INTEGRATING RISK ASSESSMENT IN DECISION MAKING

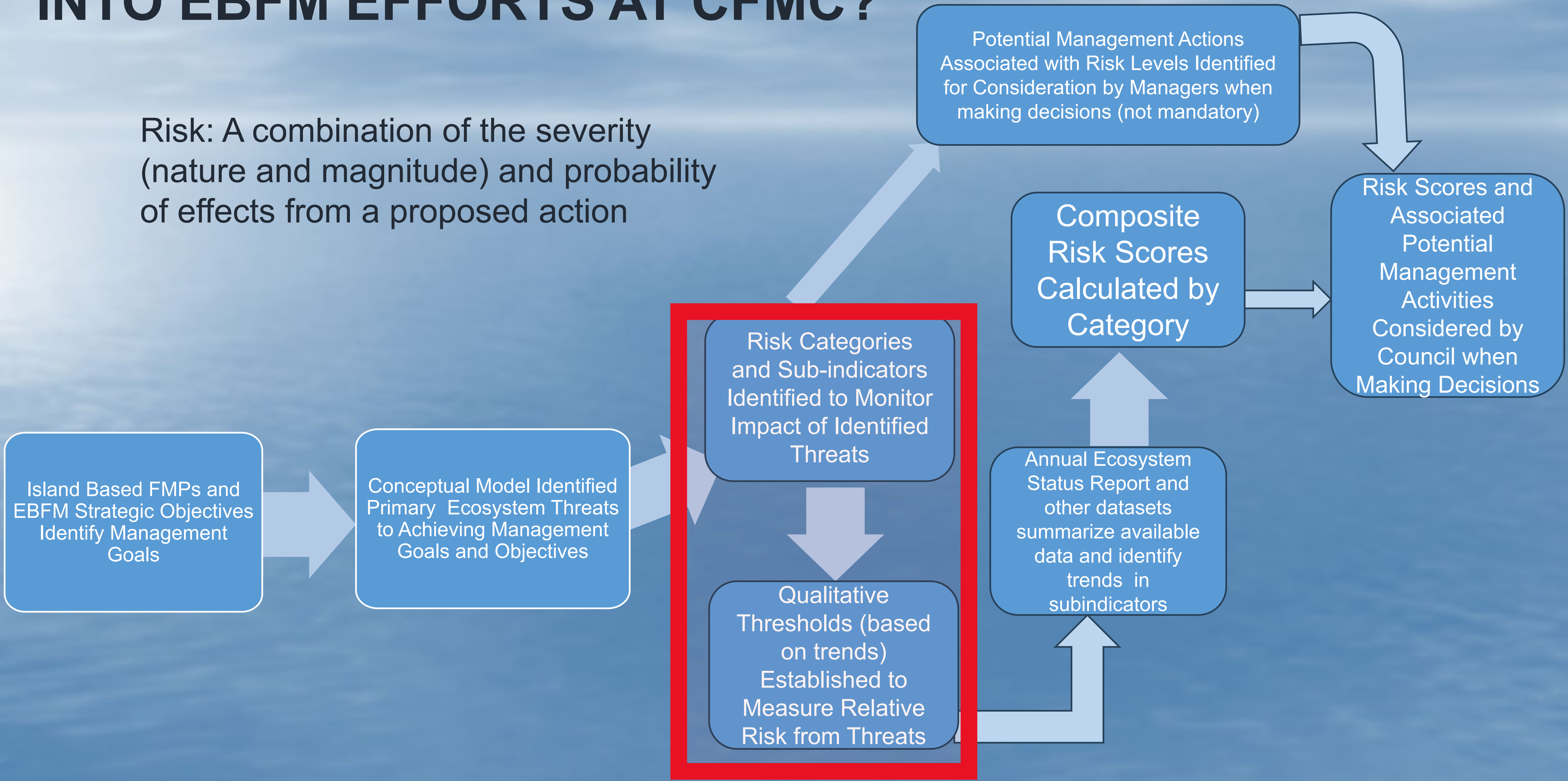
1) Overview of Selected Indicators
2) Structure and Scoring of Risk Using Indicators
3) Integrating Use of Risk Assessment Scores into a Decision-Making Process
4) Discussion of Ecosystem Level Indicators and Certain other Sub-Indicators

GOALS

- Overview of Indicators
  - Feedback on Selecting Ecosystem Level Indicators
- Overview of Risk Assessment Structure and Scoring
  - Feedback on Scoring Structure
- Integrating Risk Assessment into a Decision-Making Process
  - Discussion of Using Structured Decision-Making to Facilitate Decision Making Under Deep Uncertainty & Role Risk Assessment Plays in Weighing Policy Options
  - Discussion of Incorporating Mandated Adaptive Management Triggers Based on Risk Assessment Score

HOW DOES ECOSYSTEM RISK FRAMEWORK FIT INTO EBFM EFFORTS AT CFMC?

Risk: A combination of the severity (nature and magnitude) and probability of effects from a proposed action



CONNECTING THREATS IDENTIFIED IN CONCEPTUAL MODEL TO RISK MANAGEMENT

Top Threats Identified in Conceptual Model

Run off
Marine Diseases
Invasive Species
Water Temperature
Climate Change
Hurricanes
Coastal Development
Tourism
Disturbances
Nonpoint Pollution
Anchoring
Sargassum
Nutrients
Erosion
Port Pollution
Marine Debris
Fishing Pressure

Water Quality Related
Run off; Port Pollution; Nonpoint Pollution; Coastal Development; Erosion; Nutrients

Ecosystem Level Related
Water Temperature
Climate Change

Community-Related
Disturbances
Hurricanes

Ocean Economy Related
Tourism
Port Pollution
Marine Debris
Anchoring

RELATING RISK CATEGORIES & STRATEGIC OBJECTIVES

Ecosystem Level Risk:

- Incorporate ecosystem considerations into stock assessments
- Bring ecosystem considerations into the decision-making process
- Ensure sustainable fishing (from all sectors) to maintain ecosystem integrity, & optimizes benefits across all stakeholder groups
- Minimize the impacts of climate variability and enhance resilience of fisheries to climate variability in the US Caribbean

Risk from Distortive Pressures:

- Ensure data collection incorporates sources from all sectors (commercial, recreational, for-hire) to inform management decisions in the US Caribbean (for operational objectives)
- Support tourism opportunities that promote healthy fisheries and habitat (operational under maintain and promote social, cultural…)
- Develop education and outreach opportunities that support sustainable fisheries and habitat (operational under maintain and promote social, cultural…)
- Minimize impacts of climate variability & enhance resilience of fisheries to climate variability in the US Caribbean
- Ensure water quality is sufficient to promote healthy habitats and fish populations

Risk from Socio-Economic Impacts:

- Increase adaptive capacity of fishing communities to climate change impacts
- Minimize impacts of climate variability & enhance resilience of fisheries to climate variability in the US Caribbean

Risks to Reef Ecosystem Integrity:

- Reduce the degradation and enhance the recovery and resistance of marine habitats, particularly coral reefs
- Maintain structure and function of essential fish habitat, especially sensitive nursery habitats

CATEGORIES OF INDICATORS

Ecosystem Level Reference Points

Distortive Pressure Sensitivity

Socio-Economic Sensitivity

Coral-reef Ecosystem Sensitivity

ECOSYSTEM LEVEL INDICATORS

Potential Sub-indicators for Discussion (Most Likely to Be Calculable Based on Existing Data Sets):

- Cumulative Biomass Curve
- Fogarty Ratio
- Ryther Index
- Indicator based on biomass of herbivores or apex predators
- Functional Diversity indices
- Trends in Average Length Caught Target Species

Future alternative would be to develop trophic model of ecosystem and then use Ecosystem Traits & Health Index (2024). Note: Only published ecosystem model for US Caribbean: Guenette, S. & Hill, R " A trophic model of the coral reef ecosystem of La Parguera, Puerto Rico: synthesizing fisheries and ecological data Caribbean " J. of Science, 45(2–3):317-337 (2009). https://doi-org.proxy1.library.jhu.edu/10.18475/cjos.v45i2.a17

DISTORTIVE PRESSURE SENSITIVITY INDICATORS

Designed to evaluate risk from trends in environmental drivers (threats) identified in conceptual model that put pressure on the ecosystem and may therefore change how the system responds

Sub-Indicators

- Trends in Estimated Commercial Landings (Source: ESR/Specific dataset under discussion) (Increasing trend=increase in risk)
- Trends in Estimated Recreational Landings (Source: ESR (Sea Around Us) and/or Tournament Data (USVI DPNR) (increasing trend=increase in risk)
- Trends in Sea Surface Temperature (Source: ESR) (increasing trend=increase in risk)
- Trends in Sargassum Inundation (Source: ESR) (increasing trend=increase in risk)
- Trends in Water Quality (Source: EPA Ambient WQ datasets: pH, Turbidity & Enterococci) (increasing trends in turbidity/entero =increasing risk; increasing acidification=increasing risk)
- Trends in Water Quality (Source: Satellite land cover data by watershed used to calculate Landscape Development Intensity Index) (increasing intensity =increasing risk)
- Ocean Economy- Tourism (Source: ESR; USVI BER; PR Tourism data on Cruise Visitors/Hotel occupancy) (increasing trend =increasing risk)
- Ocean Economy – Wind Energy/Aquaculture (Source: USVI/PR/Federal Permitting records) (increasing trend=higher risk)

SOCIO-ECONOMIC SENSITIVITY INDICATORS

Designed to Measure Risk from socio-economic change in the fishing community due to changes in fishing related employment and wider disruptions in the economy

Sub-Indicator

- NOAA Community Social Vulnerability Index (use subset of index based on availability and report in ESR – need to determine what trends are considered negative and increase risk score)
  - Fishing Reliance
  - Fishing Engagement
  - Population Change
  - Household Income
- Disaster Declarations (Source: https://www.fema.gov/disaster/declarations) (Increase in frequency or recency of disasters would increase risk score)

CORAL REEF ECOSYSTEM SENSITIVITY INDICATORS

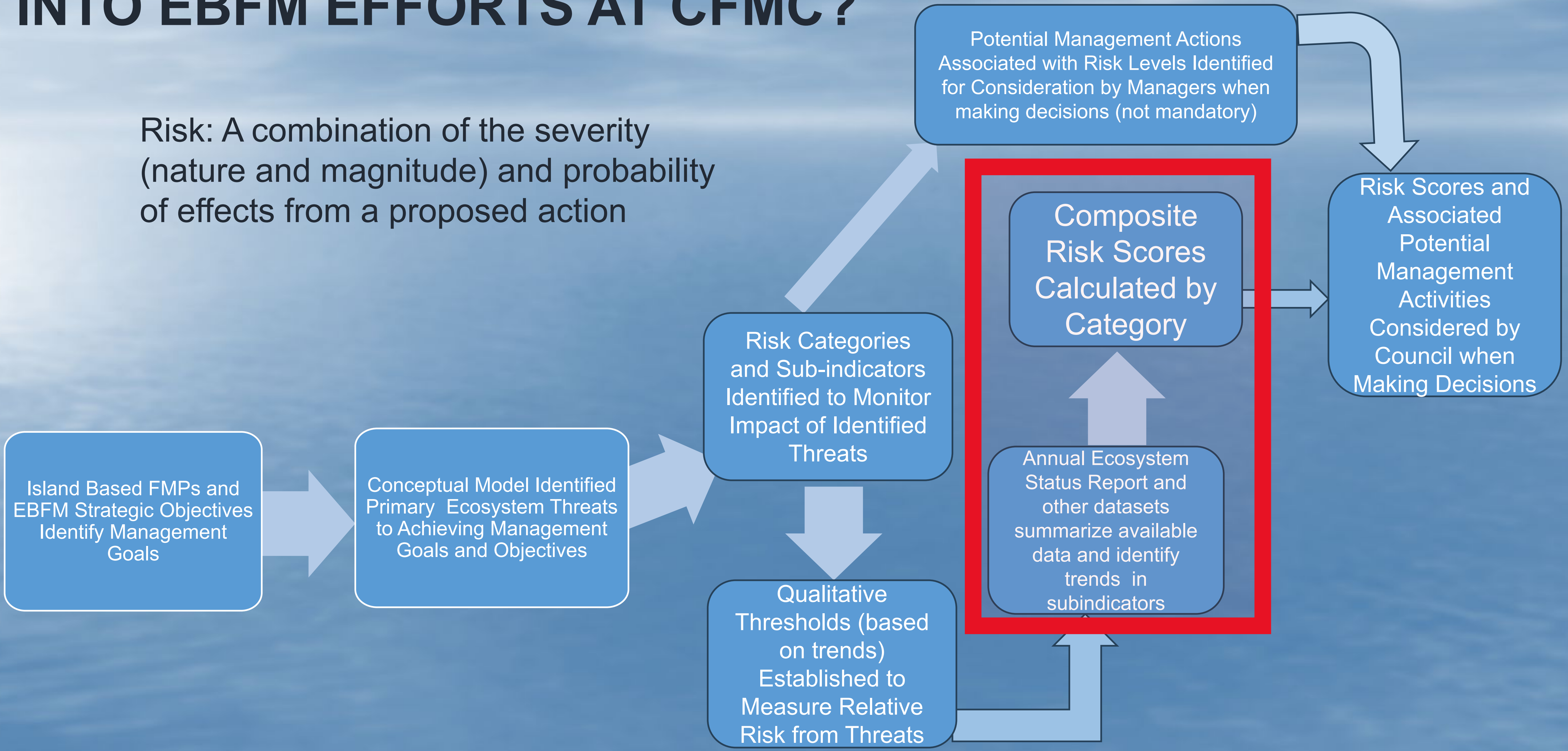
Designed to measure risk that reef ecosystem is experiencing stress or decline

Sub-Indicators

- Trends in Average Monthly Degree Heating Weeks (increasing trend=increase in risk)
- Trends in Percent Coral Cover (decreasing trend =increase in risk)
- Trends in Presence Invasive Species in reef ecosystem (increasing #=increasing risk)
- Trends in # of Endangered Species in reef ecosystem (increasing #=increase in risk)
- Change in Herbivorous Biomass (Decreasing biomass=increase in risk)

HOW DOES ECOSYSTEM RISK FRAMEWORK FIT INTO EBFM EFFORTS AT CFMC?

Risk: A combination of the severity (nature and magnitude) and probability of effects from a proposed action

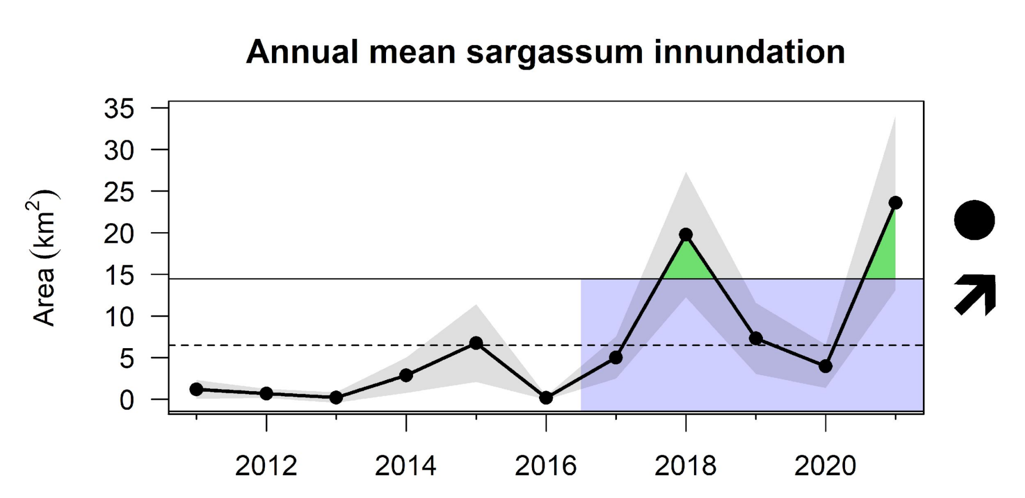


RISK COMPOSITE SCORING

Indicator Groupings	Number of Sub-Indicators	Minimum Score possible	Maximum Score possible	Point Class Interval (score to rank system conversion)
Ecosystem Level Reference Points	3	3	9	3-4=Low
				5-7=Moderate
				8-9=High
Distortive Pressure Sensitivity	8	8	24	8-12 =Low
				13-19=Moderate
				20-24=High
Socio-Economic Sensitivity	5	5	15	5-7=Low
				8-12-=Moderate
				13-15=High
Coral-reef ecosystem Sensitvity	6	6	18	6-9=Low
				10-14=Moderate
				15-18=High

EXAMPLE OF SUB-INDICATOR SCORING

ESR Dashboard

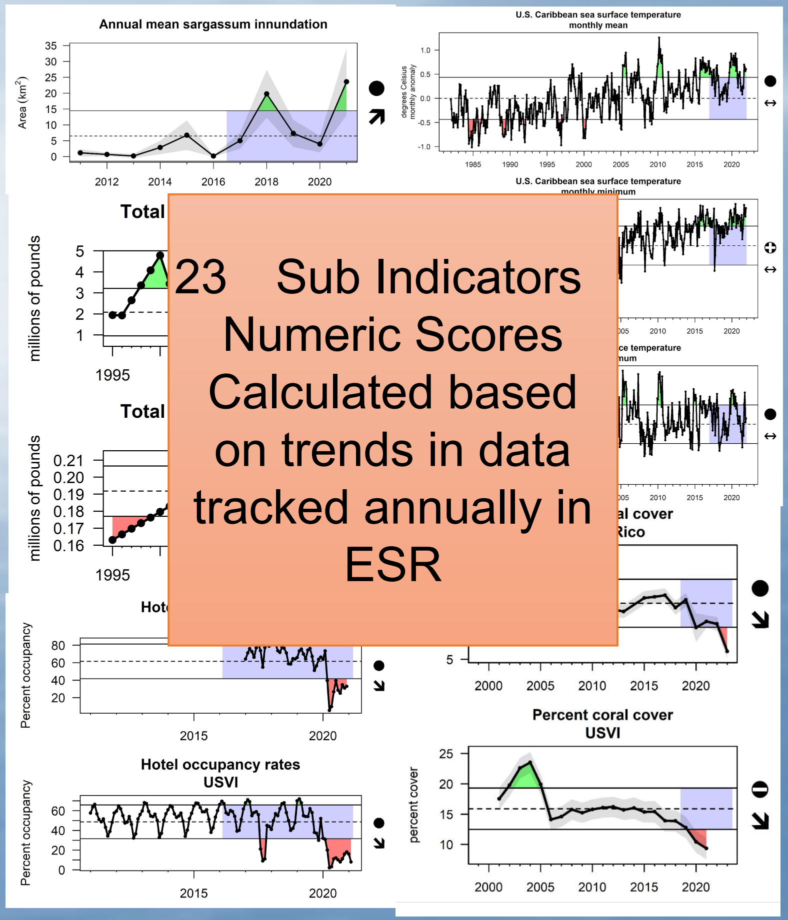


For Sargassum sub-indicator:

If Trend Arrow points Up (increasing sargassum) = 3
If Trend Arrow is Neutral (no significant change) =2
If Trend Arrow points Down (decreasing sargassum)=1

The Sargassum Indicator would add 3 points to the Distortive Pressure Sensitivity category score

EXAMPLE OF COMPOSITED RESULT



23 Sub Indicators Numeric Scores Calculated based on trends in data tracked annually in ESR

Category	Numeric Composite (Sum of scores)	Risk Score
Ecosystem Level Reference	4	Low
Distortive Pressure Sensitivity	20	High
Socio-Economic Health Sensitivity	12	Moderate
Coral Reef Health Sensitivity	18	High

WHY COMPOSITE?

To be manageable, this risk assessment needs to give a relative measure of the likelihood that a policy or action implemented by the council will not produce expected results either because something unexpected/unaccounted for will change the results or because the cumulative impact of actions by the council and/or external forces change the response of the impacted system.

Ecosystem Level Risk is a measure of the risk that the general robustness of the ecosystem is decreasing, making the ecosystem less stable.

Distortive Pressure Sensitivity is a measure of the risk that cumulative actions (by council and other outside forces) are destabilizing the ecosystem.

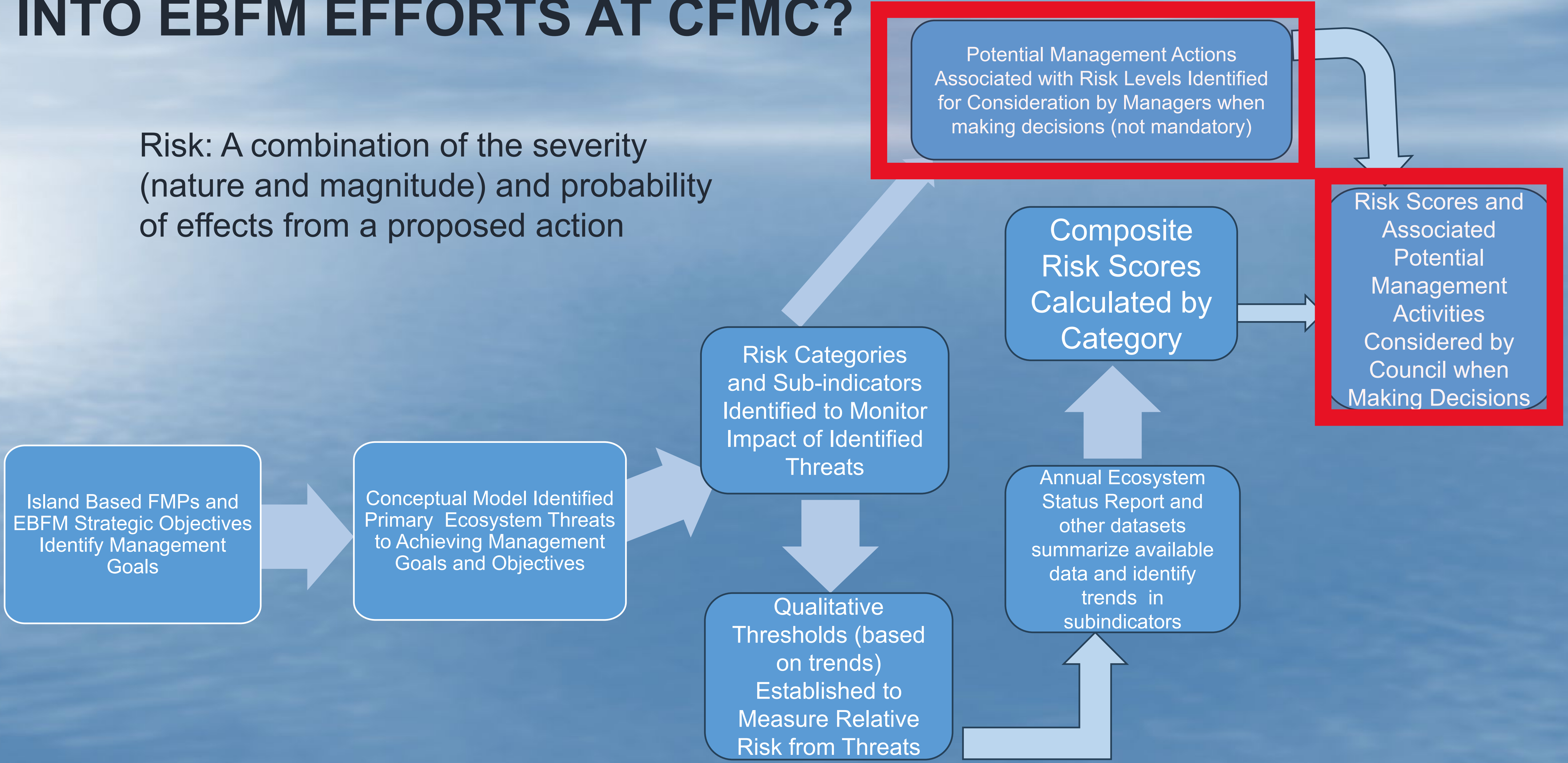
Socio-Economic Health Sensitivity is a measure of the risk that cumulative actions (by council and other outside forces) are destabilizing the human/fisher community.

Coral Reef Health Sensitivity is a measure of the risk that changes in a keystone part of the ecosystem are destabilizing the ecosystem.

Discussion Of Indicator Structure & Scoring

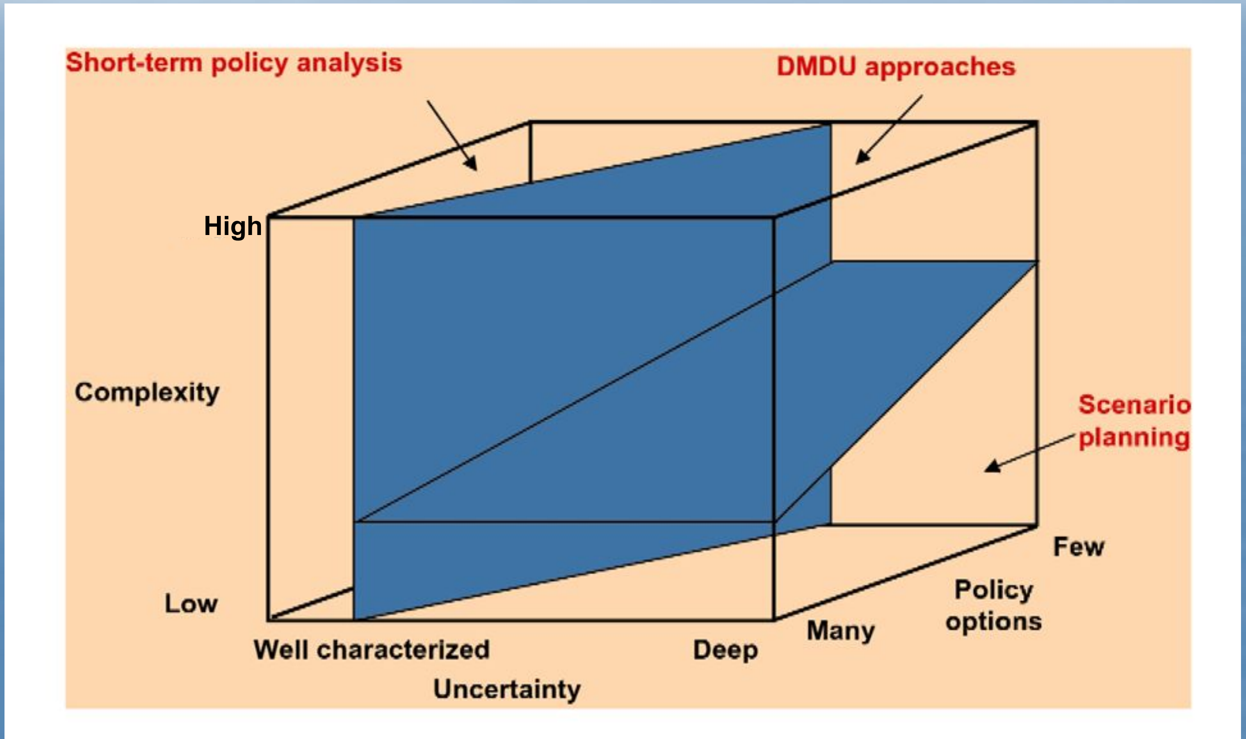
HOW DOES ECOSYSTEM RISK FRAMEWORK FIT INTO EBFM EFFORTS AT CFMC?

Risk: A combination of the severity (nature and magnitude) and probability of effects from a proposed action



MANAGING UNDER CONDITIONS OF DEEP UNCERTAINTY

- Deep uncertainty occurs when a decision involves managing a complex system about which there are many unknowns.
- Deeply uncertain conditions make managing by looking backward (past performance) ineffective because past conditions are not predictive of future conditions and system complexity makes system response unpredictable. In deeply uncertain conditions, risk assessment is only part of the toolkit. Expert opinion, modelling and using structured decision making can be used together to make decisions.



Vincent A. W. J. Marchau, Warren E. Walker, et al.
Decision Making under Deep Uncertainty: From Theory to Practice

USING RISK SCORES TO DE-RISK DECISIONS

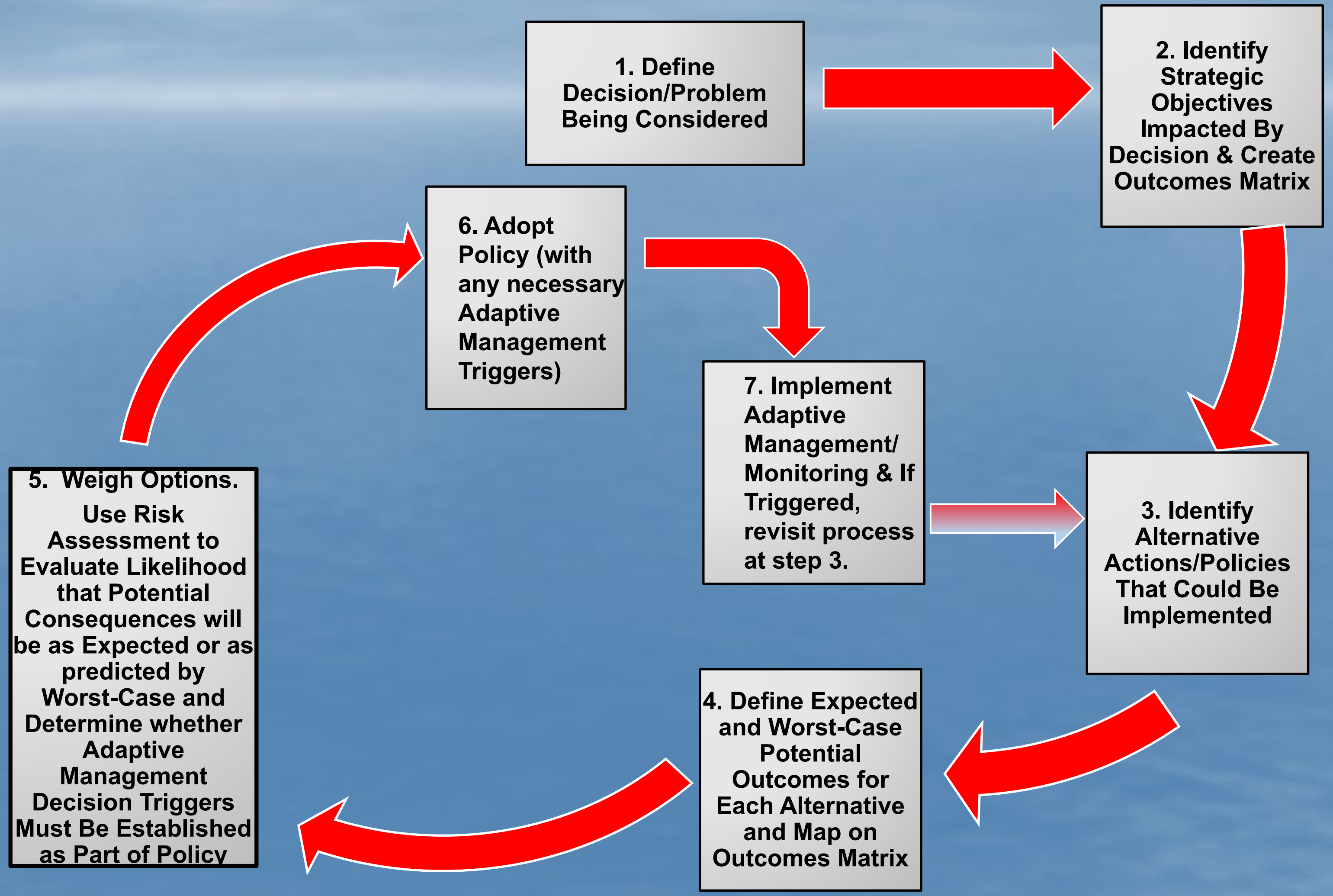
If Risk Scores in one or more categories are high, options to lower the risk that a decision will result in unanticipated consequences include the following types of management actions:

- Time limiting the action being taken
- Implementing adaptive management that includes monitoring and pre-approving triggers for when a policy change is warranted.
- Mandating scenario planning (via modelling or expert opinion) to evaluate expected and worst-case potential outcomes
- Adding or increasing buffers around adopted numeric limits.
- Gathering additional information before proceeding.

EXAMPLE: PROPOSED STRUCTURED DECISION PROCESS FRAMEWORK

Risk Assessment Uses:

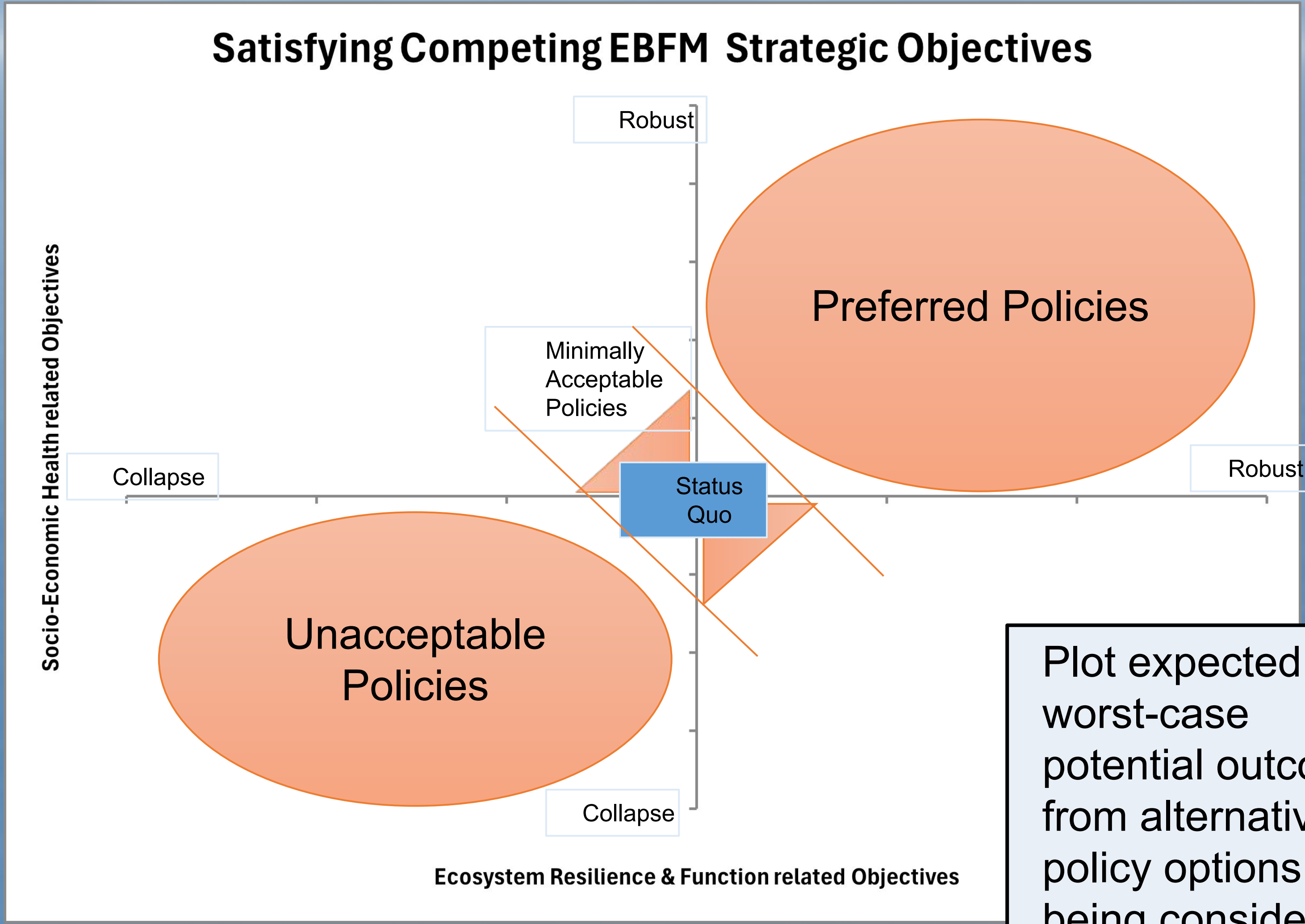
- Assist in evaluating alternatives by indicating potential that worst-case outcome of a possible policy could manifest
- Mandate when adaptive management process and triggers must be established in conjunction with an action



Adapted From: Garrard, G.E. et al "Rapid Prototyping for Decision Structuring: An Efficient Approach to Conservation Decision Analysis pg.49 In Bunnefield, N. ed. *Decision-Making in Conservation and Natural Resource Management,. Cambridge U. Press (2017)*

EXAMPLE: PROPOSED DECISION PROCESS FRAMEWORK - GENERALIZED OUTCOMES MATRIX

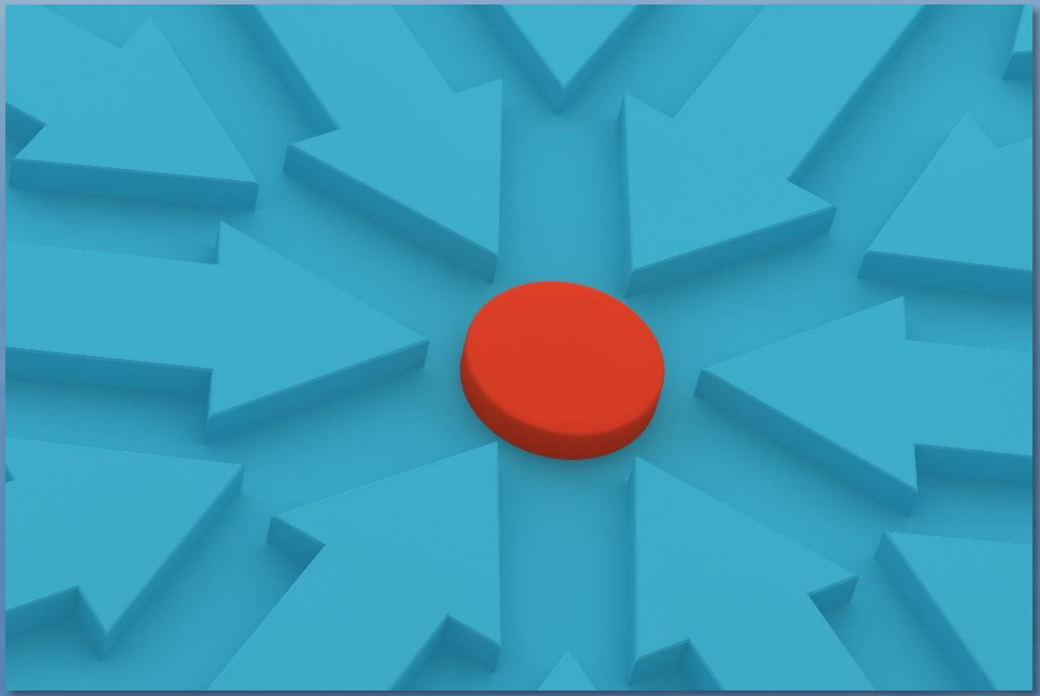
- Preferred policies result in increases to robustness of ecological and socio-economic condition
- Minimally Acceptable Policies maintain the status quo or incrementally improve either ecological function or socio-economic health at the cost of disadvantaging the other system.Tradeoffs should not result in irreversible harm to the negatively impacted system.
- Unacceptable policies result in disrupting both ecological and socio-economic systems and moving both systems toward collapse.



Plot expected and worst-case potential outcomes from alternative policy options being considered

EXAMPLE: PROPOSED DECISION PROCESS FRAMEWORK - WEIGHING OPTIONS

- Evaluate plotted potential outcomes for policy options to determine which options are anticipated to result in preferred or minimally acceptable outcomes based on expected scenario. Select preferred policy based on expected scenario.
- If a relevant risk score is high, evaluate whether worst-case scenario associated with selected policy results in at least a minimally acceptable policy. If yes, council should adopt policy but utilize de-risking strategies to decrease risk of unanticipated consequences leading to worst-case scenario manifesting. Alternatively, if selected policy, when evaluated based on worst-case scenario, would result in an unacceptable outcome, determine which policy option is preferred considering worst-case scenarios, and/or whether preferred policy option can be modified to reduce the negative impacts associated with worst-case scenario.



DISCUSSION OF UTILIZING RISK SCORES IN MANAGEMENT DECISIONS

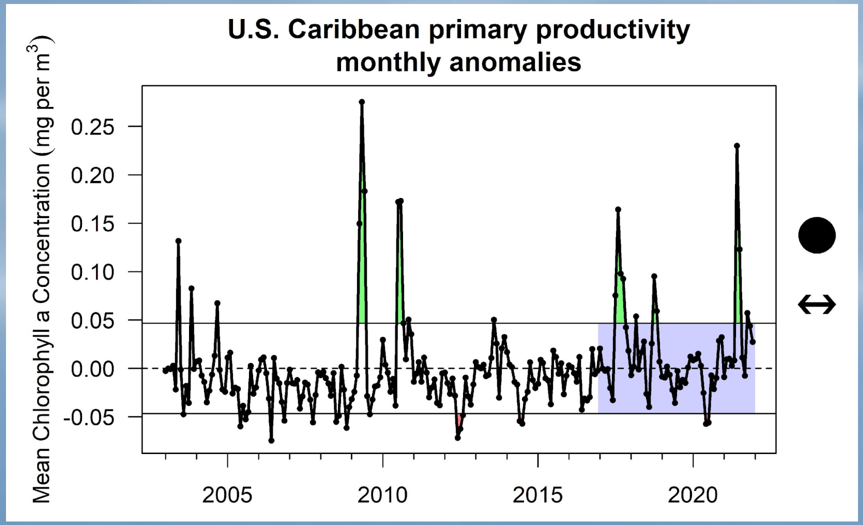
CUMULATIVE BIOMASS CURVE

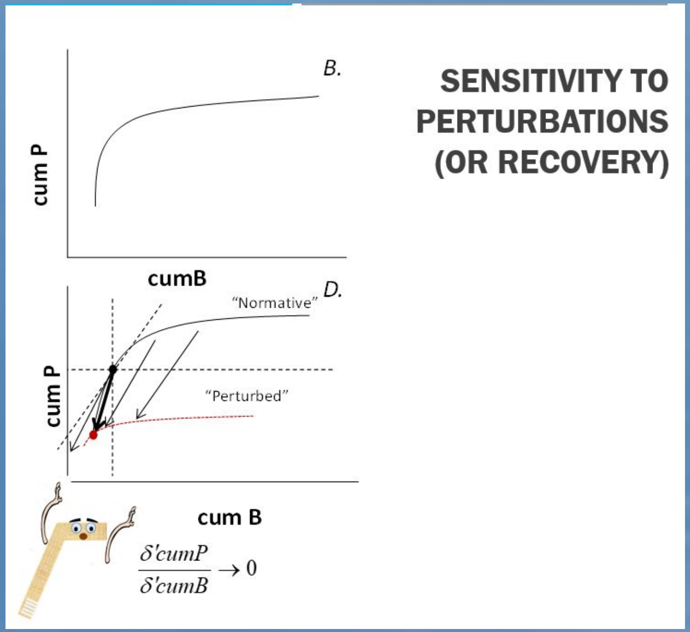
Why Relevant to EBFM and Decision Making (What does it tell us)

Will serve as an ecosystem-level reference point. Ecosystem-level benchmarks account for broader dynamics in the ecosystem and can be predictive of changing conditions.

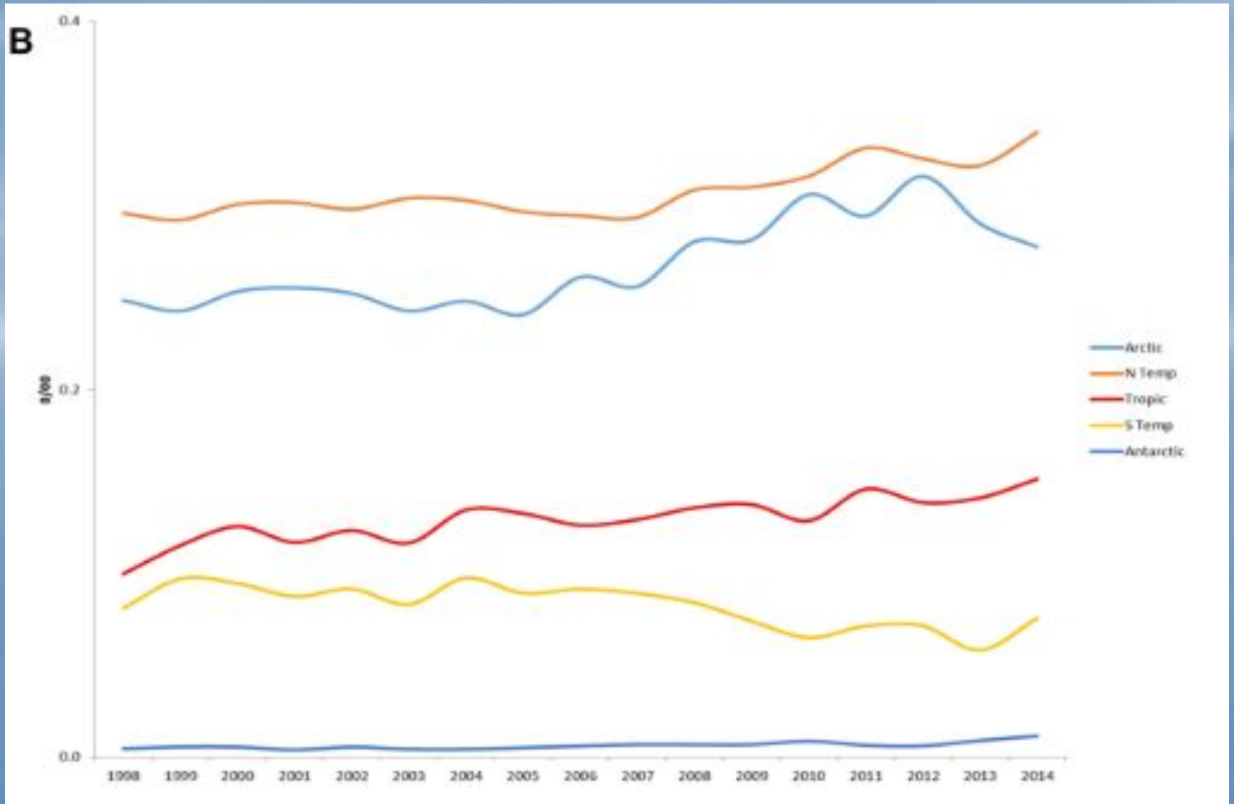
Data Required/Source: Primary Productivity & Estimates of Biomass – NOAA data (see earlier presentation)

References: Link et al. 2015, *TREE* v.30- main description; Libralato et al. 2019, *Ecol. Ind.* v. 103- thresholds





FOGARTY RATIO



The Fogarty index is the ratio of total catch to total primary productivity in an ecosystem.

Description of Indicator:

Why Relevant to EBFM and Decision Making (What does it tell us)

Indicator of Ecosystem Level Overfishing

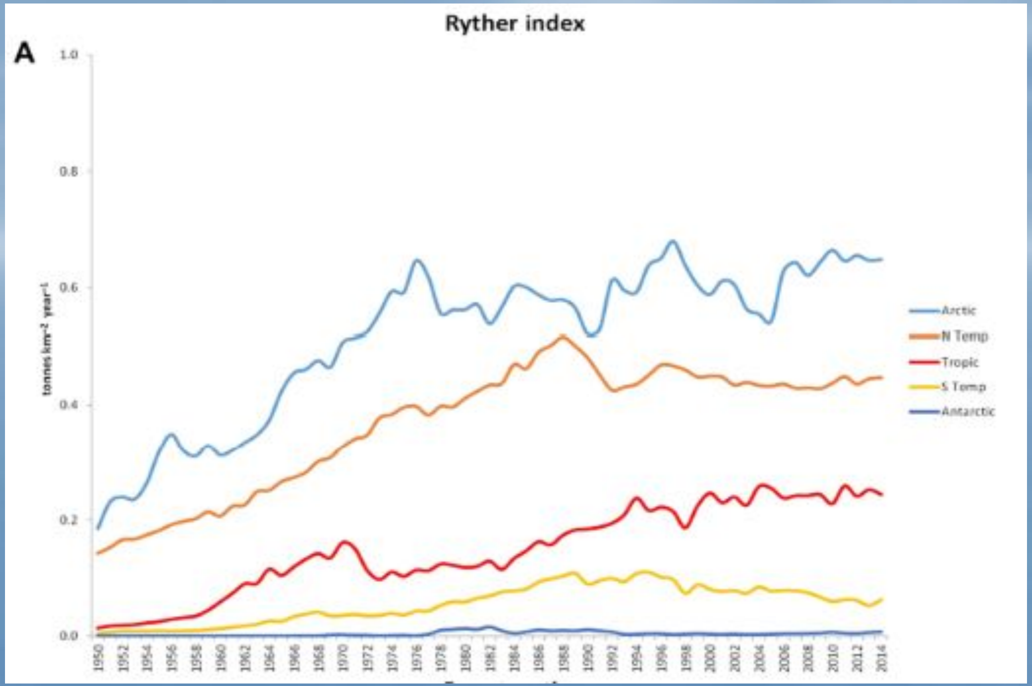
Data Required/Source: Primary Productivity Satellite Data and Catch Data (see earlier Presentation) Thresholds: Per Link presentation, need to be established based on global data

Reference: Link and Watson, Global ecosystem overfishing: Clear delineation within real limits to production Sci. Adv. 2019;5: eaav0474 26 June 2019

RYTHER INDEX

Description of Indicator:

The Ryther index is composed of total catch presented on a unit area basis for an ecosystem.



Data Required/Source: NOAA Primary Productivity/ Catch – Need to work with J. Link to refine for CFMC

Reference: Reference: Link and Watson, Global ecosystem overfishing: Clear delineation within real limits to production Sci. Adv. 2019;5: eaav0474 26 June 2019

FUNCTIONAL DIVERSITY MEASURES OF ECOSYSTEM INTEGRITY

- Functional Diversity measures the distribution and range of what organisms do in communities and ecosystems (therefore considers the complementary and redundancy of co-occurring species)
- Functional Groups can be defined based on a few behavioral/morphological characteristics (diet; food acquisition methods; habitat) or more specifically on functional traits like temperature tolerance, migratory behavior, reproductive traits.
- If general characteristics are used species diversity indices can be applied (i.e. Simpson diversity index: reflecting how many different types of species are in a community and how evenly distributed the population of each species is)
- If multiple traits are combined for analysis, then functional diversity measures are required: functional richness; functional evenness; functional divergence.

FUNCTIONAL DIVERSITY CONTINUED

- Functional Richness measures how much of an ecological niche (ie function) is occupied by the species present.
    - Can be used as an indicator for potential increases or decreases in productivity, buffering for environmental change and/or vulnerability to invasion.
- Functional Evenness measures whether mean species traits are distributed regularly within occupied trait space (ie with equal distance between nearest neighbors and equal abundances)
- Is often used to indicate under or over utilization of resources and thus potential for changes in productivity based on resource availability, the ability of system to withstand environmental change or invasive species

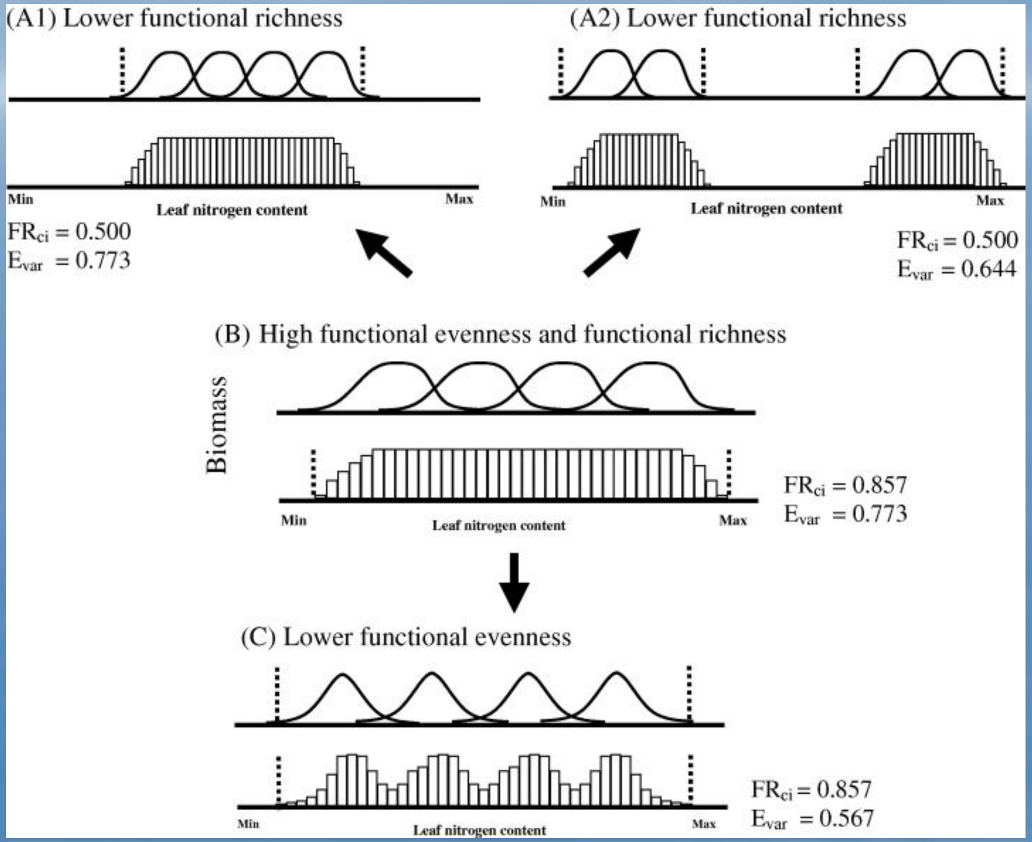
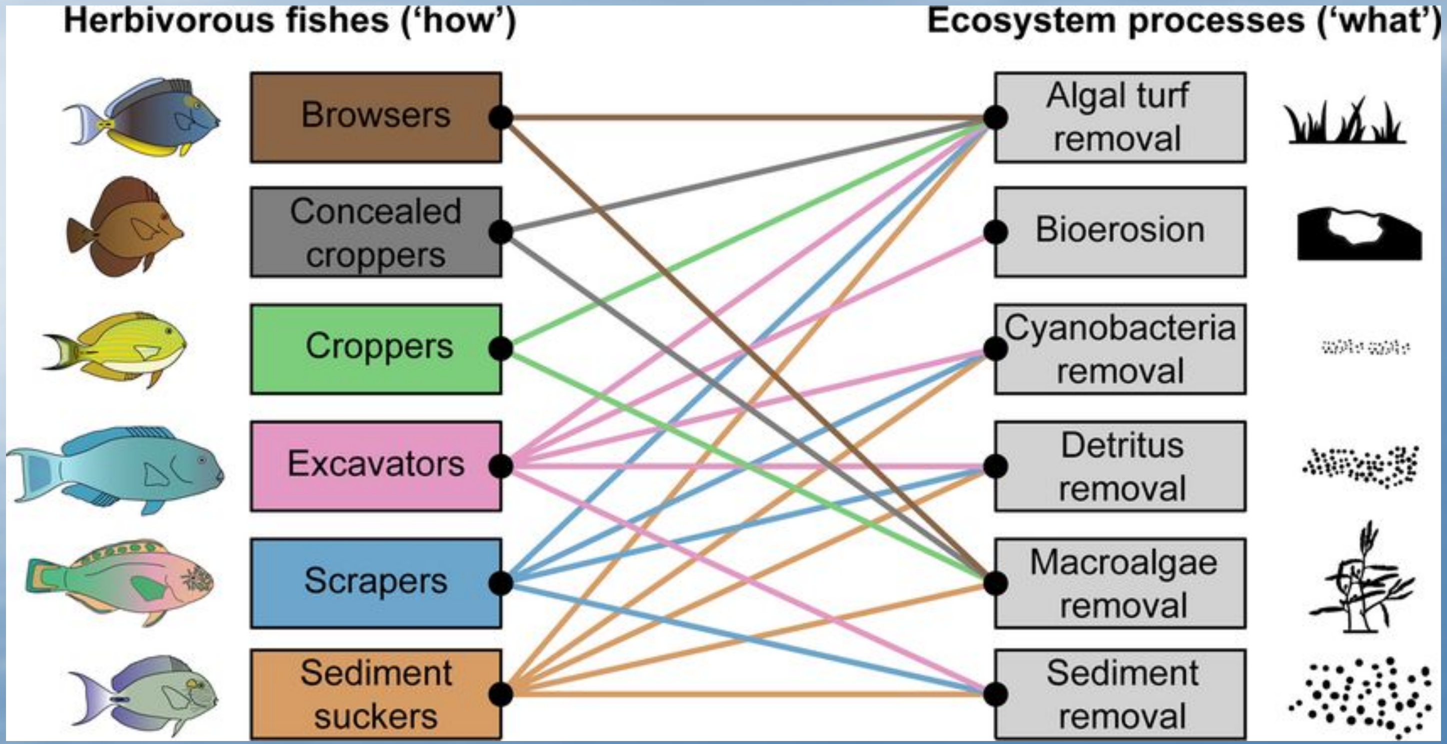


Image: Functional richness, functional evenness and functional divergence: The primary components of functional diversity October 2005Oikos 111(1):112 - 118DOI:10.1111/j.0030-1299.2005.13886.x

FUNCTIONAL DIVERSITY



Suggested Uses: Measuring functional diversity of herbivores and other functional trait groups

Assumes herbivore function is critical to reef health

For Risk Assessment: if functional diversity decreases, risk to reef health increases.

Data needed: identification of herbivore species present, functional groupings and (for evenness and divergence) herbivore abundance; Note: timing and intensity of sampling has been found to influence functional diversity analyses –

Need to determine baseline year for trend analysis.

Image from: A functional perspective on the meaning of the term 'herbivore': patterns versus processes in coral reef fishes April 2023 Coral Reefs 43(2):1-14 DOI:10.1007/s00338-023-02378-4

FUNCTIONAL DIVERSITY CONTINUED

- Functional Divergence: the variance of species' functions and the position of their clusters in the traits' space (divergence is higher if species and/or abundances are clustered at edges of trait space versus in the center of the trait space.) Indicates the degree of resource differentiation and competition among members of functional groups; high divergence can also indicate extreme differences in species within a single functional group.

- MANY ALTERNATIVES TO CALCULATE THESE MEASURES.

BIOMASS

Apex Predator Biomass

Assumes: Changes in apex predator increases risk in change of composition of community

Data required: Biomass of apex predators (sharks, large piscivores); need to determine baseline year Data Source: TBD

But See “Predatory fish depletion and recovery potential on Caribbean Reefs” Valdivia et al (2017) which suggests that spatial variation in predatory biomass might be driven by natural factors in addition to human impacts (ie some reefs even if pristine have lower carrying capacity for predators) – does this impact usefulness as risk indicator?

Herbivore Biomass

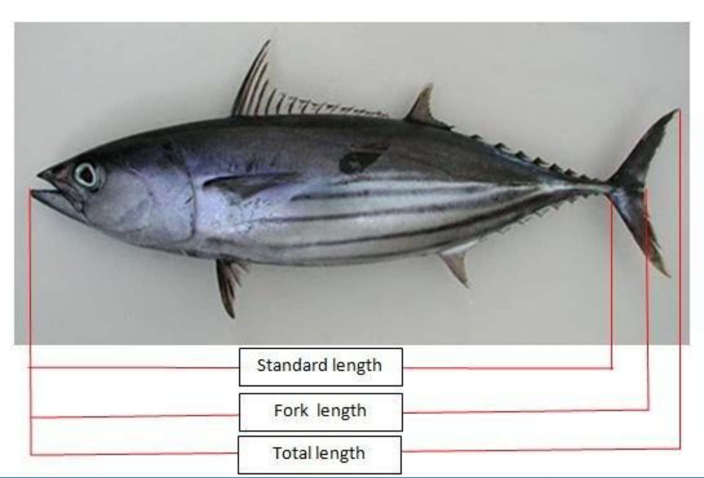
Assumes: Negative trends in herbivore biomass may increase algal cover, decreasing hard coral habitat

Data Required: Biomass of herbivores; need to determine baseline year. Data Source: PRCRMP/TCRMP

Figure 1. Images of the five top predators by biomass by three representative regions from underwater visual surveys (2005–2021). Data from the Caribbean were from Curaçao and Aruba. Sandin, S. et al Emerging insights on effects of sharks and other top predators on coral reefs Emerging Topics in Life Sciences (2022) 6 57–65 https://doi.org/10.1042/ETLS20210238

USING LENGTH-BASED INDICATORS

- Using metric average length in the exploited life stage of a population to measure overfishing pressure
- Assumes: negative trend in average length of targeted species caught indicates potential for overfishing and decreased sustainability of fishery
- See: Ault, J.S. et al "Indicators for assessing the ecological dynamics and sustainability of southern Florida's coral reef and coastal fisheries" Ecological Indicators 44 (2014) 164-172; Babcock E.A. etal "Length-based indicators of fishery and ecosystem status: Glover's Reef Marine Reserve, Belize" Fisheries Research 147(2013) 434-445.



Questions for Ecosystem Level & Other Indicators Discussion

Which indicator(s) would be most useful in this ecosystem?

For the preferred indicator(s), is the data needed available?

Could the preferred indicator(s) be calculated as part of ESR (annually?) or is another time scale more useful?

SUB-INDICATORS NOT BASED ON ESR TRENDS

TRENDS IN DISASTER DECLARATIONS

Description of Indicator: Number of FEMA Major Disaster Declarations over Time

Why Relevant to EBFM and Decision Making: Major disasters impact both ecological resources and the economy. The more recent an occurrence of disaster, the more likely both ecological and economic systems are stressed.

Year	VI	PR
2024		
2023		
2022		2
2021		
2020	1	3
2019		
2018		
2017	2	2
2016		
2015		
2014		

Data Required/Source: https://www.fema.gov/disaster/declarations Trend Analysis: Number of declarations and distance in time from current year; would need to be calculated annually

References: Social Vulnerability to Disasters, 2d ed. Brenda D. Phillips et al. (New York: CRC Press, 2013).

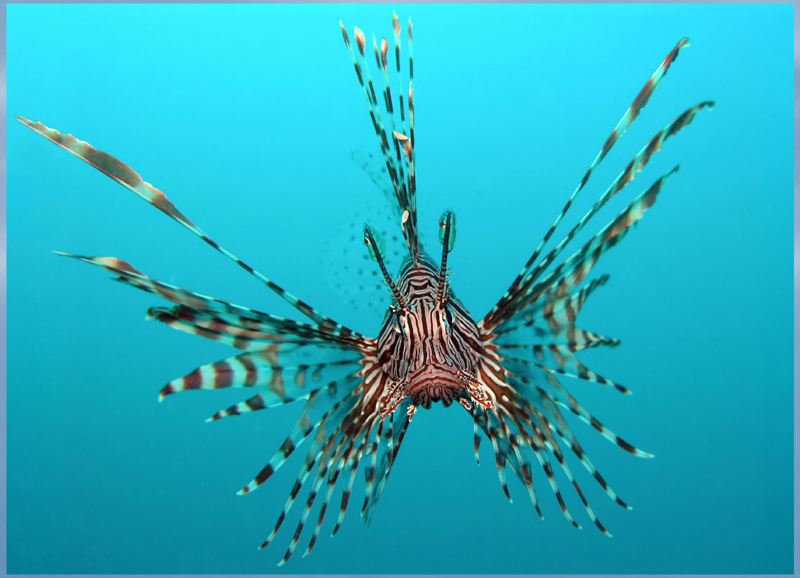
TRENDS IN # OF ENDANGERED SPECIES IN REEF ECOSYSTEM

Description of Indicator: Trends in number of listed (threatened or endangered species) species in reef ecosystem

Why Relevant to EBFM and Decision Making (What does it tell us) A species becoming endangered indicates a major decline in abundance; the greater the number of species experiencing decline, the higher the likelihood that the ecosystem is stressed or changing

Data Required/Source: Endangered Species Act Listings; territorial listings. For Trend Analysis, would need to be calculated annually and baseline year identified.

TRENDS IN PRESENCE OF INVASIVE SPECIES IN REEF ECOSYSTEM



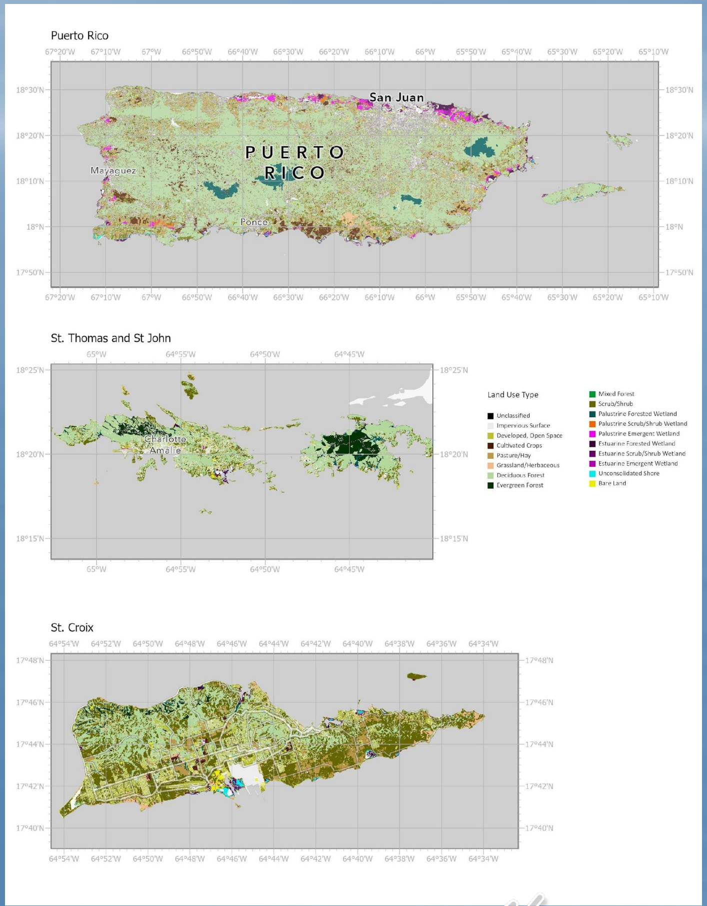
Description of Indicator: Trends over time in number of invasive species reported in ecosystem

Why Relevant to EBFM and Decision Making (What does it tell us)
Invasive species can change food web; increases in number of invasive species can indicate likelihood that system will experience change

Data Required/Source: TBD; Once location of data identified, then trend (total number of invasive species in system over time) would need to be calculated annually

TRENDS IN WATER QUALITY (LANDSCAPE DEVELOPMENT INTENSITY INDEX)

Description of Indicator: LDI is as an index of the human disturbance gradient (the level of human induced impacts on the biological, chemical, and physical processes of surrounding lands or waters) Tracking changes to Index over time demonstrates pressure from land development



Why Relevant to EBFM and Decision Making : Calculated on a watershed basis, LDI could provide indication of pressure on marine ecosystem related to changes in development patterns. An increase in intensity of development would increase pressure on marine ecosystem

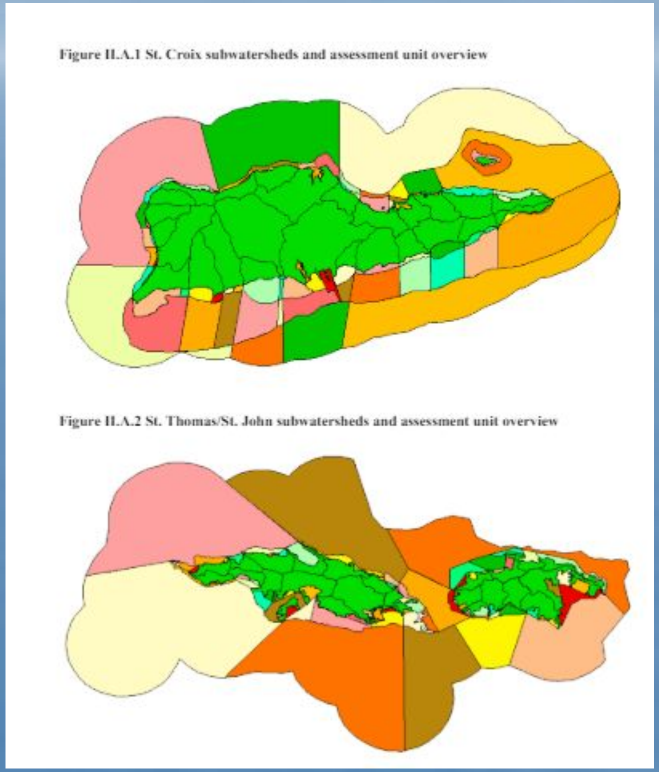
Data Required/Source: GIS and Satellite Land cover data (being compiled in ESR) + data analysis per method (See Brown and Vivas) calculated annually then time series trend data tracked

References: Brown & Vivas, Landscape Development Intensity Index Environmental Monitoring and Assessment (2005) **101:** 289–309

TRENDS IN WATER QUALITY (EPA BEACH AND AMBIENT WQ DATA)

Description of Indicator: Time series analysis of quantitative water quality data collected in connection with Clean Water Act compliance (pH, turbidity and enterococci bacteria)

Why Relevant to EBFM and Decision Making: Trends in water quality parameters (pH, turbidity and enterococci bacteria levels) can indicate if pollution stress on system is increasing.



Data Required/Source: Data from https://www.waterqualitydata.us/ would be used to create timeseries trend analysis in Ecosystem Status Report

References: https://www.epa.gov/sites/default/files/2017-02/documents/2016_usvi_303d_list.pdf

Questions For Discussion Of Sub-indicators Not Currently Included In ESR

- Will calculating and adding these indicators to ESR dashboard add value?
- Are datasets/expertise available to create trend analyses for these indicators?

Thank You!

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