 2020.

*4. Risks to meeting fishery management objectives*

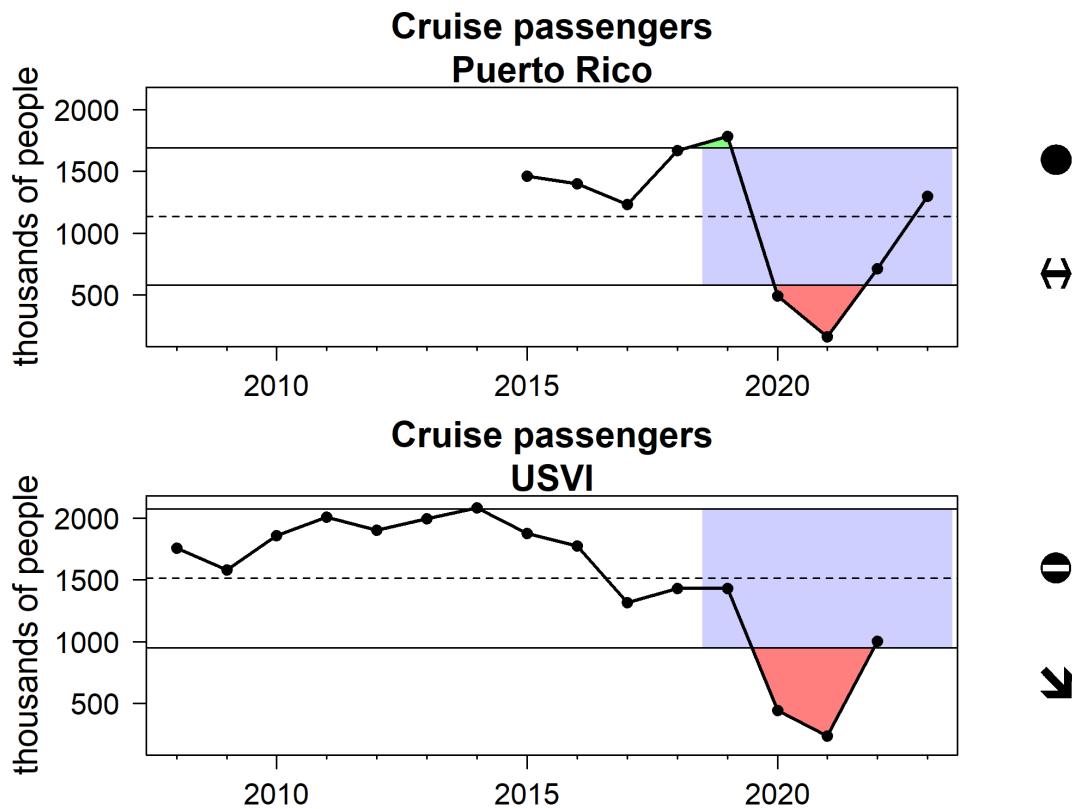


Figure 12: Cruise passengers plot

**Human population**

Indicator 15

*4. Risks to meeting fishery management objectives*

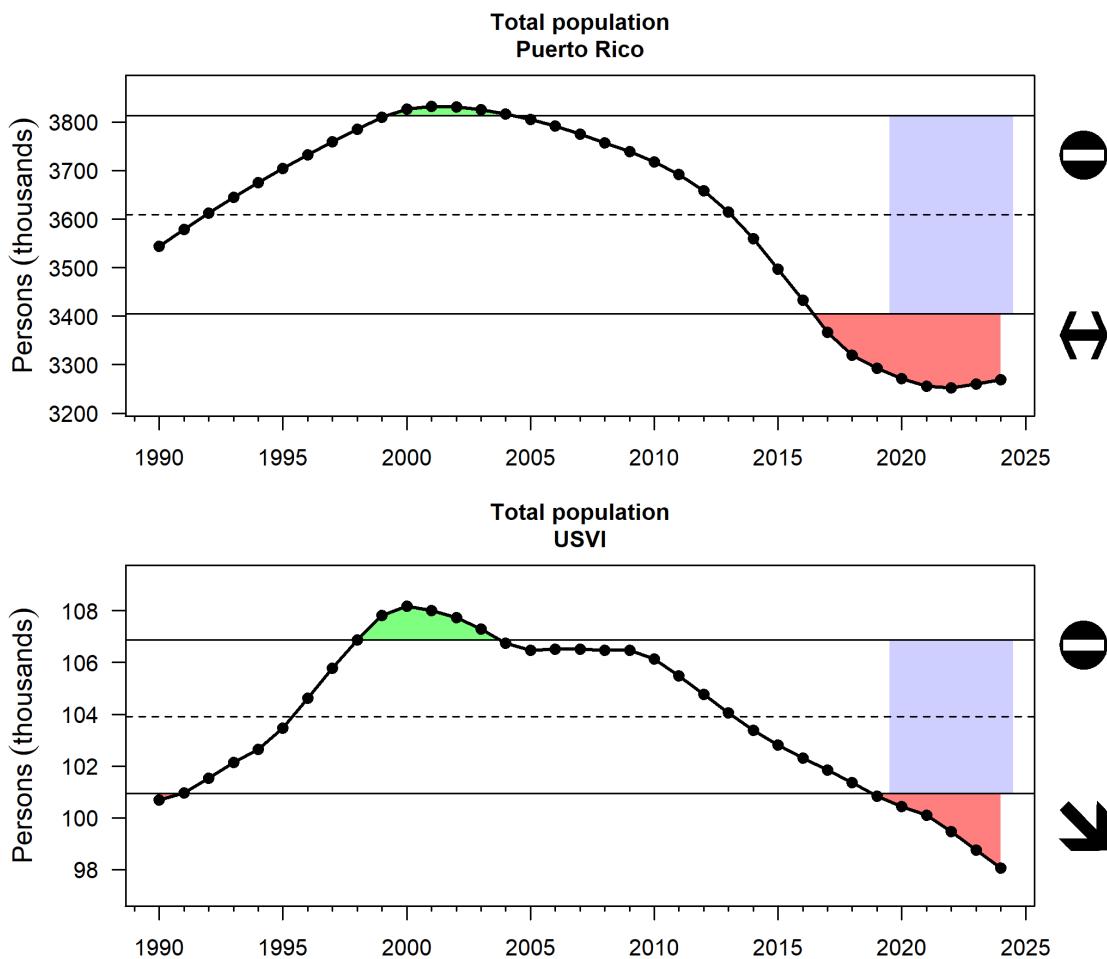


Figure 13: Population plot

## **5. Tracking performance toward fishery management objectives**

In this section, we examine indicators related to broad, ecosystem-level fishery management objectives.

### **5.1 Food production**

#### **Fishery independent surveys of economically important species**

Indicator 16 - abundance of economically important fish

5. Tracking performance toward fishery management objectives

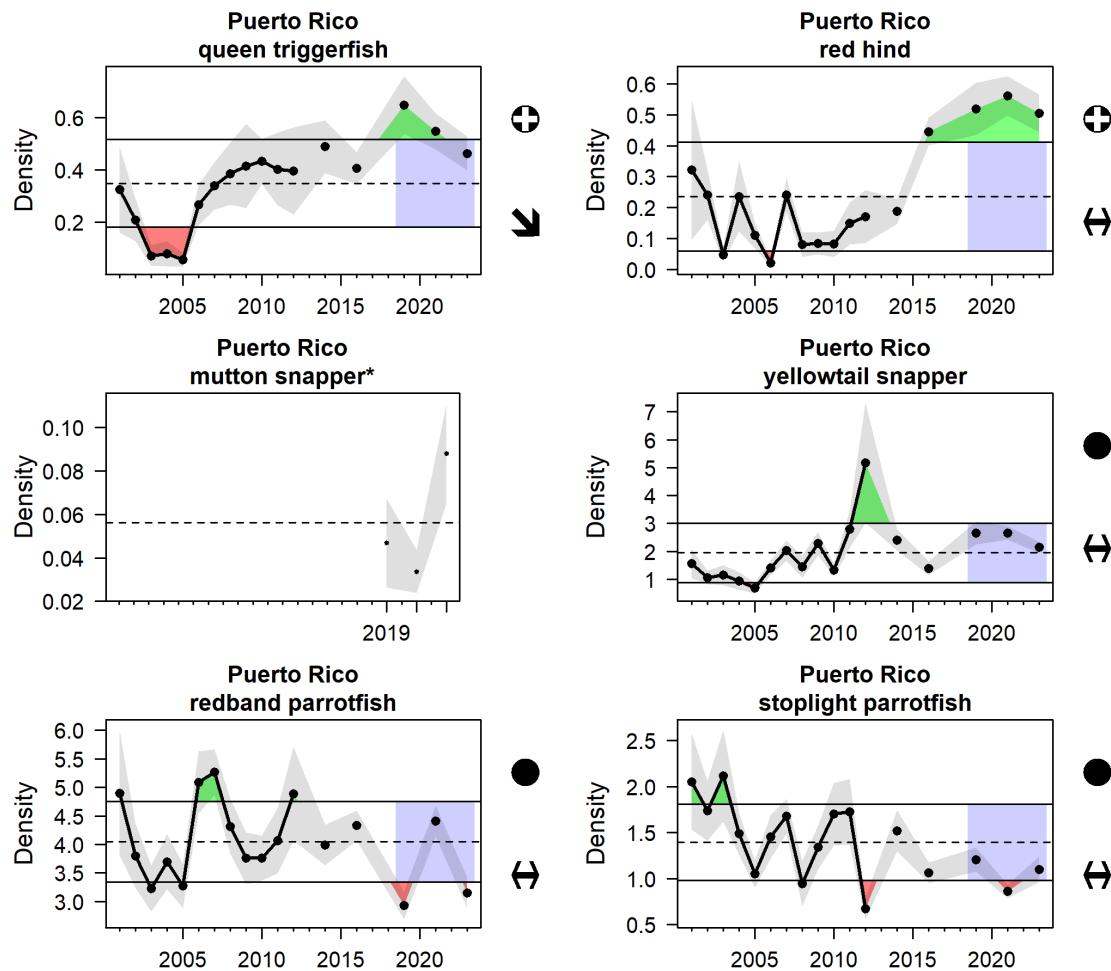


Figure 1: RVC PR

5. Tracking performance toward fishery management objectives

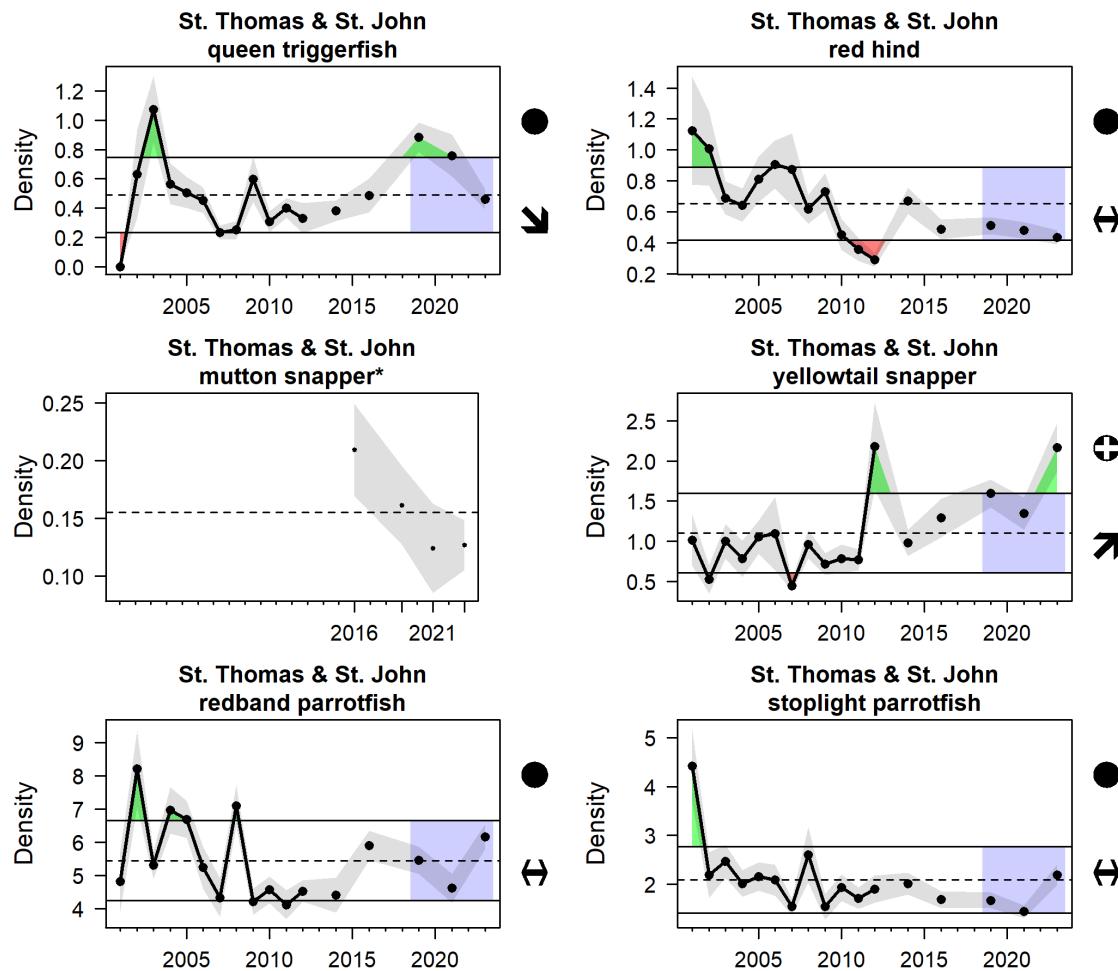


Figure 2: RVC STSJ

5. Tracking performance toward fishery management objectives

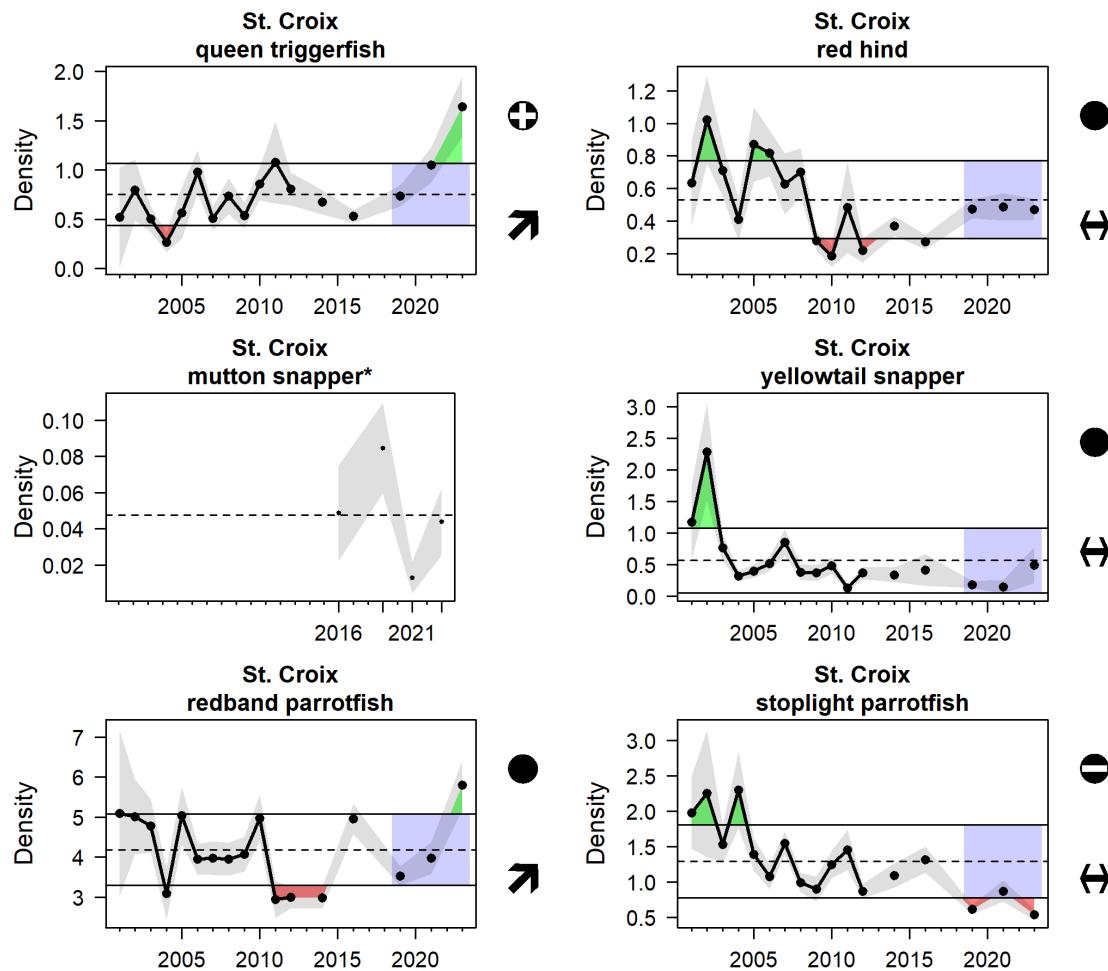


Figure 3: RVC STX

Indicator 17 - abundance of commercial fish and slope of the size spectrum based on TCRMP and PRCRMP

5. Tracking performance toward fishery management objectives

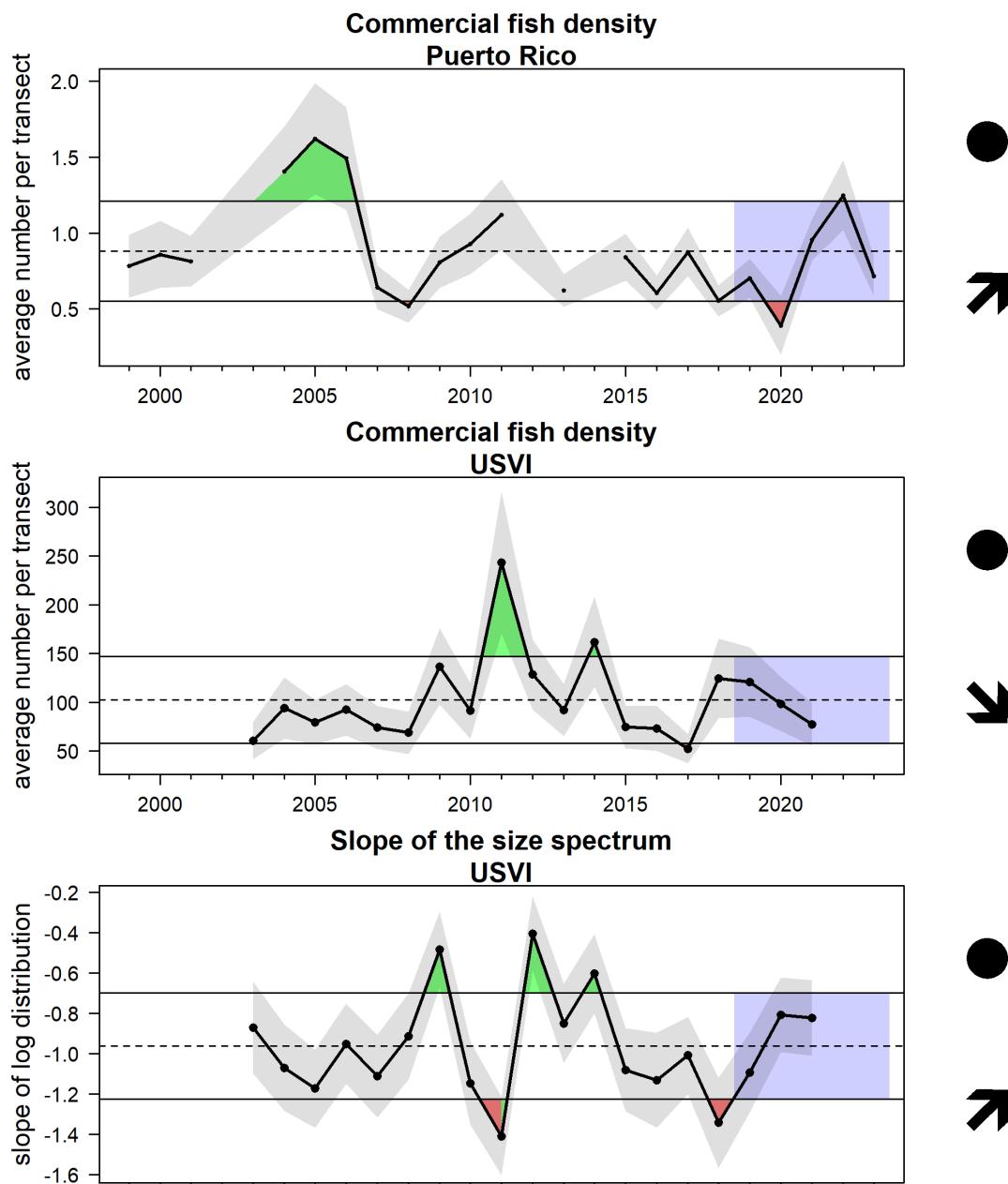


Figure 4: fish density

5. Tracking performance toward fishery management objectives

### Pelagic:demersal ratio

Indicator 18

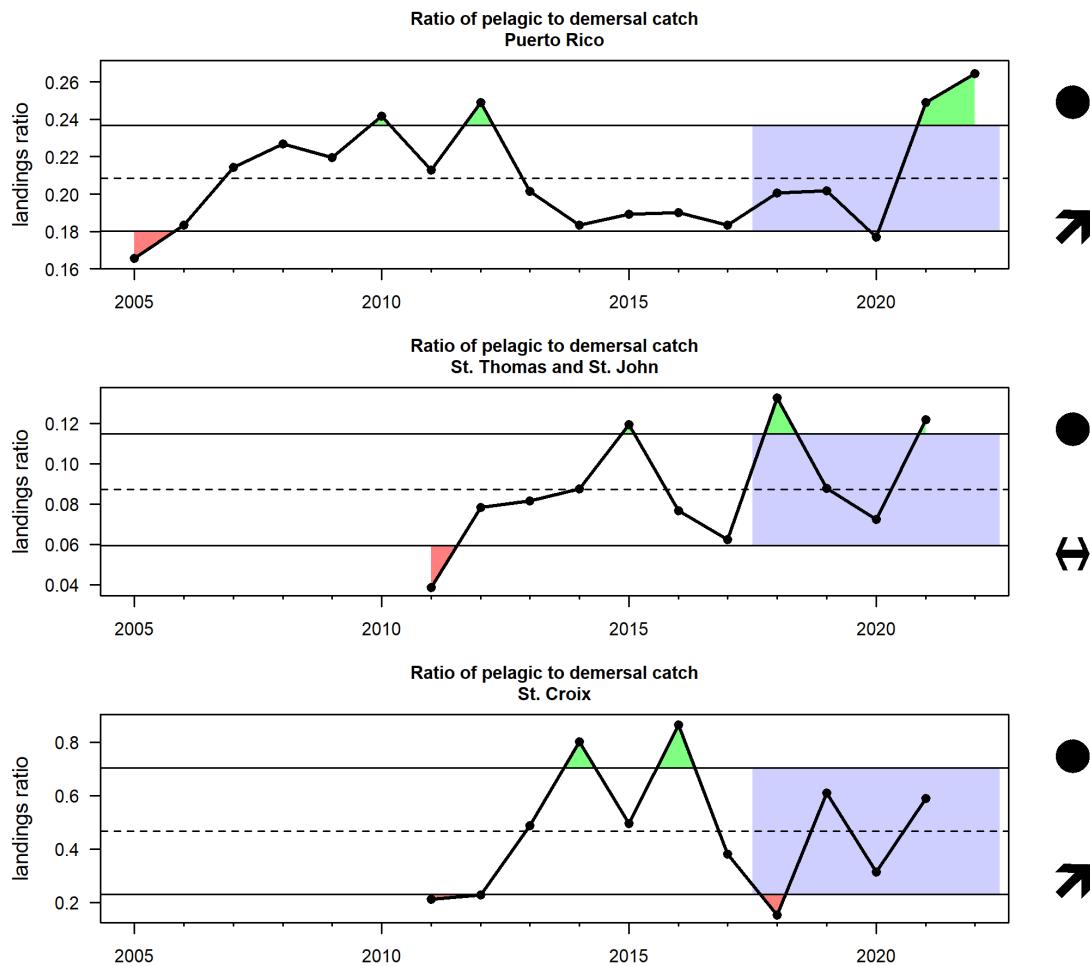


Figure 5: PD ratio

### Maximum length and size structure

Indicator 19 - Lmax indicator

## 5. Tracking performance toward fishery management objectives

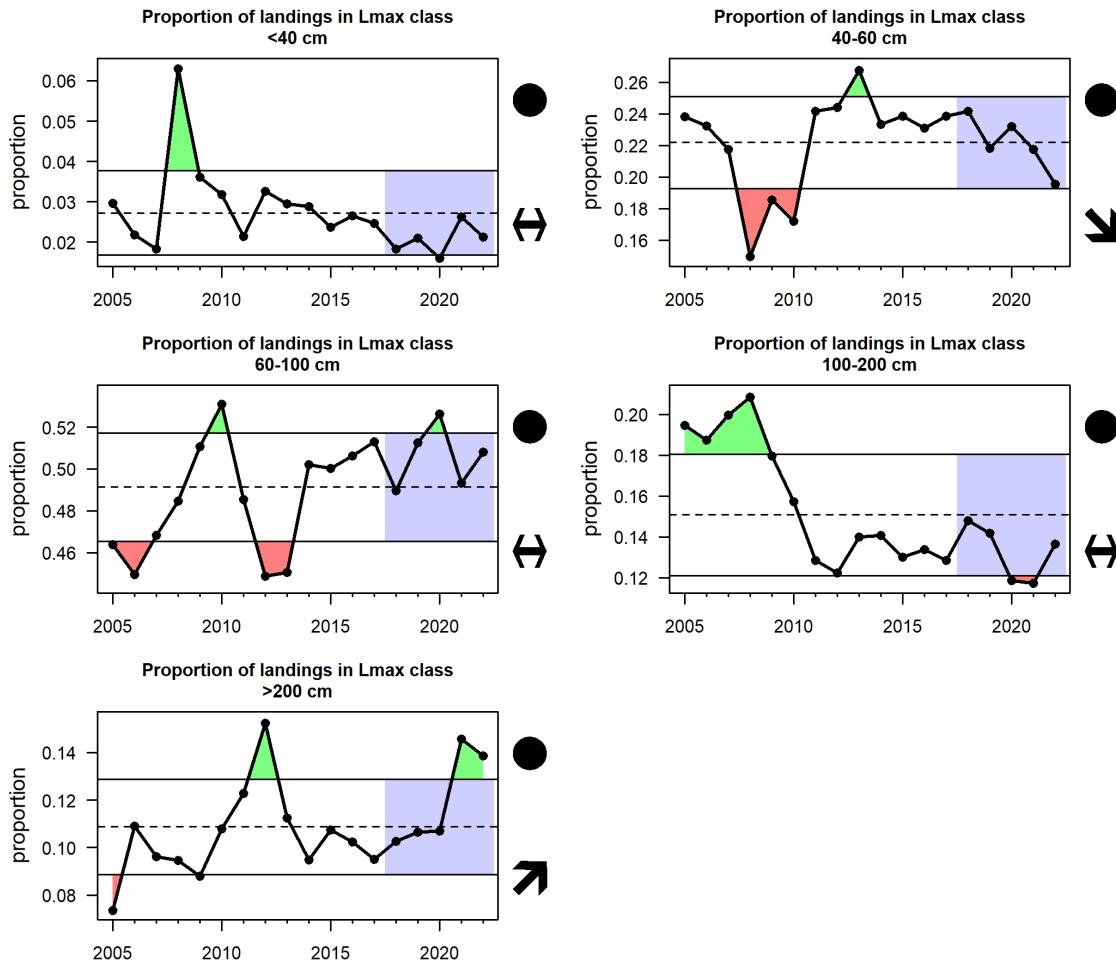


Figure 6: PR Lmax

## 5. Tracking performance toward fishery management objectives

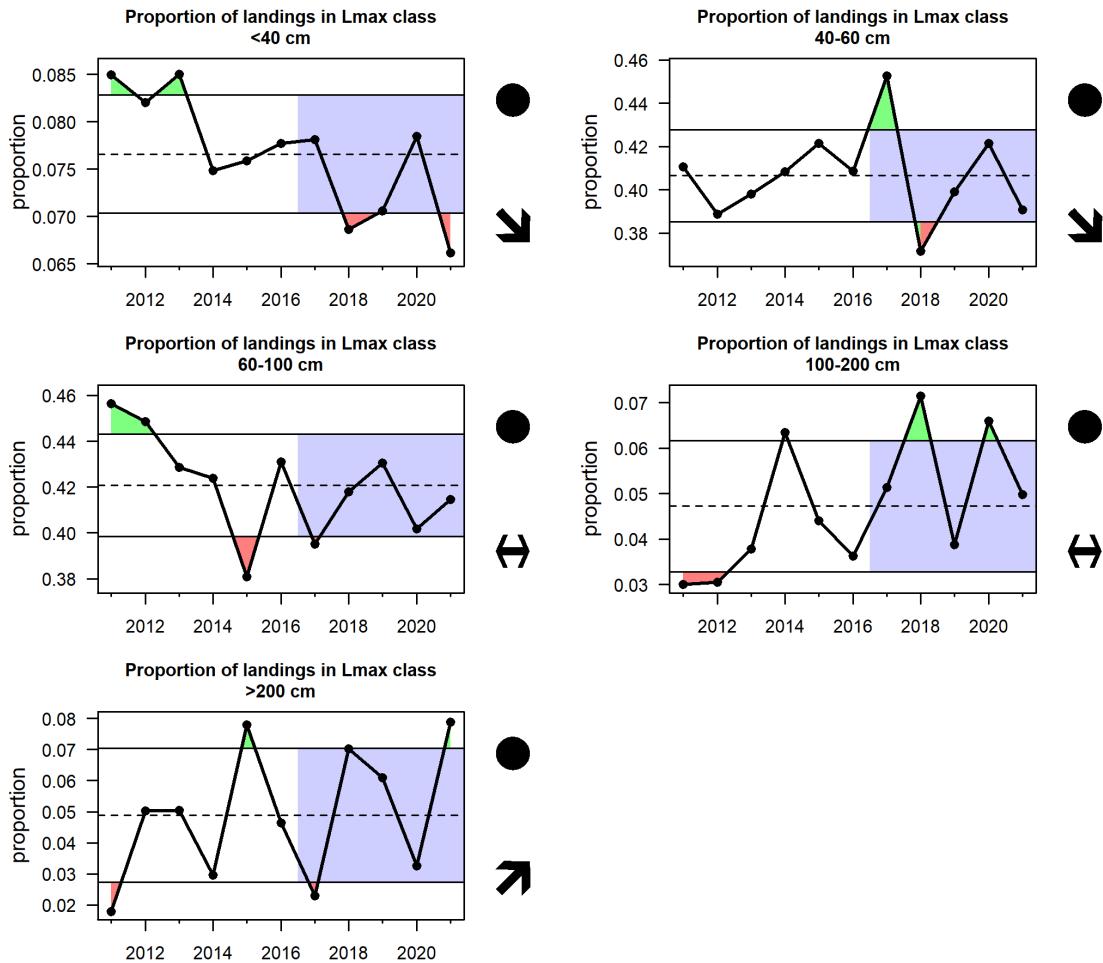


Figure 7: STT Lmax

## 5. Tracking performance toward fishery management objectives

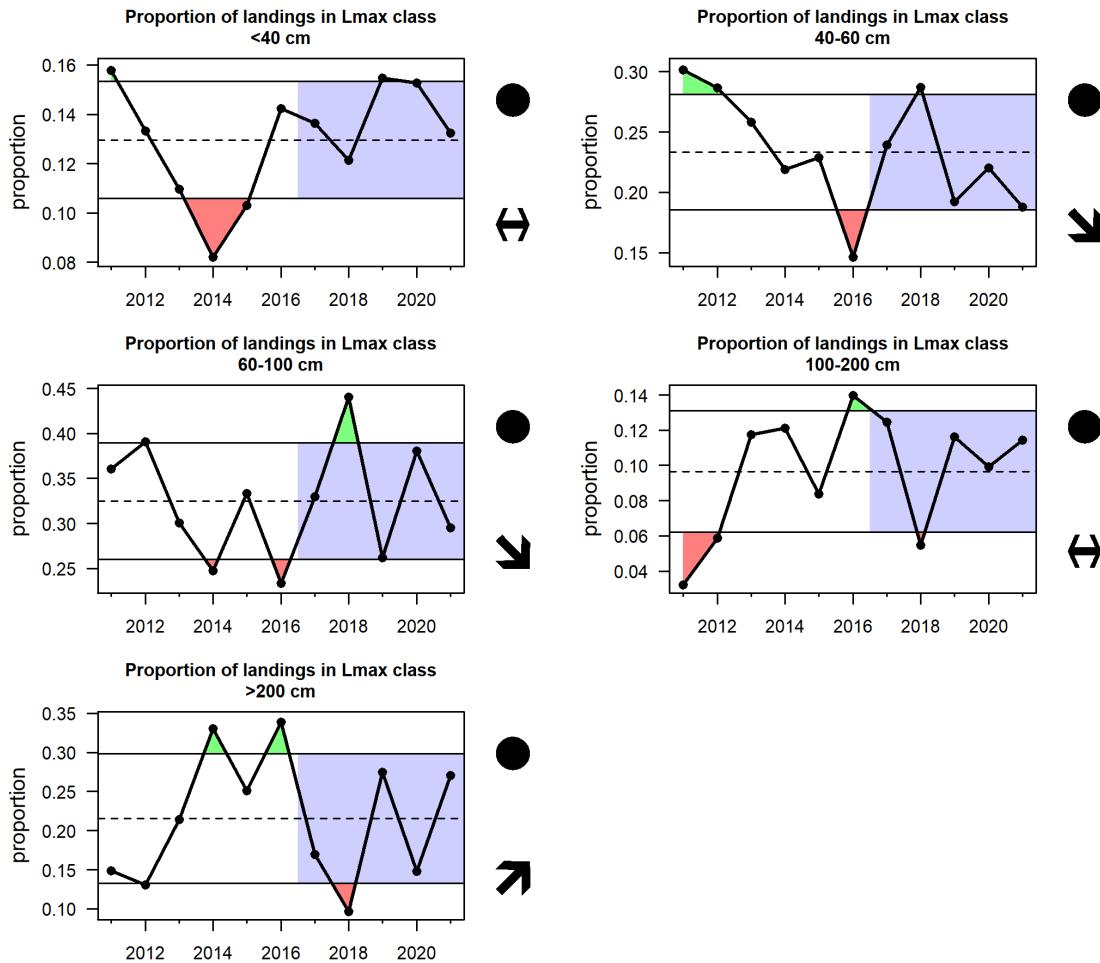


Figure 8: STX Lmax

## Commercial landings

Indicator 20 - total landings

## 5. Tracking performance toward fishery management objectives

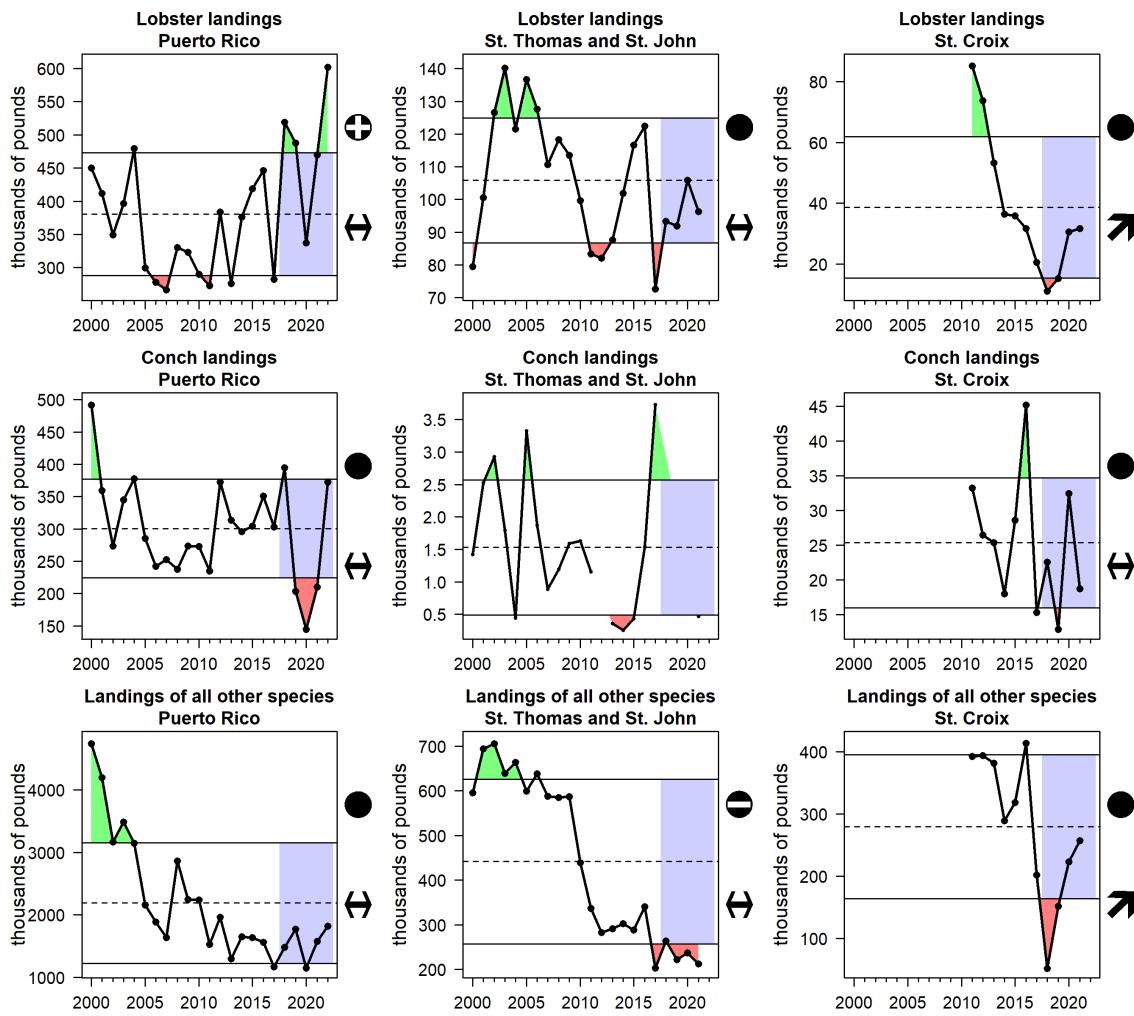


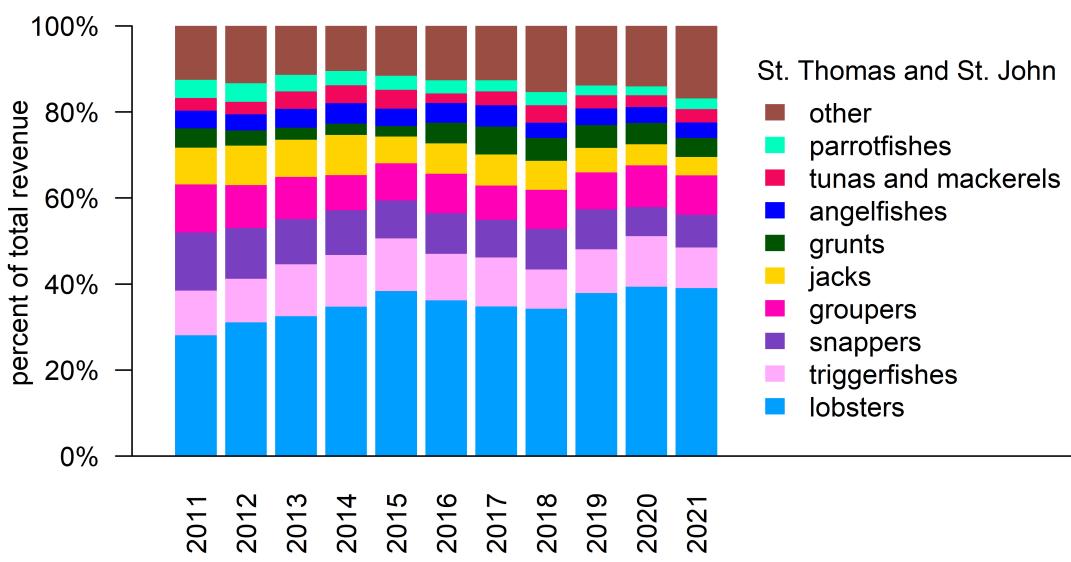
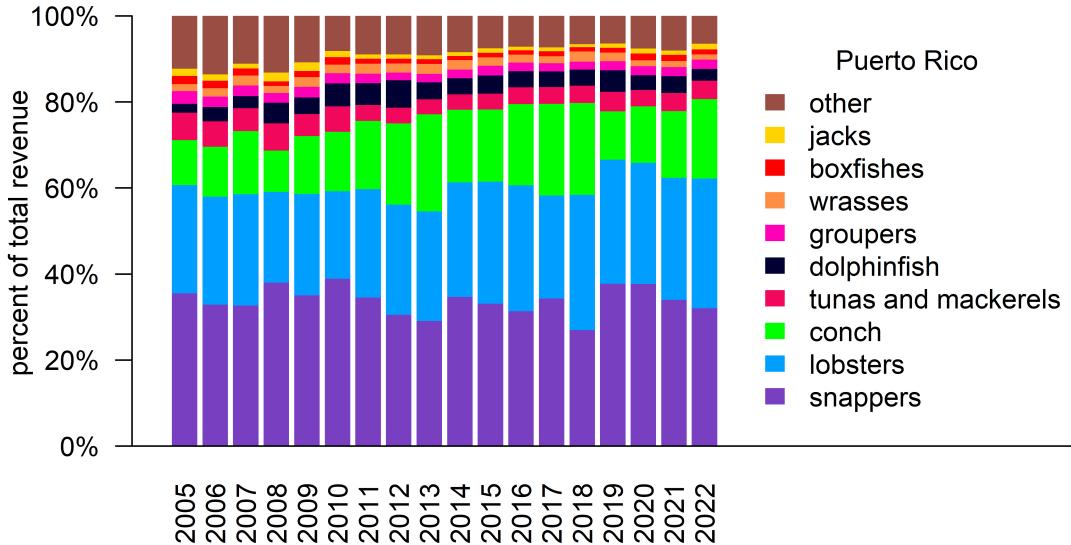
Figure 9: Total landings

## 5.2 Socioeconomic health

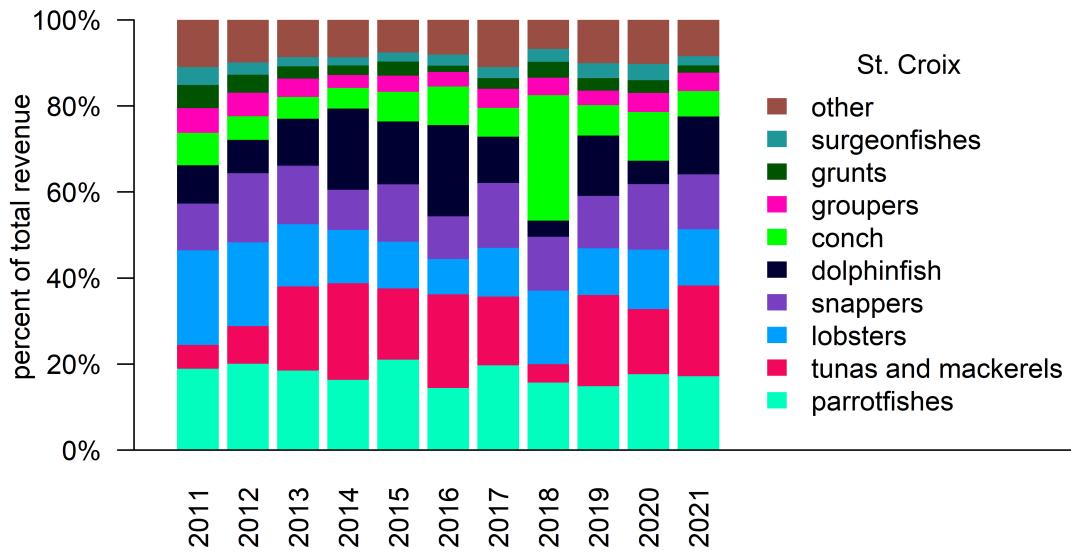
### Total, lobster and conch revenues

Indicator 21 - percent revenues by species group

5. Tracking performance toward fishery management objectives



## 5. Tracking performance toward fishery management objectives

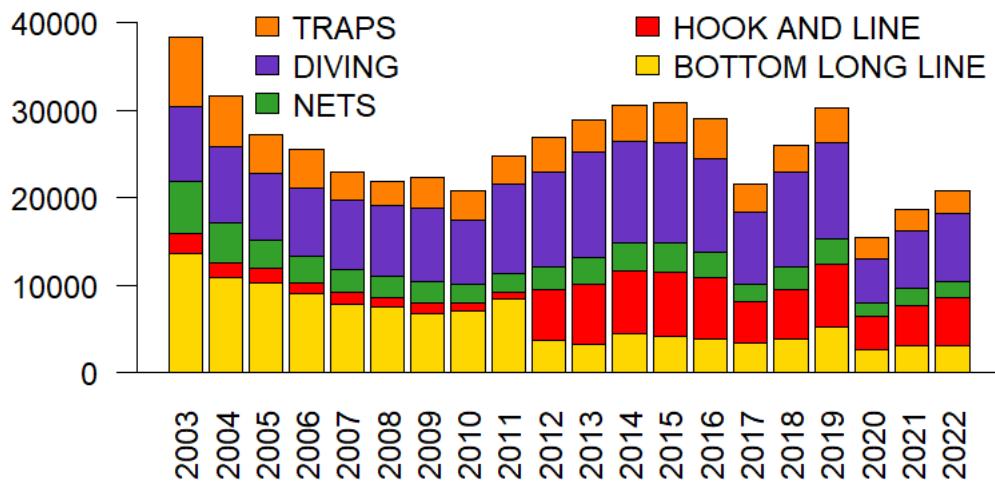


### Total, lobster and conch trips

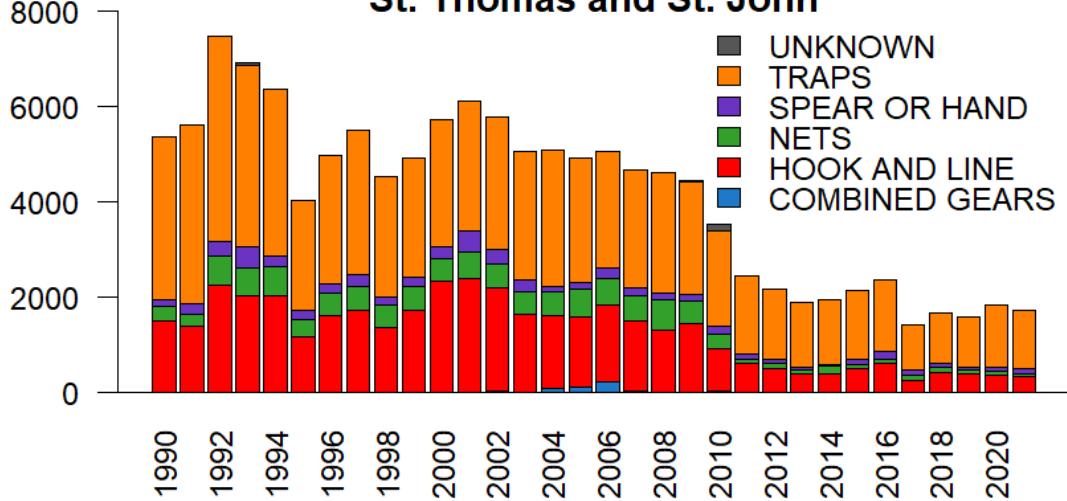
Indicator 22 - number of trips

5. Tracking performance toward fishery management objectives

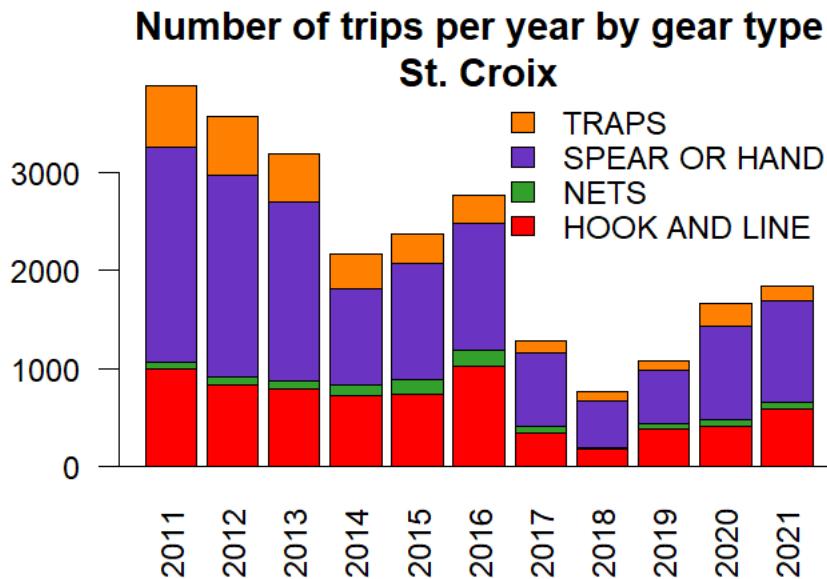
### Number of trips per year by gear type Puerto Rico



### Number of trips per year by gear type St. Thomas and St. John



5. Tracking performance toward fishery management objectives



**Ocean economy establishments, employment, and wages**

Indicator 23

5. Tracking performance toward fishery management objectives

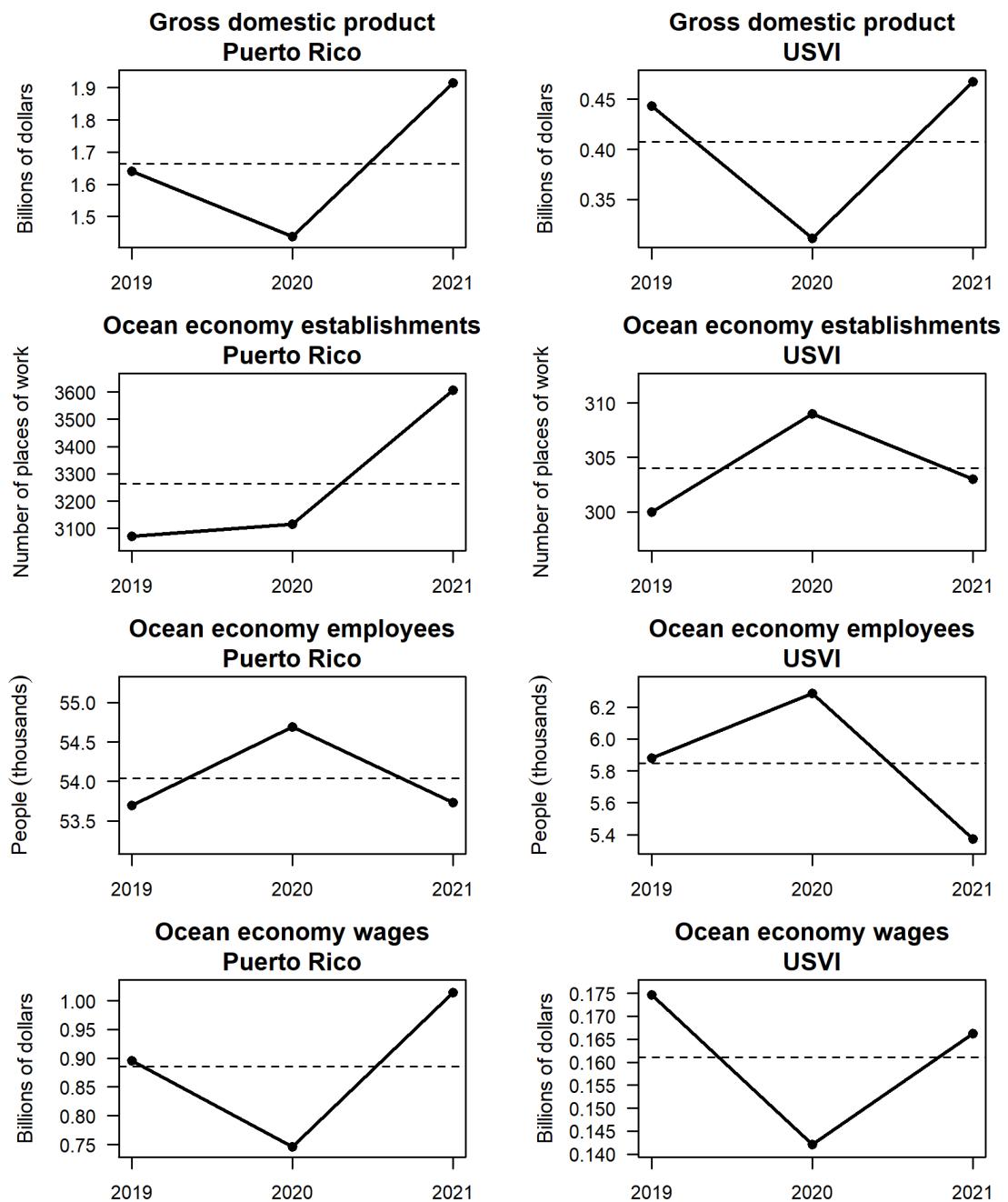


Figure 10: Ocean economy

## 5. Tracking performance toward fishery management objectives

### GDP

Indicator 24

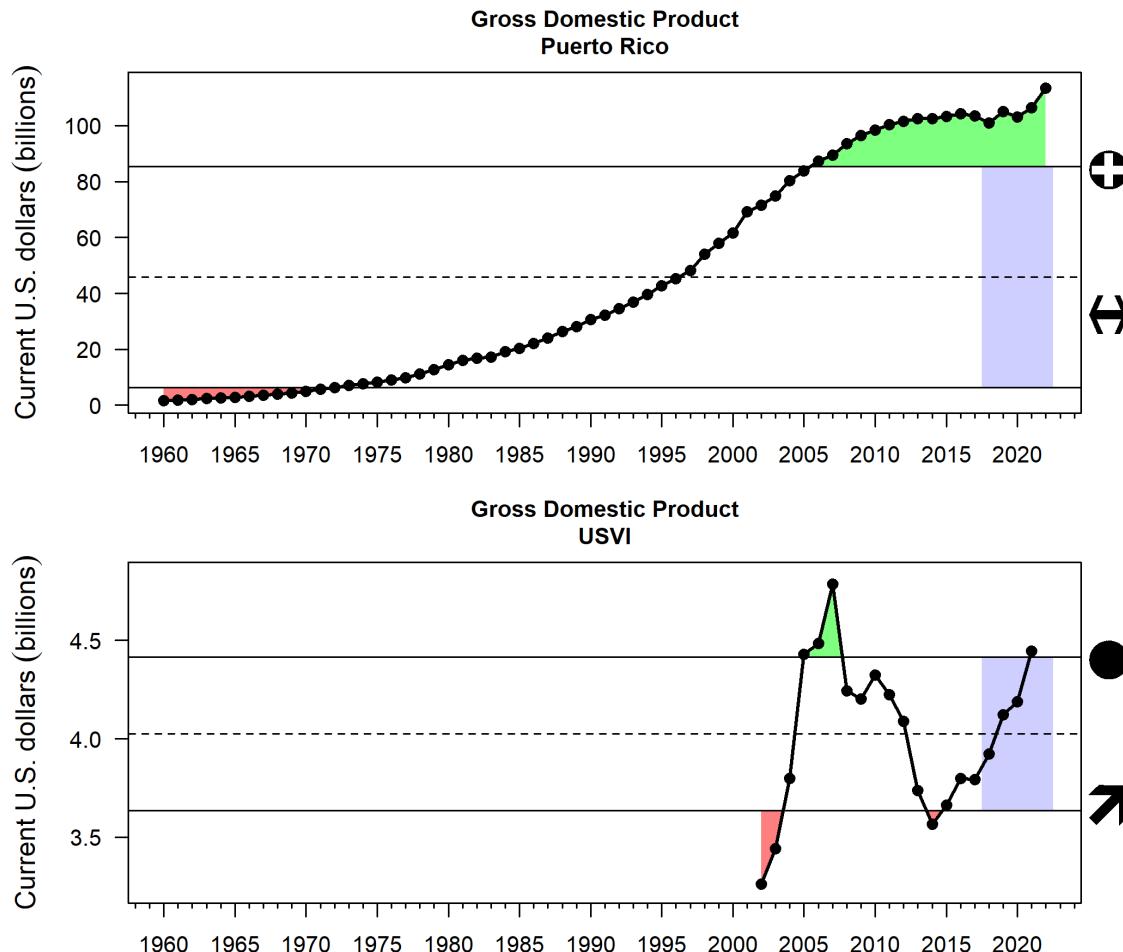


Figure 11: GDP

### Unemployment

Indicator 25

5. Tracking performance toward fishery management objectives

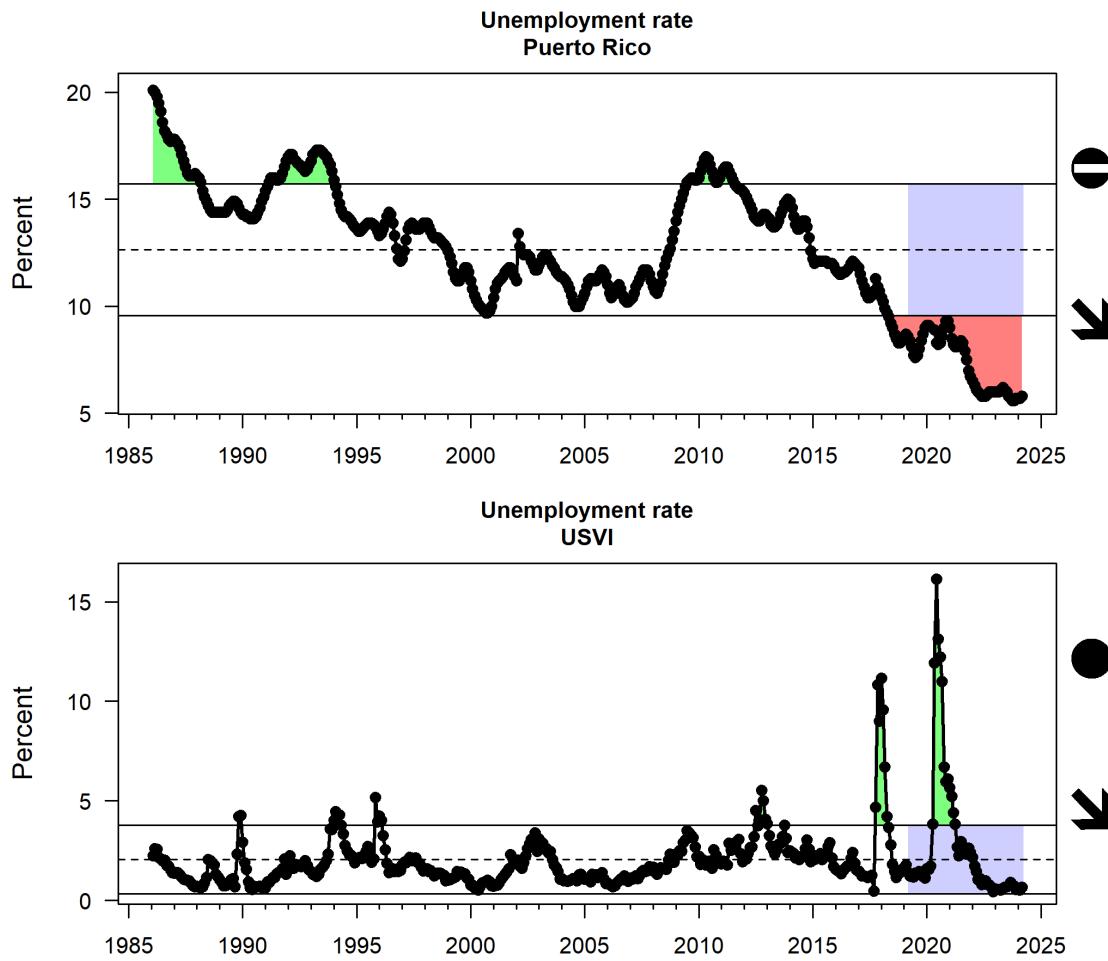


Figure 12: Unemployment

### 5.3 Equity

#### Gini coefficient for distribution of landings and revenue

Indicator 26

5. Tracking performance toward fishery management objectives

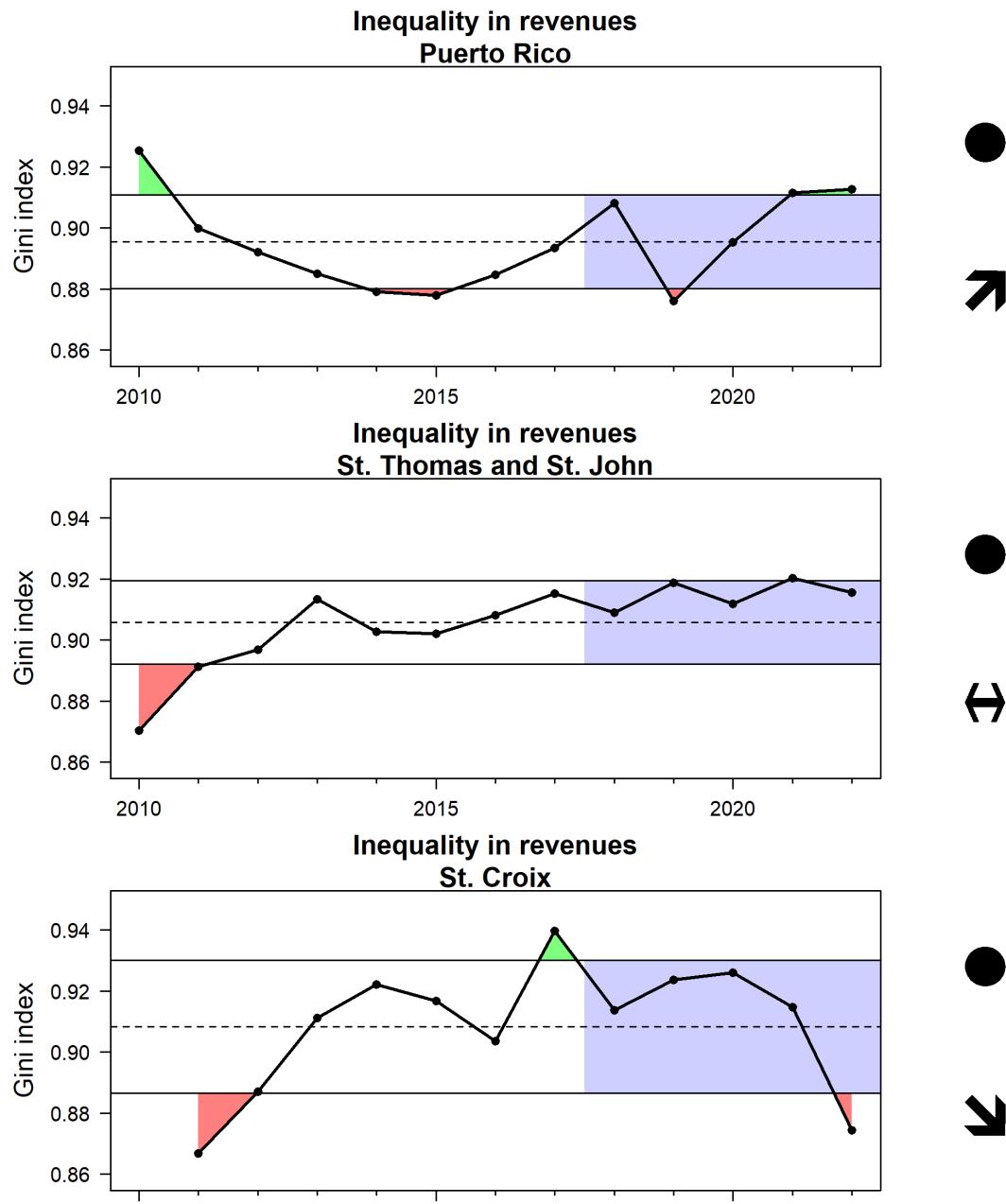
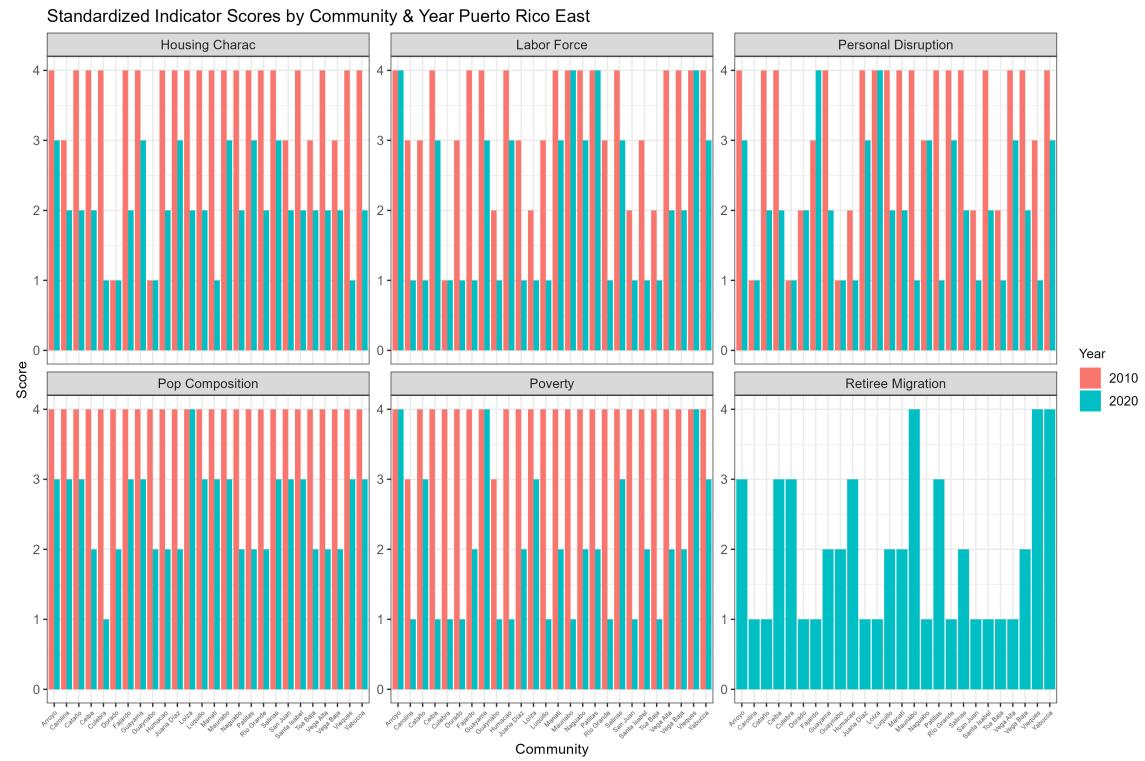


Figure 13: Gini coefficient

## 5. Tracking performance toward fishery management objectives

### Environmental justice, economic, and gentrification pressure

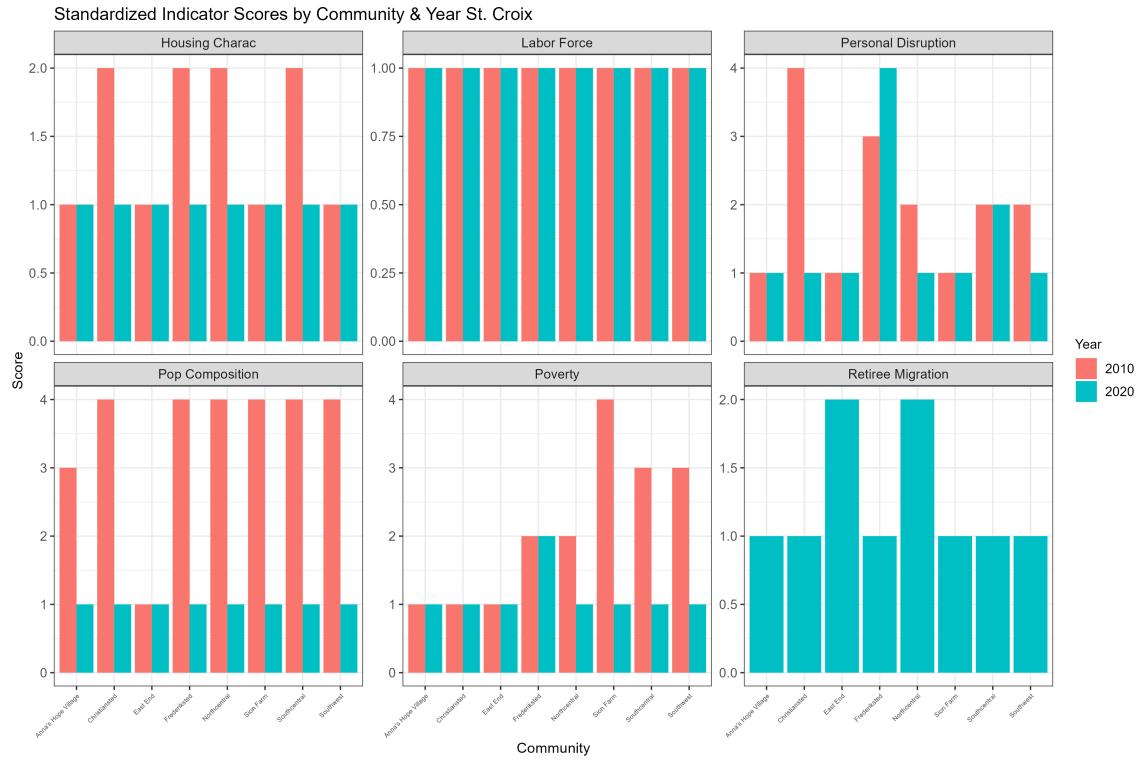
#### Indicator 27



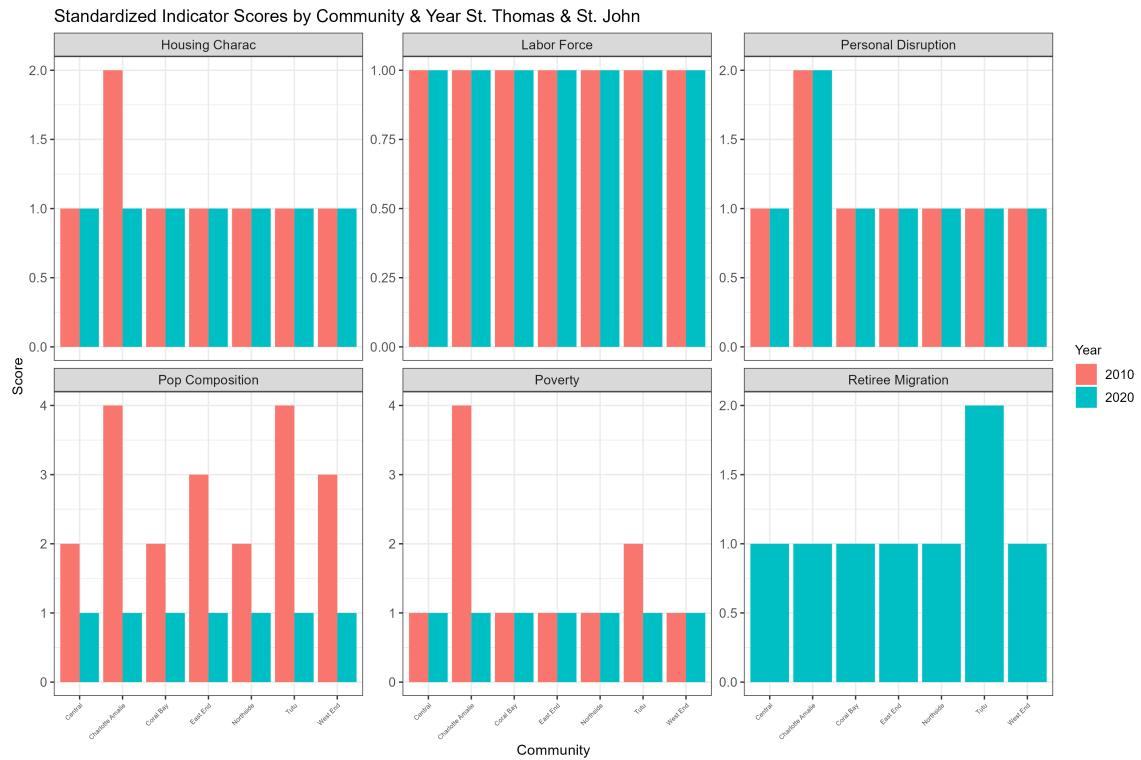
## 5. Tracking performance toward fishery management objectives



## 5. Tracking performance toward fishery management objectives



## 5. Tracking performance toward fishery management objectives



## 5.4 Engagement and participation

### Recreational landings

Indicator 28

5. Tracking performance toward fishery management objectives

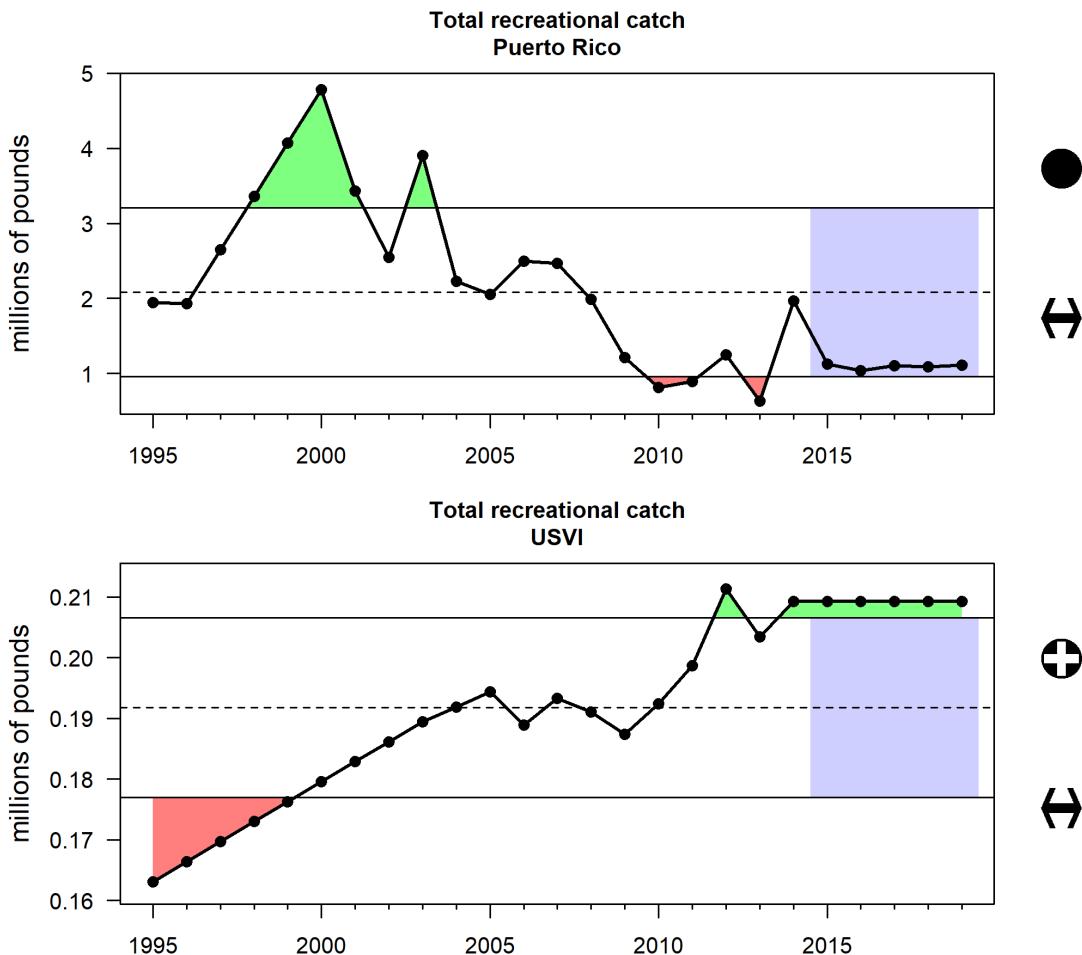
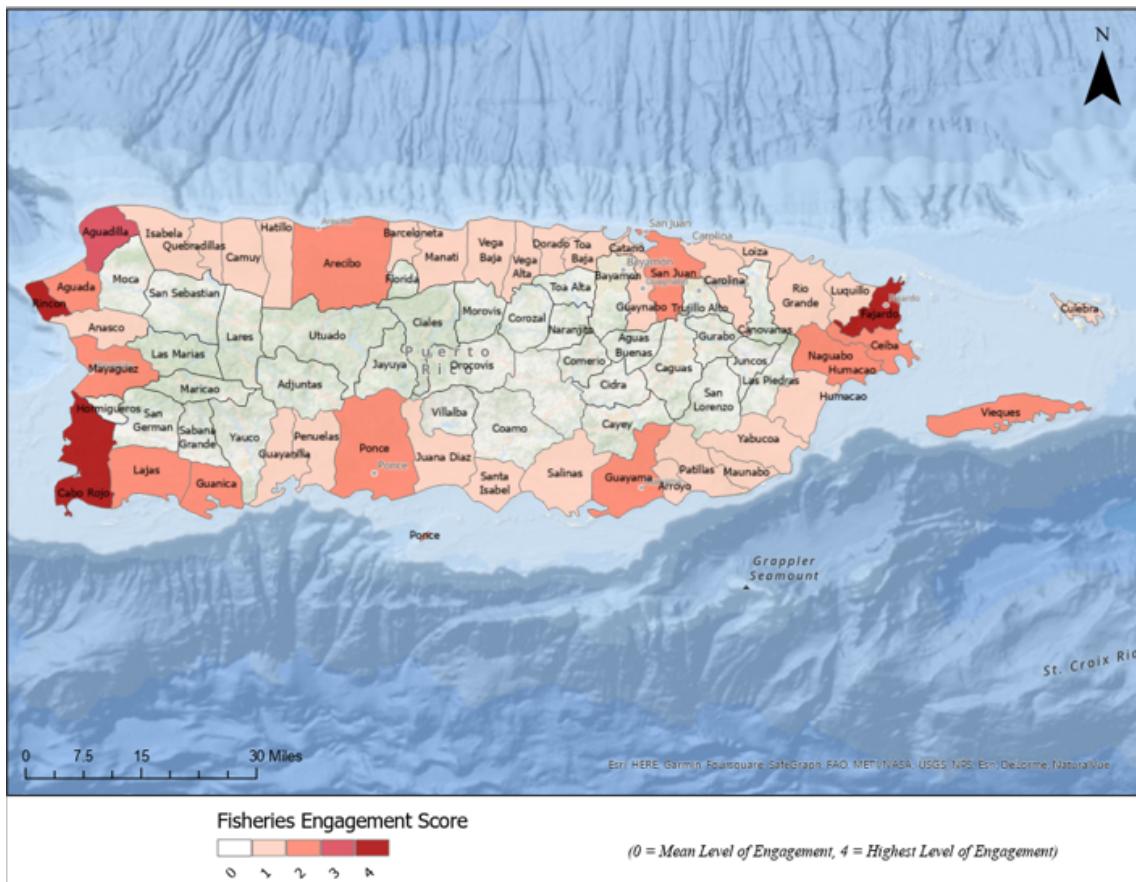


Figure 14: Rec catch

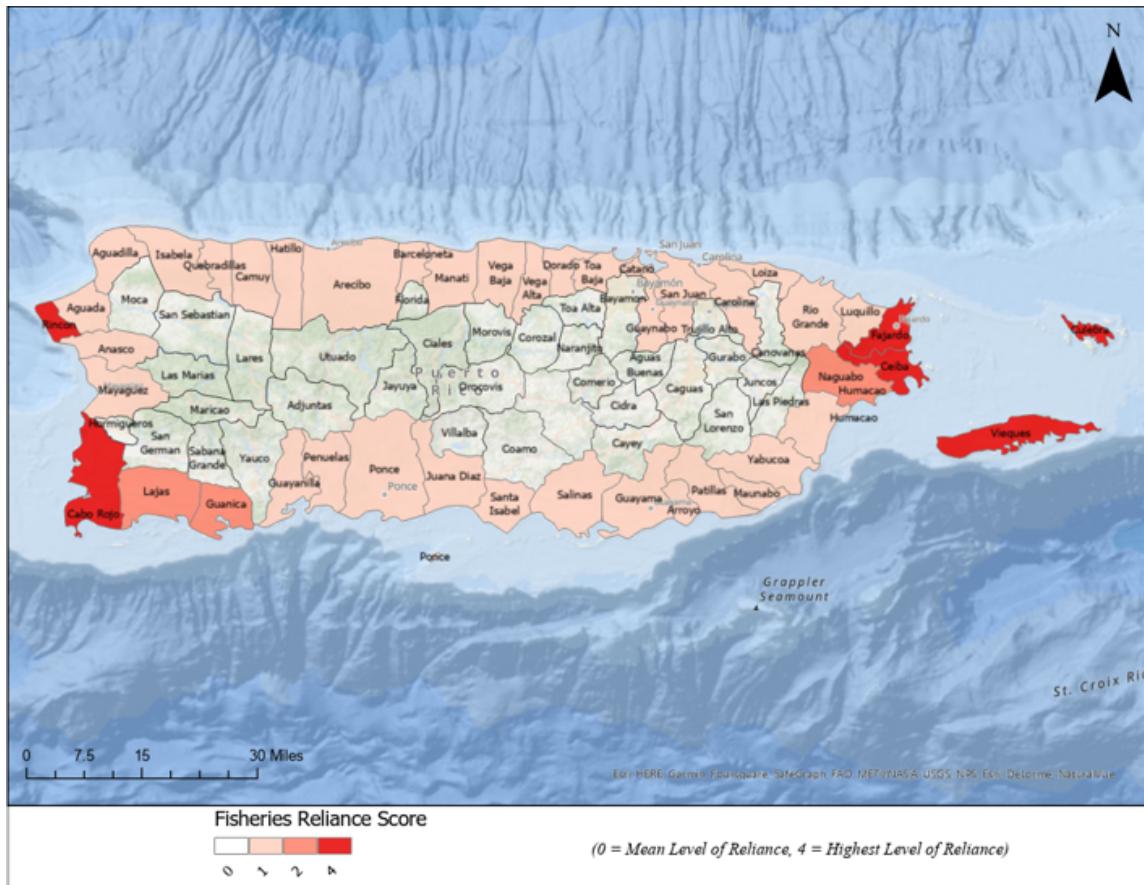
### Commercial fishing engagement and reliance

Indicator 29

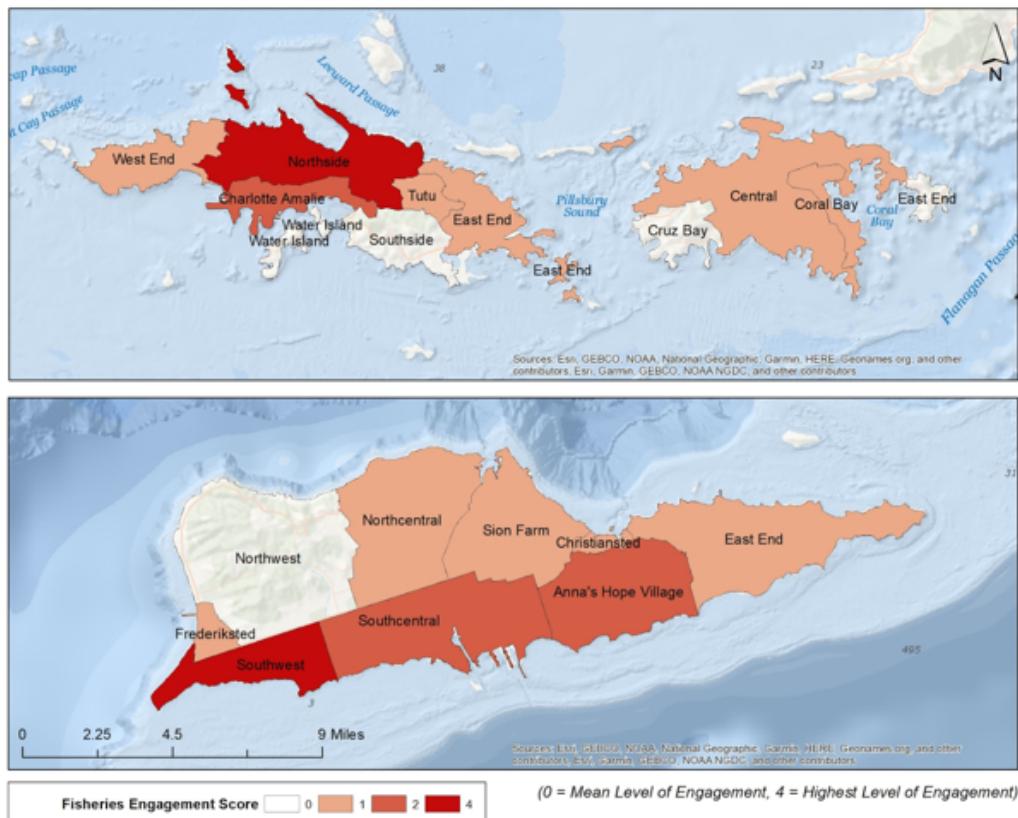
## 5. Tracking performance toward fishery management objectives



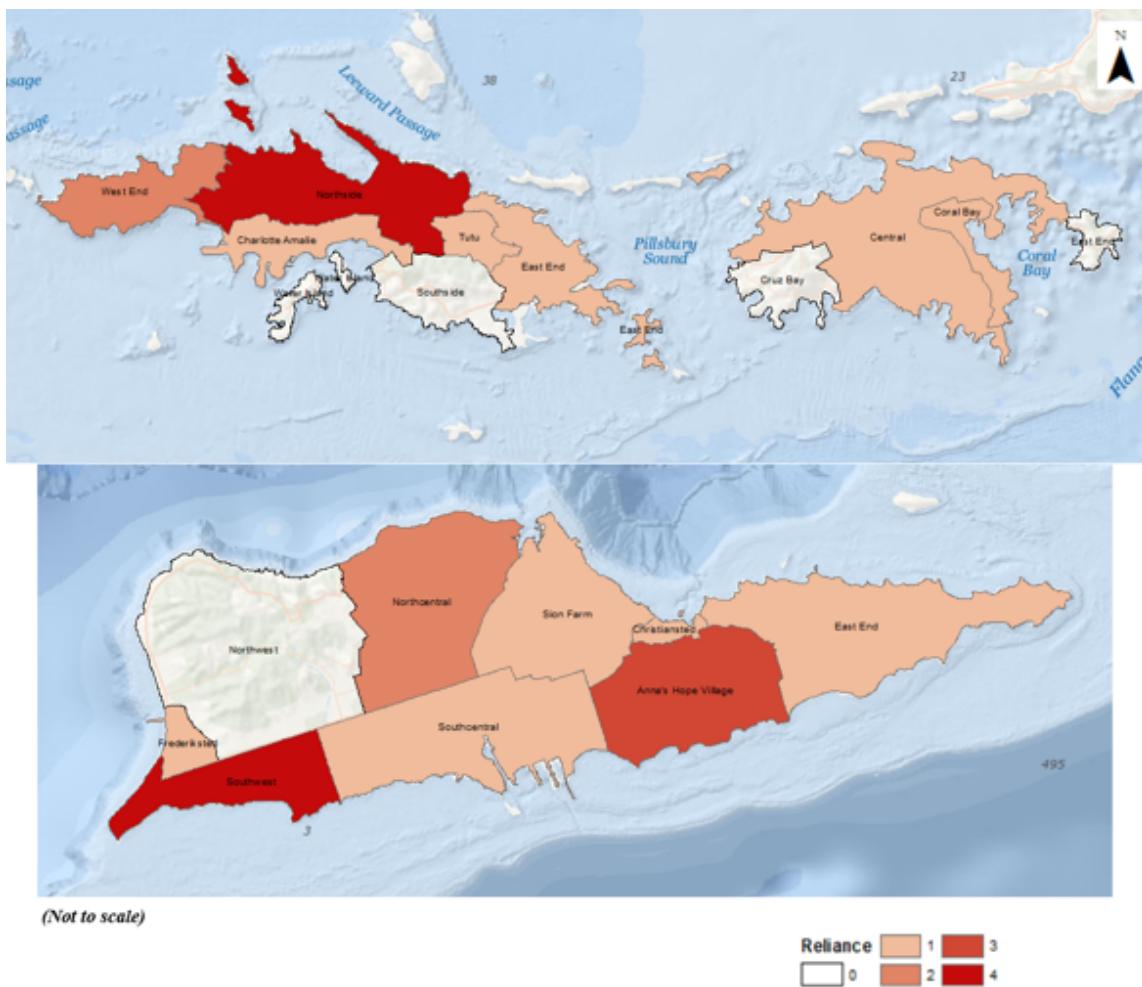
## 5. Tracking performance toward fishery management objectives



## 5. Tracking performance toward fishery management objectives



## 5. Tracking performance toward fishery management objectives



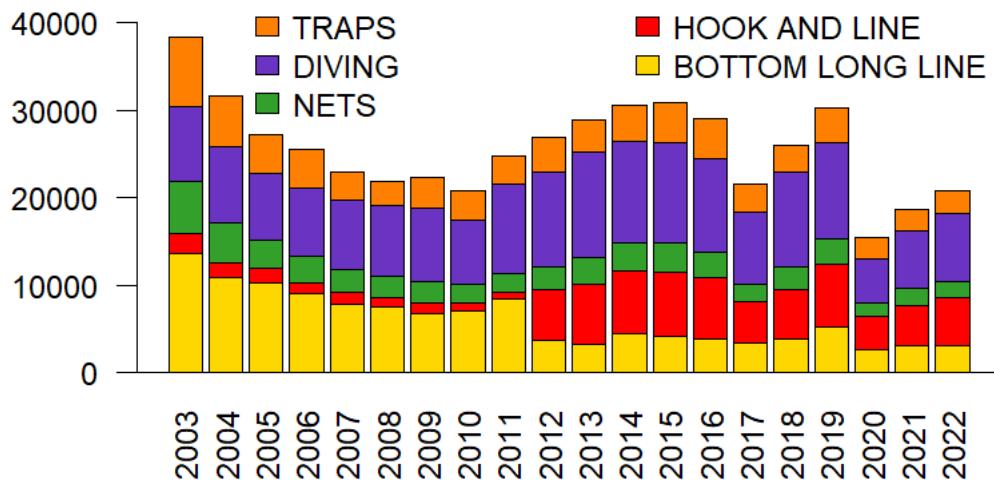
## 5.5 Bycatch reduction

### Changes in gear type

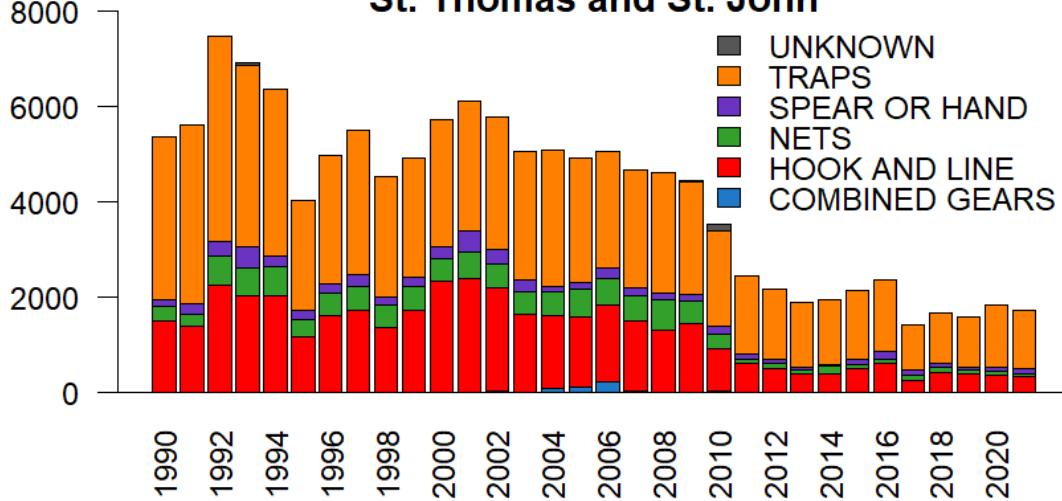
Indicator 30

5. Tracking performance toward fishery management objectives

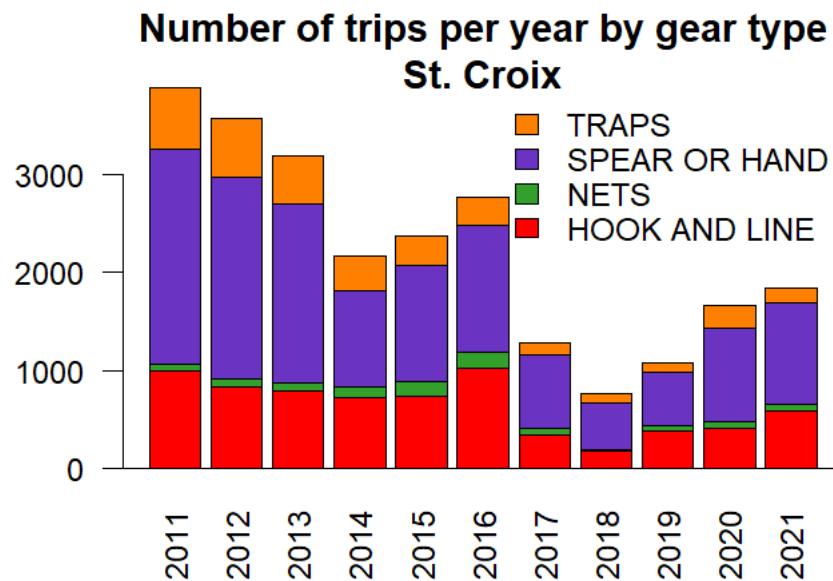
### Number of trips per year by gear type Puerto Rico



### Number of trips per year by gear type St. Thomas and St. John



5. Tracking performance toward fishery management objectives



5. Tracking performance toward fishery management objectives

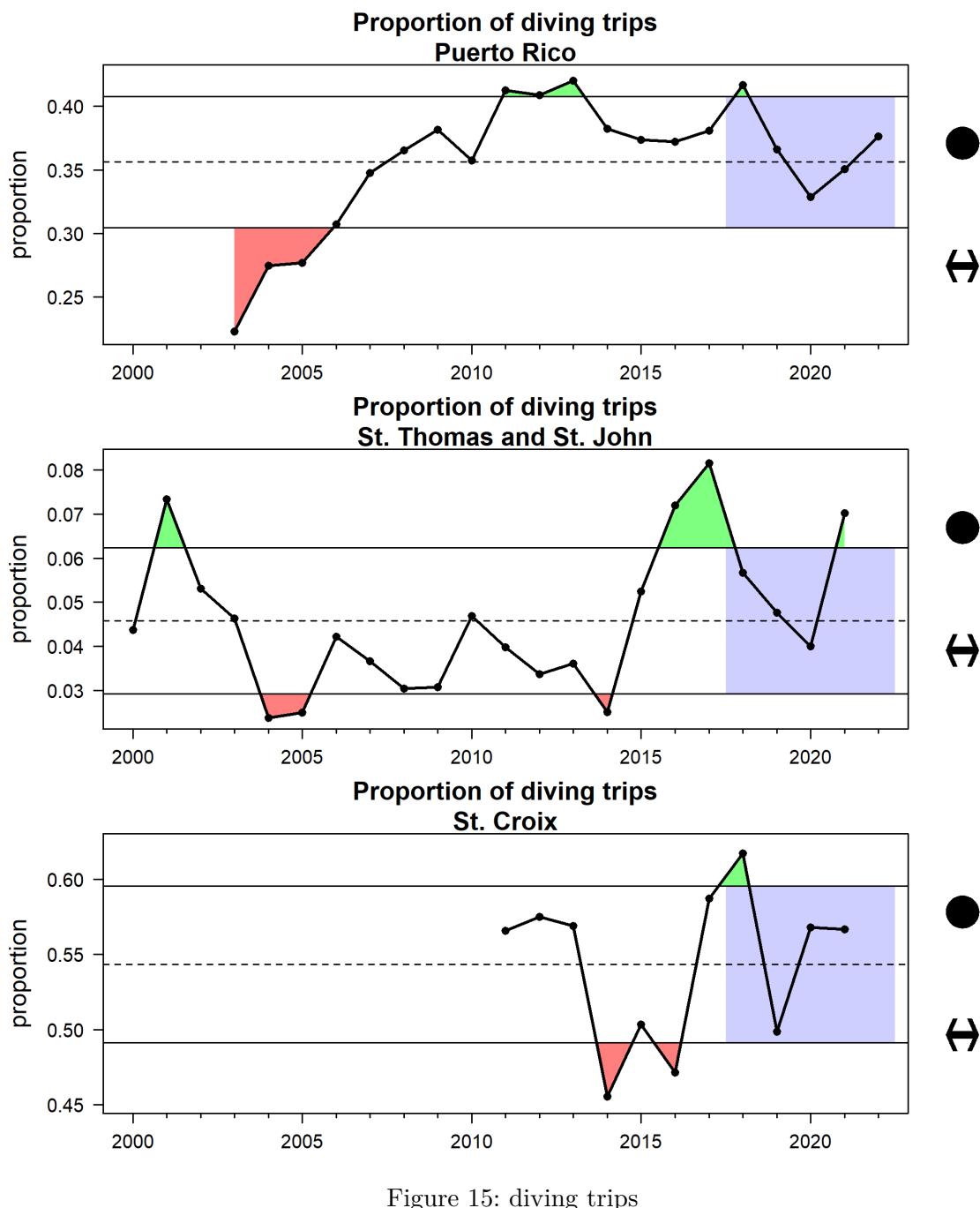


Figure 15: diving trips

## 5. Tracking performance toward fishery management objectives

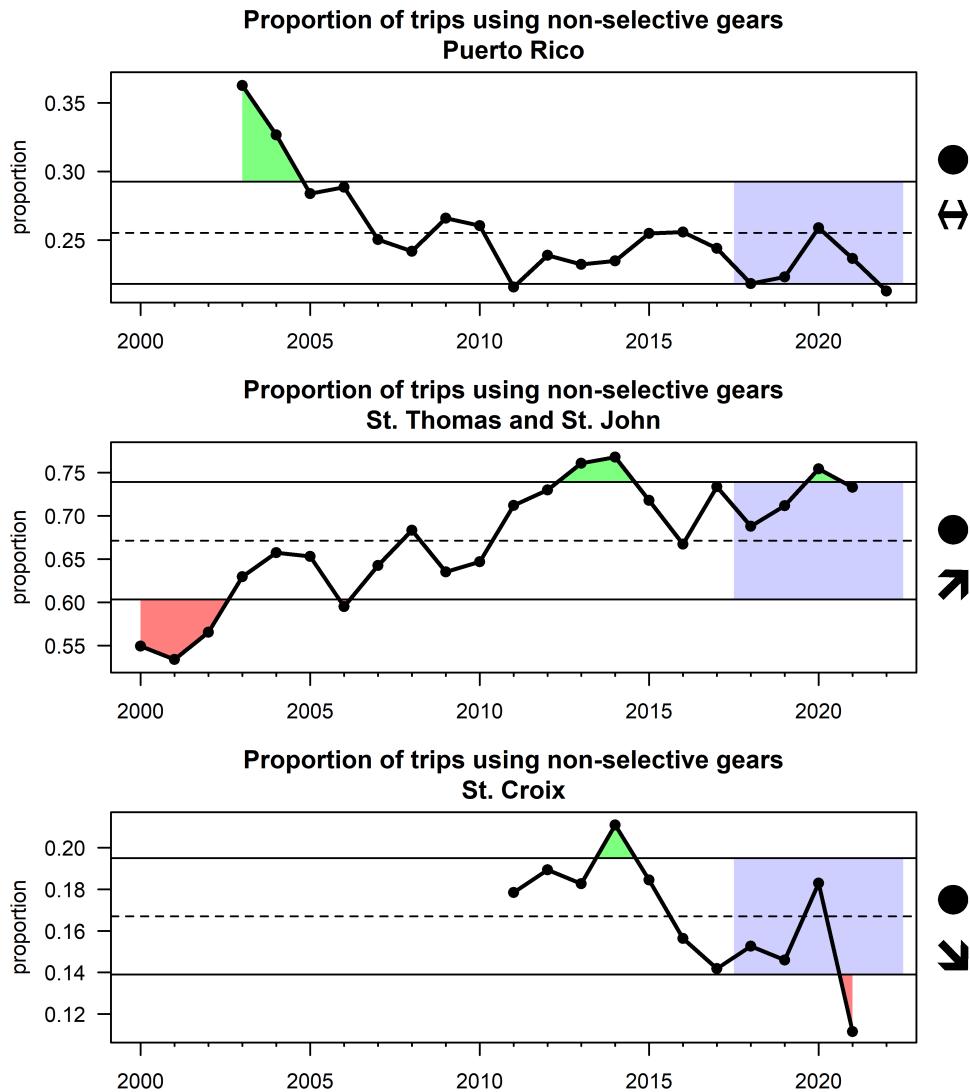


Figure 16: Non-selective gears

## 5.5 Governance

### Number of new regulations

Indicator 31

## 5. Tracking performance toward fishery management objectives

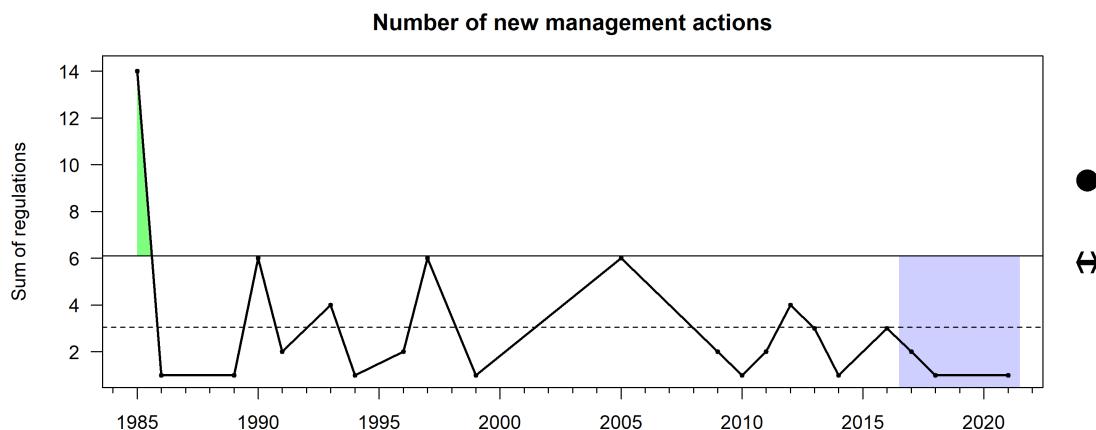


Figure 17: Regulations

### Percent of species with informative catch limits

Indicator 32

5. Tracking performance toward fishery management objectives

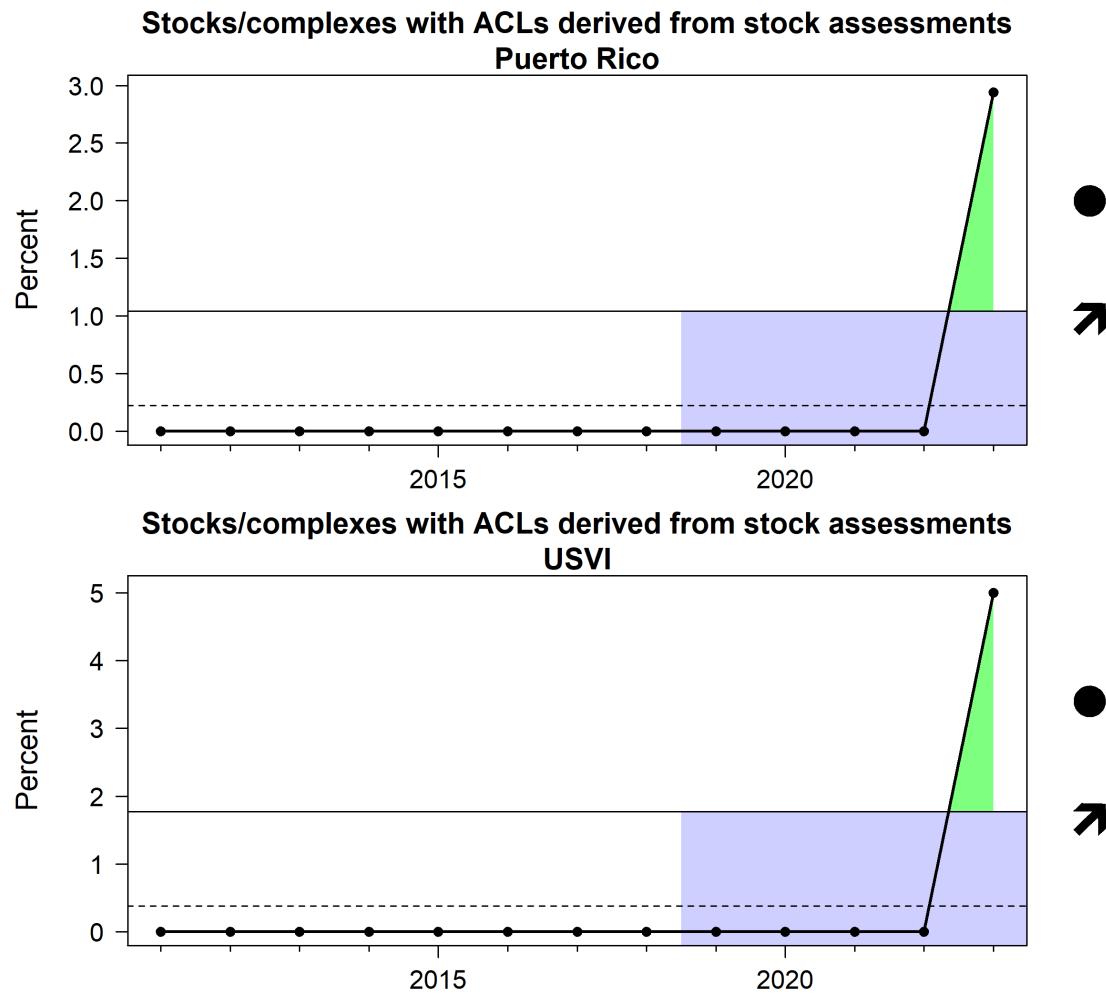


Figure 18: Tier 3 plot

**Number of education and outreach events**

Indicator 33

5. Tracking performance toward fishery management objectives

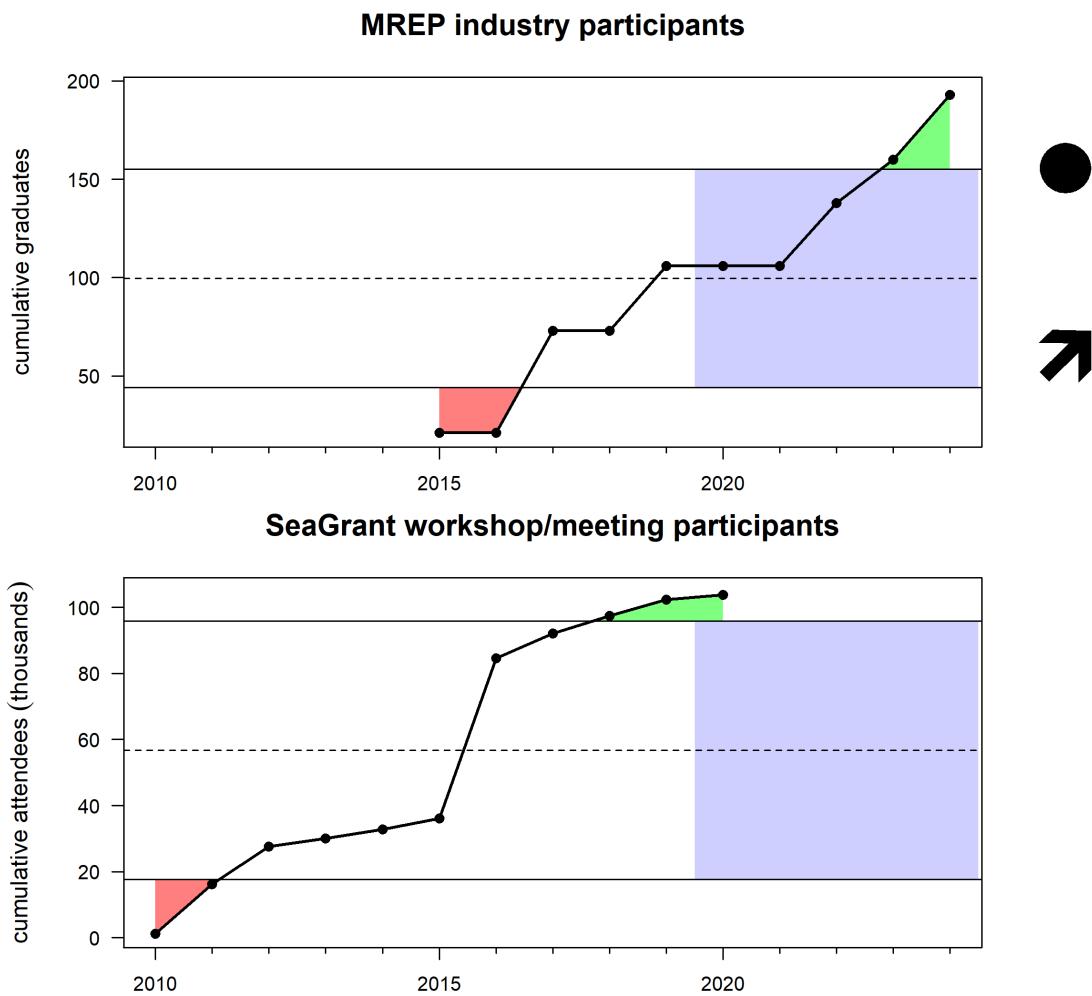


Figure 19: Outreach

**Number of enforcement actions**

Indicator 34

## 5. Tracking performance toward fishery management objectives

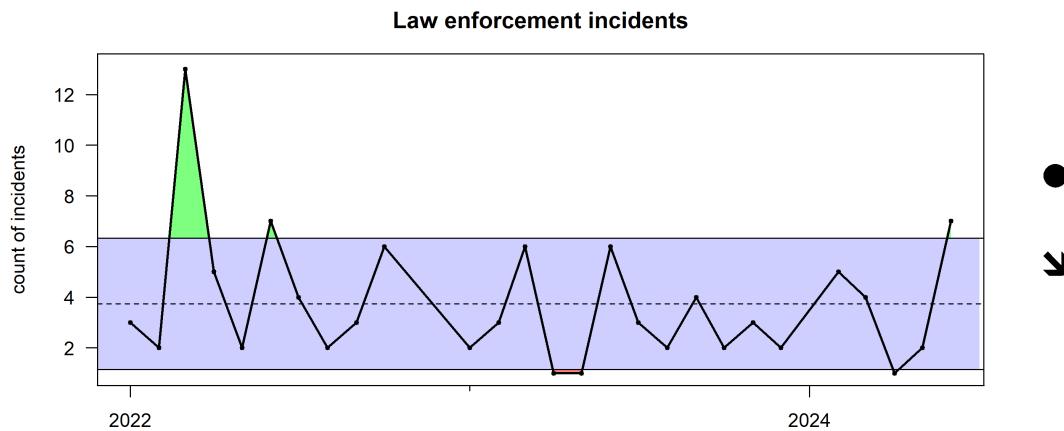


Figure 20: Enforcement

## 5.6 Protection of ecosystems

### Percent coral cover and coral species diversity

Indicator 35

5. Tracking performance toward fishery management objectives

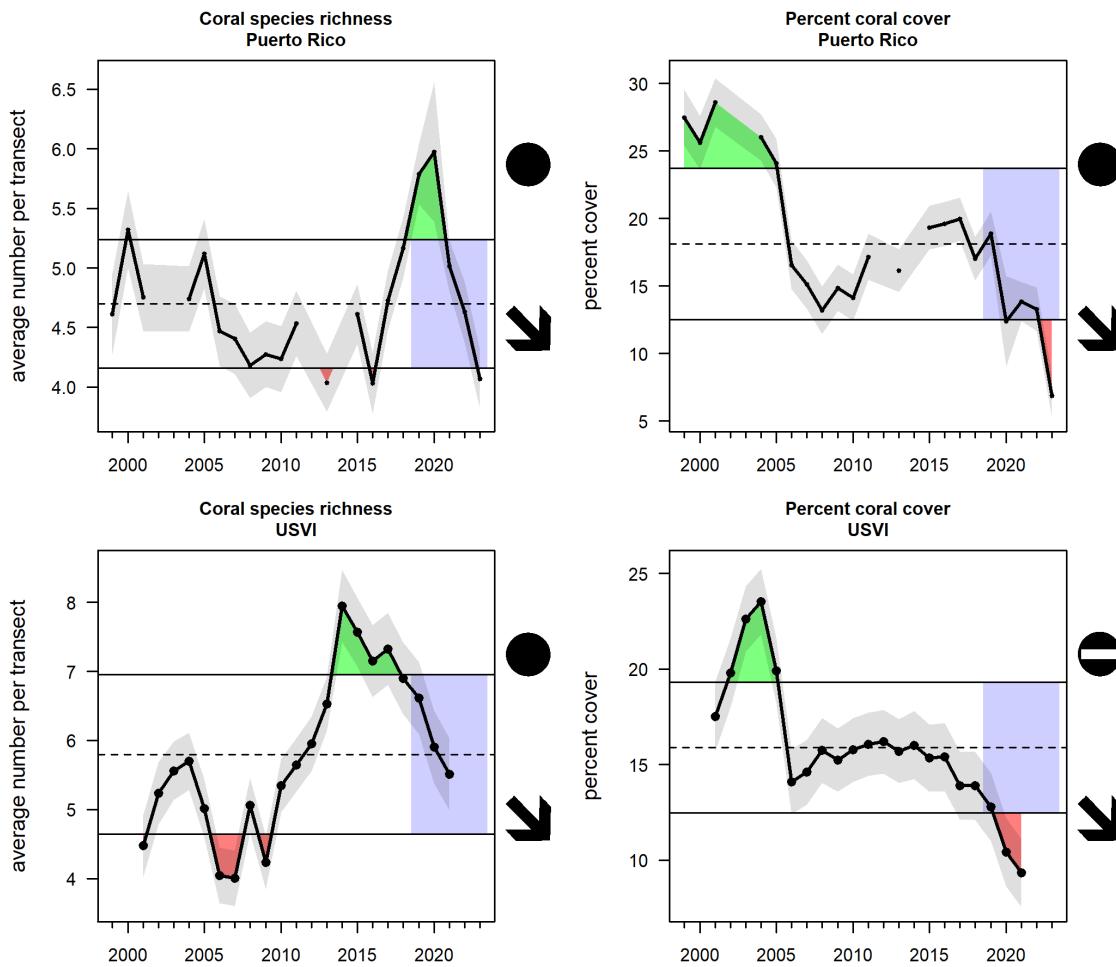


Figure 21: Coral

## **6. Integrated ecosystem perspectives**

Stoplight plot (maybe this should be in the beginning material)

## **7. Research Recommendations**

### **Data gaps**

## **8. Acknowledgements**

## 9. Contributors

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## **9. References**

## **10. Data source table**