# ENVIRON 761:
Threat Mapping

Instructor: John Fay

# Overview

- Threats to biodiversity

- Classifying threats

- Incorporating threats in conservation planning

- State of spatial analysis in threat mapping
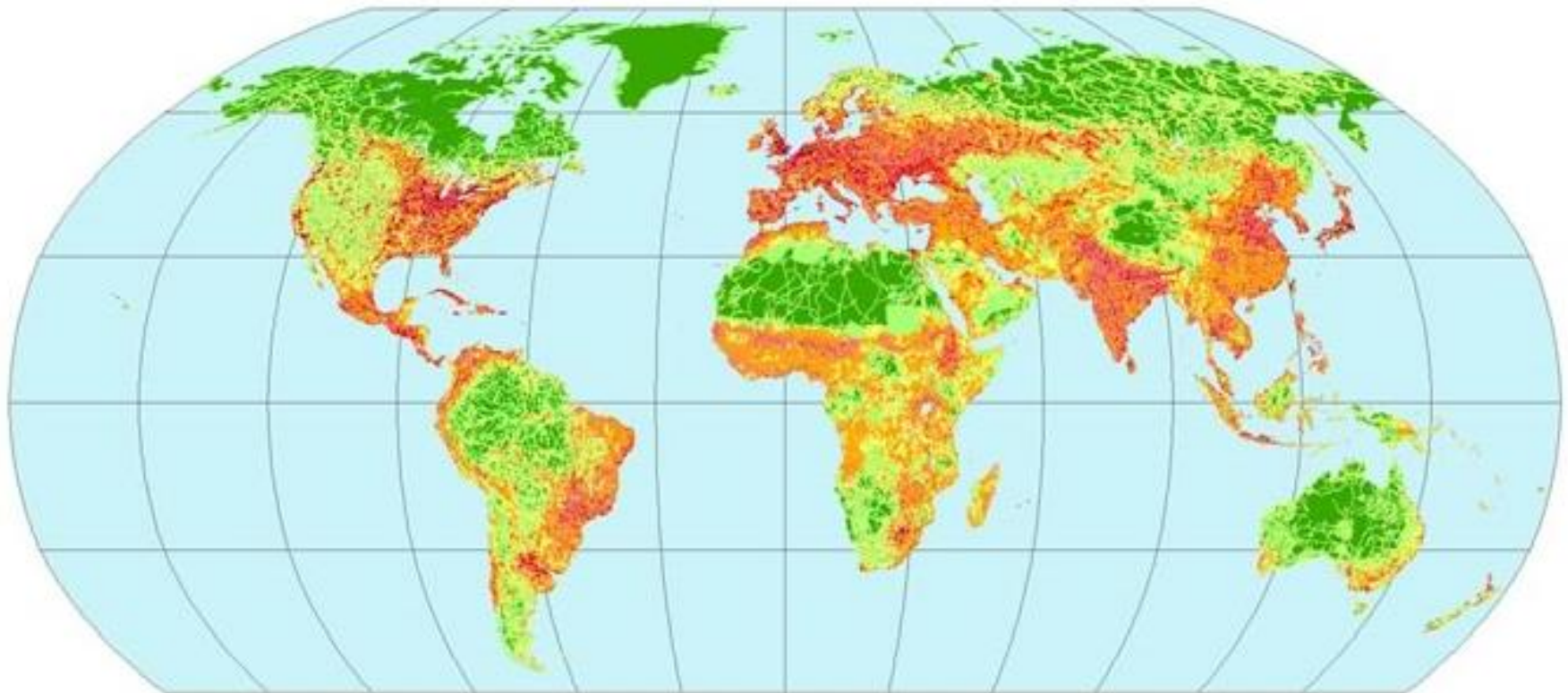
# The "Original Conservation Crisis"



Threat = Flood

# Today's Conservation Crisis…



The Human Footprint ver. 2

Global

http://sedac.ciesin.columbia.edu/wildareas/

## The Human Footprint Index

The Human Footprint Index (HF) expressses as a percentage the relative human influence in each terrestrial biome. HF values range from 0 to 100. A value of zero represents the least influenced - the "most wild" part of the biome with value of 100 representing the most influenced (least wild) part of the biome.

Copyright 2008. The Trustees of Columbia University in the City of New York. Source: Center for International Earth Science Information Network (CIESIN), Columbia University and Wildlife Conservation Society, the Bronx Zoo, New York. The Last of the Wild Data set. Available at http://www.sedac.ciesin.columbia.edu/wildareas
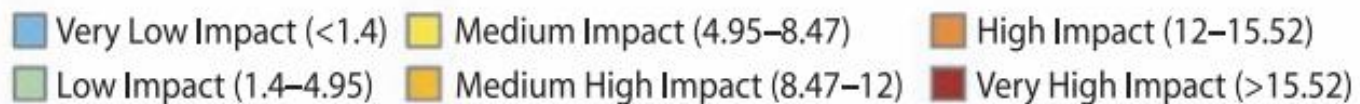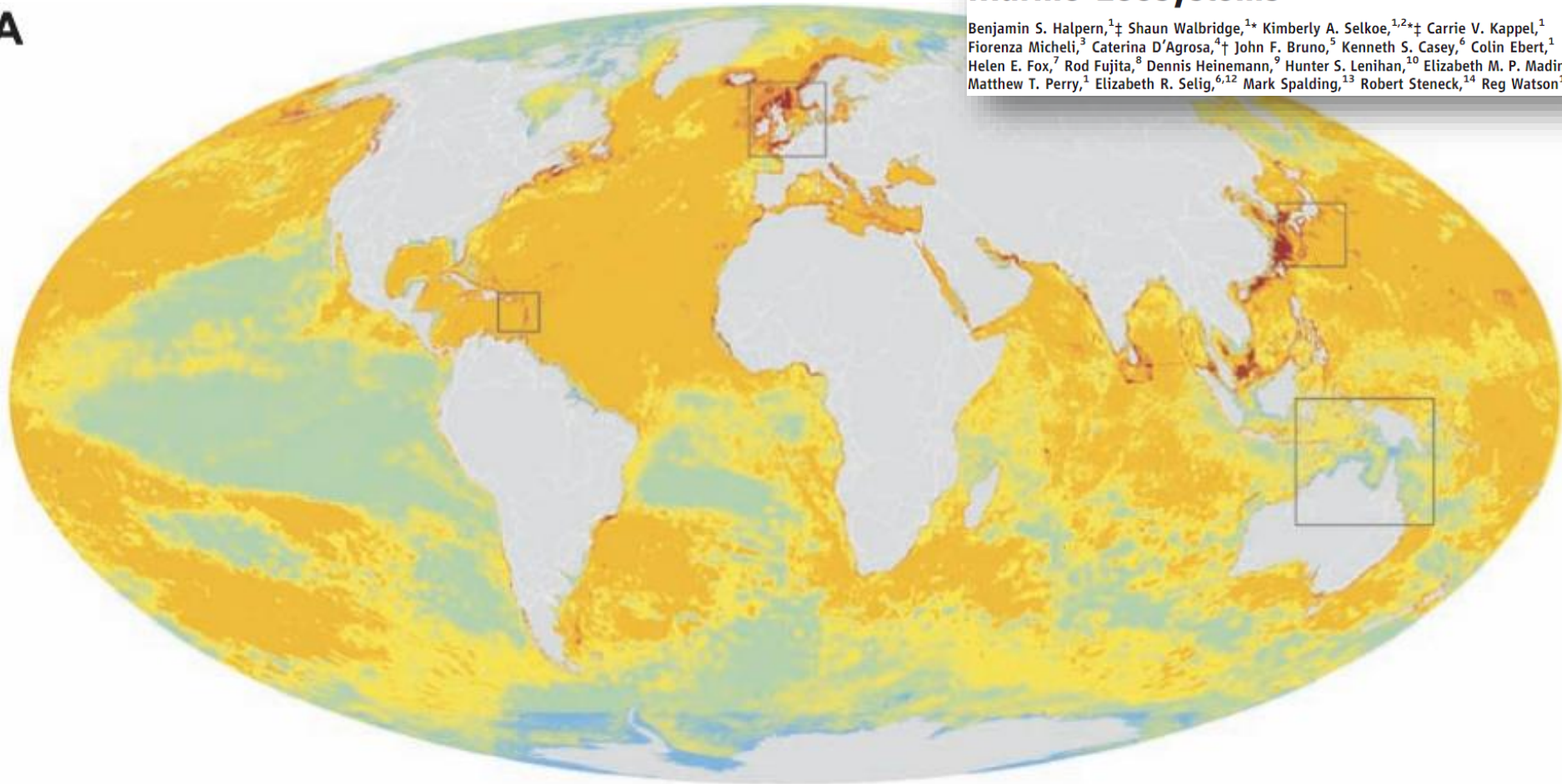
Robinson Projection

### Human Footprint Index

1   10   20   30   40   60   80

Publish Date: 03/07/08

# Today's Conservation Crisis...



A Global Map of Human Impact on Marine Ecosystems

Benjamin S. Halpern,[1]‡ Shaun Walbridge,[1]* Kimberly A. Selkoe,[1,2]*‡ Carrie V. Kappel,[1]
Fiorenza Micheli,[3] Caterina D'Agrosa,[4]† John F. Bruno,[5] Kenneth S. Casey,[6] Colin Ebert,[1]
Helen E. Fox,[7] Rod Fujita,[8] Dennis Heinemann,[9] Hunter S. Lenihan,[10] Elizabeth M. P. Madin,[11]
Matthew T. Perry,[1] Elizabeth R. Selig,[6,12] Mark Spalding,[13] Robert Steneck,[14] Reg Watson[15]

Very Low Impact (<1.4)    Medium Impact (4.95–8.47)    High Impact (12–15.52)
Low Impact (1.4–4.95)    Medium High Impact (8.47–12)    Very High Impact (>15.52)
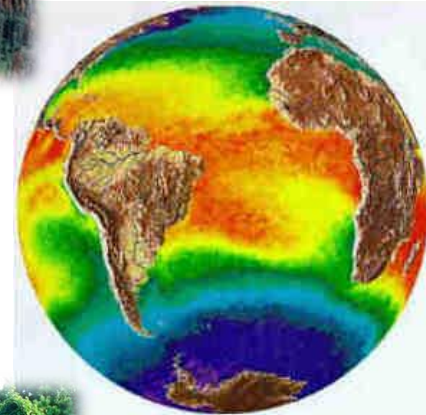
# Threat analysis: *Central questions*

- How does one create these "threat maps"?

- What *is* a threat?

- Are threats more severe in selected locations?

- What role does GIS play in evaluating the impacts of threats in conservation planning?
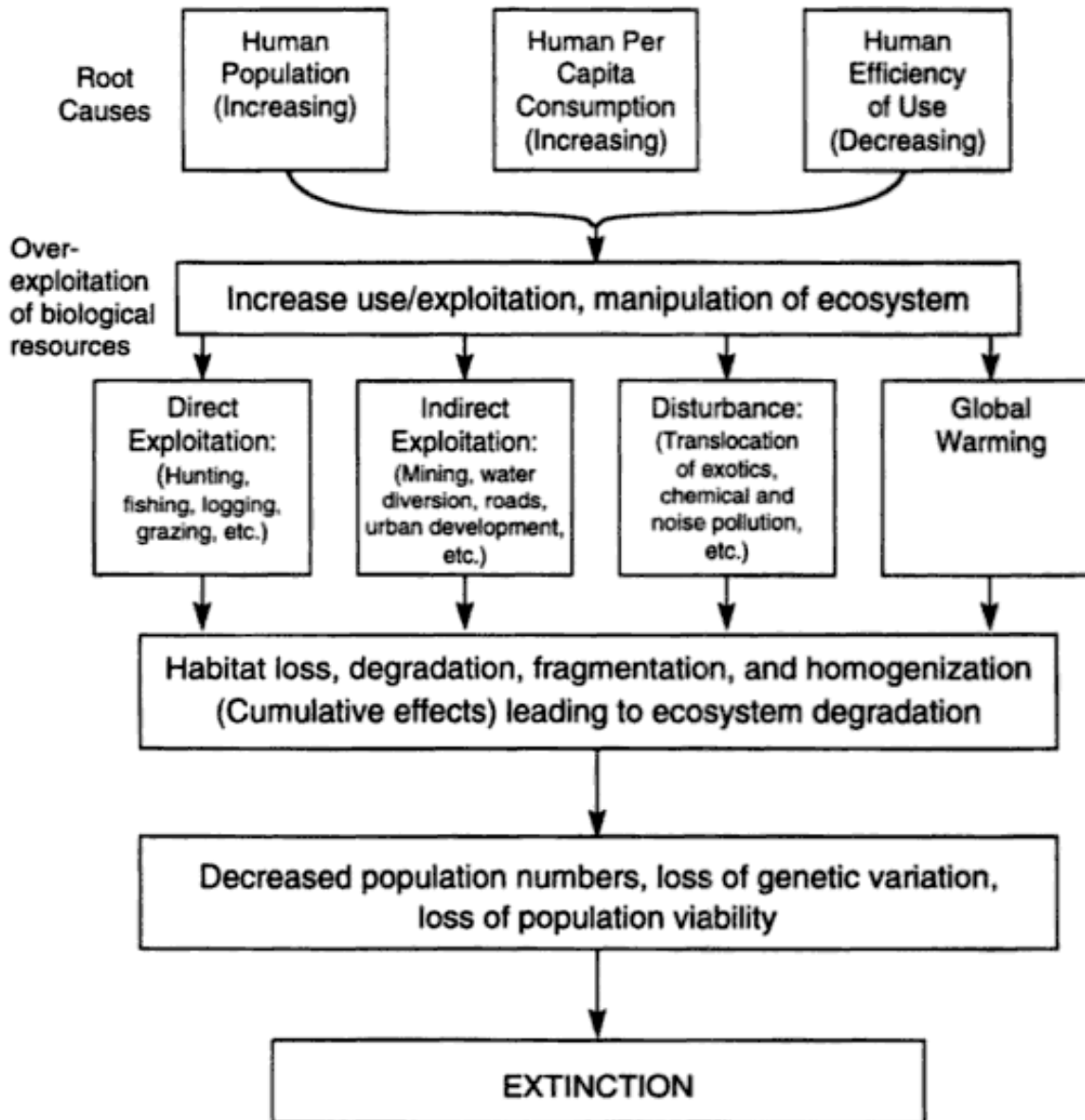
  *Lab: Mapping threats to our pronghorn antelope.*

# What's causing biodiversity loss?

# Threats: Root causes and pathways



Saving Nature's Legacy: Protecting And Restoring Biodiversity (p 51) By Reed F. Noss, Allen Cooperrider (1994)
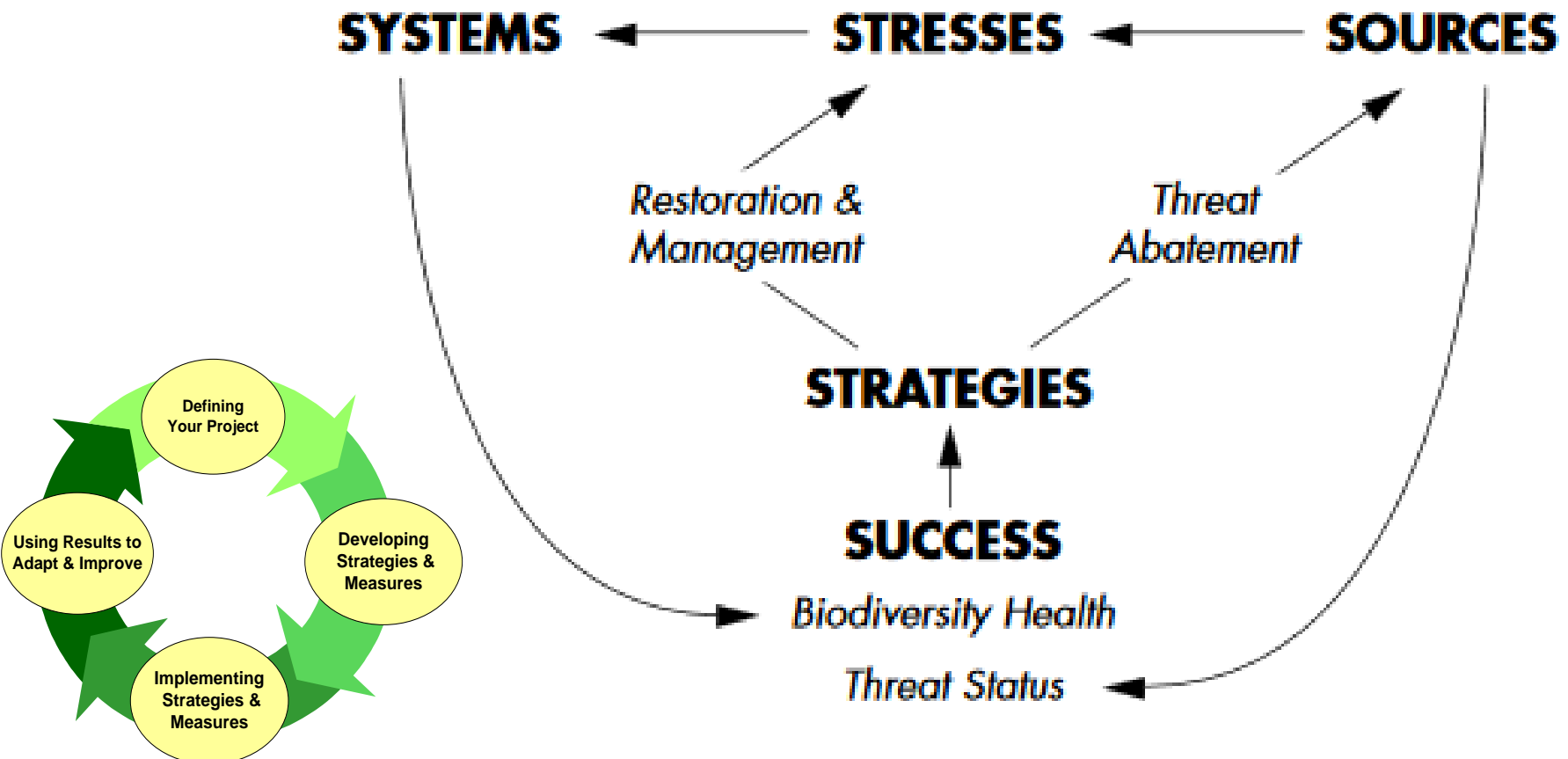
# *Root* causes of biodiversity loss

- Demographic change

- Inequality & poverty

- Public policies, markets, and politics

- Macroeconomic policies and structures

- Social change and development biases

*In short, it's a pretty complex issue!*
*(and not one we are prepared to address here)*

http://awsassets.panda.org/downloads/analytic.pdf

# Threats in conservation planning



The Five-S Framework for Site Conservation:

A Practitioner's Handbook for Site Conservation Planning and Measuring Conservation Success

Conservation GATEWAY
The Nature Conservancy
Protecting nature. Preserving life.™

SYSTEMS ← STRESSES ← SOURCES

Restoration & Management

Threat Abatement

STRATEGIES

SUCCESS

Biodiversity Health

Threat Status

Defining Your Project

Developing Strategies & Measures

Implementing Strategies & Measures

Using Results to Adapt & Improve

# Stresses & Sources

**SYSTEMS** ← **STRESSES** ← **SOURCES**



**Stresses**: Impair the viability of targets, e.g., sedimentation, habitat destruction



**Sources**: The proximate cause of the stress, e.g. cows in the stream

# Stresses & Sources

- Stress: a degraded condition or "symptom" observed in a conservation target resulting from a direct threat.
  - not a threat in and of itself
  - ecological attribute outside of natural range & variation

- Source: the *cause* of a given threat

Reduce exposure to **source**

Treat **stress**

# Stresses to a system: examples

- <u>Habitat destruction</u> -- affects area of habitat or occurrence area  *(Size)*

- <u>Altered vegetation structure or composition</u> -- affects characteristic native species  *(Condition)*

- <u>Altered fire regime</u> -- affects fire intensity /return interval  *(Landscape Context)*

# TNC Conservation Action Planning

Conservation by Design Gateway

**Conservation Action Planning: Basic Practice 4**

*This step helps you to identify the various factors that immediately affect your project's focal targets and then rank them so that you can concentrate your conservation actions where they are most needed. Specific questions that this step answers include:*

- *"What threats are affecting our targets?"*
- *"Which threats are more of a problem?"*

# TNC Conservation Action Planning

Conservation by Design Gateway

**Conservation Action Planning: Basic Practice 4**

## *Expected Outputs*

- *A list of <u>stresses</u> for each focal conservation target.*

- *Ratings of the scope and severity of each <u>stress</u>.*

- *A list of <u>sources</u> of stress for each focal conservation target.*

- *Ratings of the contribution and reversibility for each <u>source</u>.*

- *A ranking of the <u>sources</u> of <u>stress</u> affecting each focal target and a determination of the critical threats affecting your overall project.*

# TNC Conservation Action Planning

Conservation by Design Gateway

**Conservation Action Planning: Basic Practice 4**

## *Steps*

1. Select a target and review its key ecological attributes

2. Identify stresses / altered key ecological attributes

3. Apply stress-rating criteria and calculate <u>stress rank</u>

4. Identify sources of stress (Use IUCN-CMP taxonomy)

5. Apply source of stress rating criteria & calculate <u>threat rank</u>
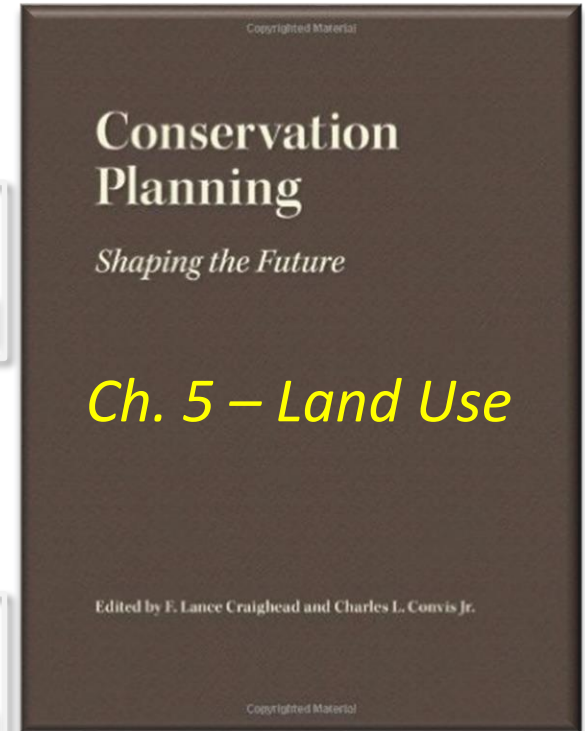
   *…repeat for other targets*
   *…compile threat summary*

GIS ?

# Practical steps to threat mapping *(w/GIS)*

*From Theobald (2013) in Conservation Planning book*

1. Identify relevant threats to include in the study.

2. Obtain spatial datasets to represent each threat.    GIS

3. Convert the raw value for each threat into commensurate units (e.g., from 0 to 1).

4. Specify weights for each threat to reflect the relative importance of each.    GIS

5. Conduct a sensitivity analysis to evaluate robustness for the weighting structure.

Conservation Planning
*Shaping the Future*

*Ch. 5 – Land Use*

Edited by F. Lance Craighead and Charles L. Convis Jr.

# 1. Identify threats to include in analysis…

*TNC:*

SETTING PRIORITIES

Ecoregional Assessment Toolbox

http://www.conservationgateway.org/Documents/Std10AnalyzeThreatsFeb06.pdf

Evaluate threats (stresses/sources) individually,
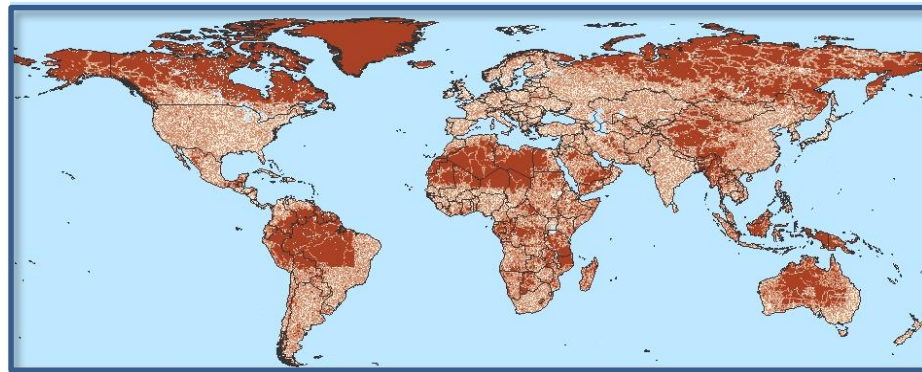for each target (or each target group)

- Use multiple sources of threat information
  - *Experts…*
  - *Literature, reports, databases:*
    - ➢ IUCN
    - ➢ Natural heritage programs
    - ➢ NatureServe
    - ➢ LCCs
    - ➢ Conservation data centers
    - ➢ Government agencies
  - *Spatial data…*

NatureServe®

**Gauging Ecological Threats in the Southeastern United States**

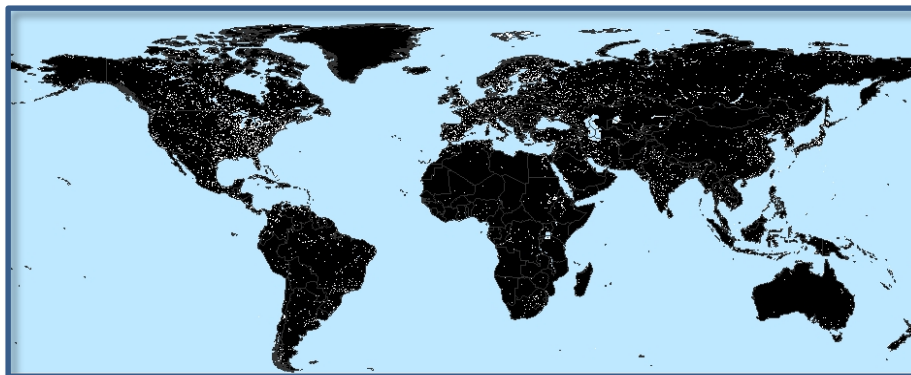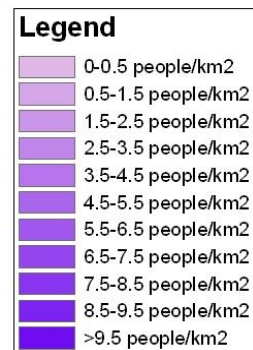Analysis will help guide the South Atlantic Landscape Conservation Cooperative
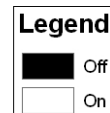
# TNC: Spatial data to identify threats...



DISTANCE TO NEAREST ROAD

Legend
- 0 - 2 Km
- 2 - 15 Km
- Greater than 15 Km

POPULATION DENSITY

Legend
- 0-0.5 people/km2
- 0.5-1.5 people/km2
- 1.5-2.5 people/km2
- 2.5-3.5 people/km2
- 3.5-4.5 people/km2
- 4.5-5.5 people/km2
- 5.5-6.5 people/km2
- 6.5-7.5 people/km2
- 7.5-8.5 people/km2
- 8.5-9.5 people/km2
- >9.5 people/km2

LIGHTS AT NIGHT

Legend
- Off
- On
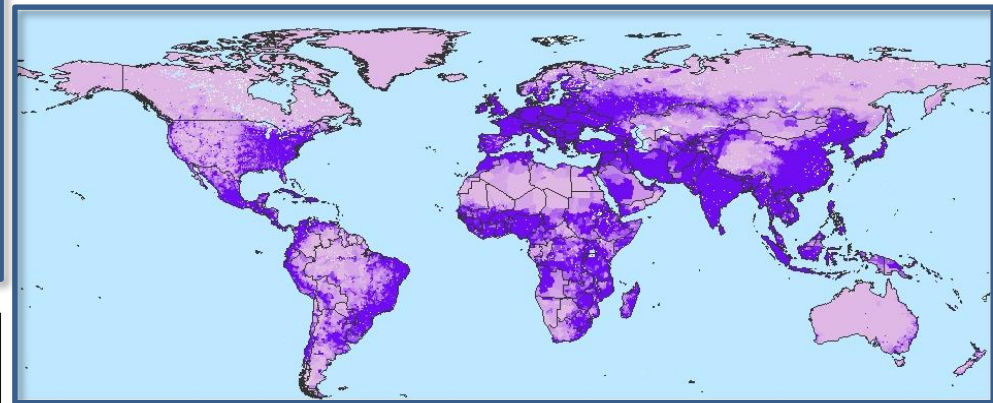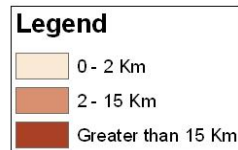
# 1. Identify threats to include in analysis...

Theobald (Ch. 5):

Integrating land use and landscape change with conservation planning

*Identify relevant threats to include, striving for comprehensiveness and avoiding redundancy when identifying each indicator.*
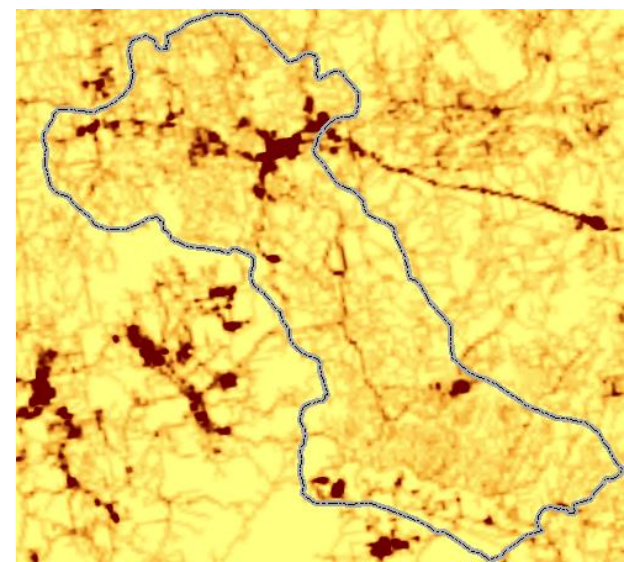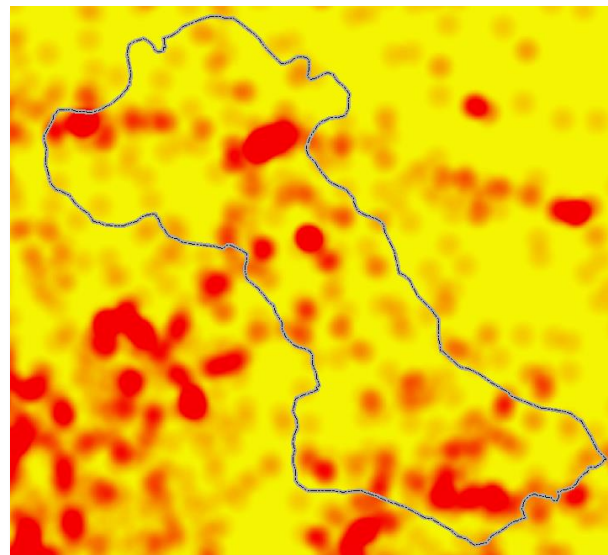
# 2. Obtain spatial data to represent threats

Theobald (Ch. 5):

*Obtain spatial datasets that best represent each threat (indicator), being explicit about what is being measured, what the units are, and what scale (grain) is.*
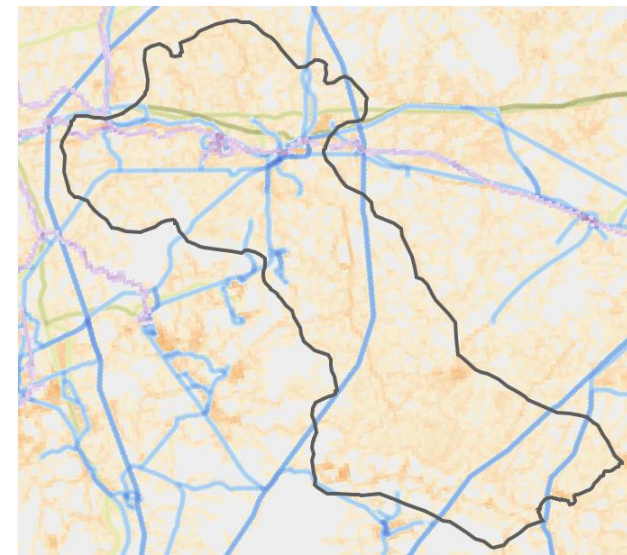


*Road density*

Proportion of 30m pixel occupied by road

*Housing density*

# dwellings within 150m of cell center

*Infrastructure*

Presence of power line or pipeline in cell (1/0)

# 2. Obtain spatial data to represent threats

**Table 5.2.** Commonly used and readily available datasets on global land use/land cover

| Name and description | Source |
| --- | --- |
| Gridded Population of the World v3—Depicts the "nighttime" distribution of human population across the globe at 30 ft. (~ 1 km) Global Rural-Urban Mapping Project—Human population density | Center for International Earth Science Information Network http://sedac.ciesin.columbia.edu/gpw/ |
| Nighttime lights —Defense Meteorological Satellite Program-Operational Linescan System—records low levels of visible near-infrared radiance at night at ~ 2.7 km (Sutton et al. 2009) | National Geophysical Data Center http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html |
| Global Land Cover 2000—European Commission, Joint Research Centre, Global Environment Monitoring Unit at 1 km | European Commission, Joint Research Centre http://bioval.jrc.ec.europa.eu/products/glc2000/products.php |
| GlobCover—European Space Agency, Ionia GlobCover | European Space Agency http://www.esa.int |
| MODIS—Land Cover (MOD12Q1) at 500 m | Goddard Space Flight Center http://modis-land.gsfc.nasa.gov/landcover.html |
| Global Human Footprint v2 (Last of the Wild)—A composite measure of the Human Influence Index (HII) normalized by biome and realm, created from population density, human land use and infrastructure, and human access at 1 km (Sanderson et al. 2002) | Center for International Earth Science Information Network http://sedac.ciesin.org/data/set/wildareas-v2-human-footprint-geographic |
| Global map of accessibility—each location represents the time it would take to travel (via road, rail, boat, etc.) to the nearest city of at least 50,000 people in 2000. | European Commission, Joint Research Centre http://bioval.jrc.ec.europa.eu/products/gam/index.htm |

Source: David M. Theobald.

# Land use vs. land cover...

- Land use = human modification

- Inferred from land cover

  - *Many possible uses from a single cover type...*



Water (11)
Open Space Developed (21)
Low Intensity Developed (22)
Medium Intensity Developed (23)
High Intensity Developed (24)
Barren Land (31)
Deciduous Forest (41)
Evergreen Forest (42)
Mixed Forest (43)
Shrub/Scrub (52)
Grassland (71)
Pasture/Hay (81)
Cultivated Crops (82)
Woody Wetlands (90)
Emergent Herbaceous Wetlands (95)

# Land use & Conservation Planning

## Modification Types

- <span style="color:red">Development, habitat alteration\*</span>
    - *For residential and commercial land uses…*
- Extractive resource use
    - *For agriculture, mining, energy production…*
- <span style="color:red">Transportation infrastructure\*</span>
- Invasive species
    - *Purposeful or unknowingly (seeds, plants, pests)*
- Hunting, collecting

> *\* Most prevalent in GIS analysis as changes can be mapped more easily*

# *Need for a standard lexicon of threats*

Like the periodic table or Linneaus' taxonomic system, threats could benefit from a unified classification system



*Salafsky et al. (2007)*

# Threat taxonomy



- A standard lexicon to unify conservation action

- Guidelines for experts to help identify which threats apply to a particular conservation project

- Facilitate cross-project learning & development of science (database development)

- Create general summaries for broader organizational purposes.

http://www.conservationmeasures.org/initiatives/threats-actions-taxonomies/threats-taxonomy

# Threats taxonomy (IUCN-CMP)

| | |
|---|---|
| Simple | • clear language & examples; understandable by all |
| Hierarchical | • logical grouping; facilitates use at various levels |
| Comprehensive | • contains all possible threats (at least at higher levels) |
| Expandable | • enables new items to be added as discovered |
| Exclusive | • any given item fits in one and only one place |
| Scalable | • same terms applied at all levels |

**A Standard Lexicon for Biodiversity Conservation:
Unified Classifications of Threats and Actions**

NICK SALAFSKY,*††† DANIEL SALZER,† ALISON J. STATTERSFIELD,‡ CRAIG HILTON-TAYLOR,§
RACHEL NEUGARTEN,† STUART H. M. BUTCHART,‡ BEN COLLEN,** NEIL COX,††
LAWRENCE L. MASTER,‡‡ SHEILA O'CONNOR,§§ AND DAVID WILKIE***

# Threats taxonomy (IUNC-CMP)

1. Residential & Commercial Development

2. Agriculture & Aquaculture

3. Energy Production & Mining

4. Transportation & Service corridors

5. Biological resource use

6. Human intrusions & disturbance

7. Natural systems modifications

8. Invasive & other problematic species & genes

9. Pollution

10. *Geologic events*

11. *Climate change & severe weather*

# Threat datasets *(Theobald, Table 5.4)*

Table 5.4. Datasets and data gaps related to biodiversity/ecosystem threats for the United States

| Threat type | Dataset | Strengths | Weaknesses | Data gaps |
|---|---|---|---|---|
| **1. Residential and commercial development** | | | | |
| Housing and urban areas | National Land Cover Dataset v2 (2001, 2006); NLCD retrofit (1992, 2001), NLCD v1 (1992) (http://www.mrlc.gov) <br><br> US Geological Survey Gap Land Cover v1 (http://gapanalysis.usgs.gov/data/land-cover-data/) <br><br> LANDFIRE (http://www.landfire.gov) <br><br> Housing density from census blocks (e.g., ICLUS/SERGoM) | Standard product and multidate allows change detection <br> Distinguishes semicultural classes (e.g., plantations) <br> Can compare to "potential natural" vegetation (biophysical settings) <br> Quantifies patterns of disturbance beyond urban fringe | Urban cover misses residential <1 dwelling unit per acre <br><br><br> Coarser and variable sized analytical unit | Age of development <br> Direct measures of human activity such as noise, light, pets |
| Commercial and industrial areas | National Land Cover Dataset v2 | Medium and high intensity development classes | Cannot differentiate from high-density residential or specific uses (e.g., retail, wholesale, service, etc.) | Urban land uses |
| Tourism and recreation areas | Protected Areas Database—US (CBI v1.1, GAP v1.2) (http://www.protectedlands.net/padus/) | Infer tourism and recreation areas from management types | Does not identify spatial distribution of use within protected area or seasonality | Number of visitors, mode of use (motorized/non), pets |

# 2. Obtain spatial data to represent threats

*Summary (so far):*

- Use experts/literature to identify stresses to targets.

- Use the threat taxonomy to facilitate creating a comprehensive but not redundant threat list for each target.

- Seek data appropriate to the scale of your analysis.

*Next: Weighting and combining threats…*

# Ranking Threats

**Step 1.4 Threat Ranking**

*WWF Standards of Project and Programme Management:*

"Threat rankings provide a systematic process that helps teams focus their actions and address the most important threats at a site"

# Threat *Scope*

The proportion of the target that can reasonably be expected to be affected by the threat within ten years, given the continuation of current circumstances and trends.  For ecosystems and ecological communities, measured as the proportion of the target's occurrence. For species, measured as the proportion of the target's population.

**4 = Very High:** The threat is likely to be pervasive in its scope, affecting the target across all or most (71-100%) of its occurrence/population.

**3 = High:** The threat is likely to be widespread in its scope, affecting the target across much (31–70%) of its occurrence/population.

**2 = Medium:** The threat is likely to be restricted in its scope, affecting the target across some (11–30%) of its occurrence/population.

**1 = Low:** The threat is likely to be very narrow in its scope, affecting the target across a small proportion (1-10%) of its occurrence/population.

# Threat *Severity*

Within the scope, the level of damage to the target from the threat that can reasonably be expected given the continuation of current circumstances and trends. For ecosystems and ecological communities, typically measured as the degree of destruction or degradation of the target within the scope. For species, usually measured as the degree of reduction of the target population within the scope.

**4 = Very High:** Within the scope, the threat is likely to <u>destroy or eliminate</u> the target, or reduce its population by 71-100% within ten years or three generations.

**3 = High:** Within the scope, the threat is likely to <u>seriously degrade</u>/reduce the target or reduce its population by 31-70% within ten years or three generations.

**2 = Medium:** Within the scope, the threat is likely to <u>moderately degrade</u>/reduce the target or reduce its population by 11-30% within ten years or three generations.

**1 = Low:** Within the scope, the threat is likely to only <u>slightly degrade</u>/reduce the target or reduce its population by 1-10% within ten years or three generations.

# Threat *irreversibility* (permanence)

The degree to which the effects of a threat can be reversed and the target affected by the threat restored. It is assessed for the impact of the threat on the target (stress), not the threat itself (source).

**4 = Very High:** The effects of the threat cannot be reversed, it is very unlikely the target can be restored, and/or it would take more than 100 years to achieve this (e.g., wetlands converted to a shopping centre).

**3 = High:** The effects of the threat can technically be reversed and the target restored, but it is not practically affordable and/or it would take 21–100 years to achieve this (e.g., wetland converted to agriculture).

**2 = Medium:** The effects of the threat can be reversed and the target restored with a reasonable commitment of resources and/or within 6–20 years (e.g., ditching and draining of wetland)

**1 = Low:** The effects of the threat are easily reversible and the target can be easily restored at a relatively low cost and/or within 0–5 years (e.g., off-road vehicles trespassing in wetland).

# Applying Threat Rankings

- Develop a list of all direct threats in your area
  - Use IUCN-CMP threat taxonomy as a guide

- List all conservation targets

- Identify which threats affect which targets
  - Rank <u>scope</u>, <u>severity</u>, and <u>irreversibility</u> for each target

- Add up the rankings scores for a given target
  - Scope + severity = Magnitude

- Sum up threats across all targets:

  Which threat is most dire in your area?

# Threat ranking example

| DIRECT THREAT | TARGET: Sharks | | | | | TARGET: Coral Reefs | | | | | TARGET: Intertidal Systems | | | | | TARGET: Seabirds | | | | | SITE RANKING | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SCOPE | SEVERITY | IRREVERSIBILITY | TOTAL | CLASSIFICATION | SCOPE | SEVERITY | IRREVERSIBILITY | TOTAL | CLASSIFICATION | SCOPE | SEVERITY | IRREVERSIBILITY | TOTAL | CLASSIFICATION | SCOPE | SEVERITY | IRREVERSIBILITY | TOTAL | CLASSIFICATION | TOTAL | CLASSIFICATION |
| Illegal shark fishing by boats from mainland | 4 | 3 | 3 | 17 | Very High | | | | | | | | | | | | | | | | 17 | High |
| Global warming | | | | | | 4 | 3 | 3 | 17 | Very High | | | | | | | | | | | 17 | High |
| Diver & anchor damage | | | | | | 1 | 2 | 1 | 7 | Low | | | | | | | | | | | 7 | Low |
| Legal but unsustainable fishing by local fishermen | | | | | | 3 | 3 | 3 | 15 | High | 3 | 2 | 3 | 13 | Medium | | | | | | 28 | Very High |
| Sewage | | | | | | | | | | | 1 | 1 | 1 | 5 | Low | | | | | | 5 | Low |
| Potential oil spills | | | | | | | | | | | 1 | 2 | 2 | 8 | Low | 2 | 3 | 2 | 12 | Medium | 20 | High |
| Introduced predators (rats) | | | | | | | | | | | | | | | | 2 | 3 | 2 | 12 | Medium | 12 | Medium |

Note: Total = 2*(scope + severity) + Irreversibility

# Alternative threat ranking schemes

Margolis & Salafsky (1998)

- Considers threats overall for a site, not by target
- Threats ranked on <u>scope</u>, <u>severity</u>, and <u>*urgency*</u>

  *(Urgency* = importance of taking immediate action)

| DIRECT THREAT | SCOPE | SEVERITY | URGENCY | TOTAL | CLASSIFICATION |
|---|---|---|---|---|---|
| Agriculture frontier expansion | 7 | 8 | 9 | 24 | Very High |
| Commercial fishing | 1 | 2 | 1 | 4 | Low |
| Freshwater turtle and turtle eggs over-harvesting | 3 | 7 | 4 | 14 | Medium |
| Hunting | 8 | 4 | 7 | 19 | High |
| Illegal Logging | 6 | 5 | 8 | 19 | High |
| Mining | 2 | 9 | 5 | 16 | Medium |
| Paiche (Invasive fish species) | 4 | 6 | 6 | 16 | Medium |
| Palm exploitation | 5 | 3 | 2 | 10 | Low |
| Unsustainable Brazil nut management | 9 | 1 | 3 | 13 | Medium |
| TOTAL | 45 | 45 | 45 | | |

# Threats in conservation planning

*Need to evaluate the <u>scope</u> and <u>severity</u>
of threats and understand their <u>causes</u>*

1.  Organize information on threats

2.  Use multiple sources of threats information

3.  Describe/diagram their root causes and stresses

*What role does spatial analysis play?*

# Threat ranking & GIS

*What role does spatial analysis play?*

- Threat identification

- Estimating threat scope/extent

- Estimating threat severity

- Combining and ranking threats

# Case Study: Caribbean Island Assessment



REGIONAL CONSERVATION ASSESSMENT OF THE INSULAR CARIBBEAN

Terrestrial Environmental Risk Surface used to Indicate Suitability of Candidate Areas

Threats

- Agriculture
- Population Density
- Tourism

http://www.journalconsplanning.org/2008/JCP_v4_4_McPherson.pdf

# Intensity and influence of threats

FIGURE 2  Examples of intensity distance decay in Environmental Risk Surface models based on one risk element for polygon, line, and point features. Red shades indicate higher levels of intensity values in near proximity to the risk element, and shades of yellow to blue indicate varying degrees of intensity decay based on the user-specified influence distance from the risk element (Schill and Raber 2008).
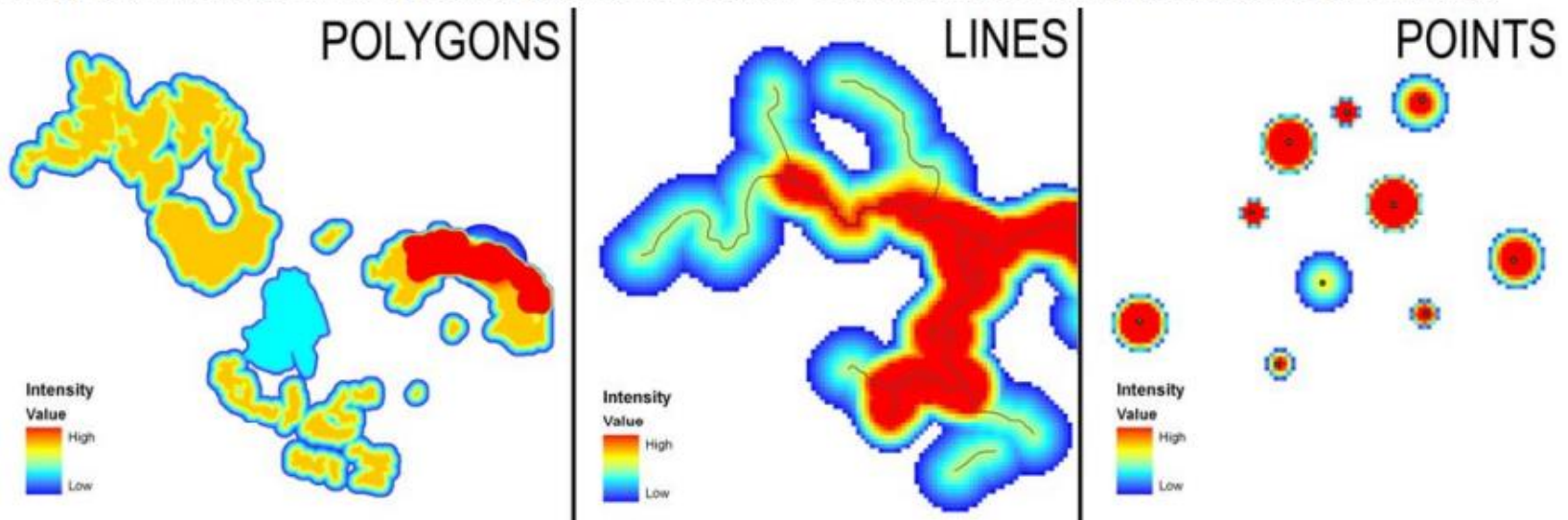
1. Assemble data that best represent risk elements
2. Assign intensity and influence distances
3. Develop risk tables listing targets and their level of risk

http://www.journalconsplanning.org/2008/JCP_v4_4_McPherson.pdf

# Threat: Agriculture

FIGURE 3  The S-curve used to reflect the hypothesized relationship between energy input intensity and impact for agriculture. The logistic agricultural function that was generated to fit intensity values along the curve is $0.8348/(1+24.457*EXP(-0.1037*raw\ cost))$.

Agriculture Impact Classes

| Kcal Equivalent | Normalized Value |
|---|---|
| 1-3 | 0.05 |
| 4-7 | 0.11 |
| 8-11 | 0.17 |
| 12-17 | 0.25 |
| 18-21 | 0.5 |
| 22-32 | 0.75 |
| 33-39 | 0.87 |
| 40+ | 0.95 |

Severity

Scope
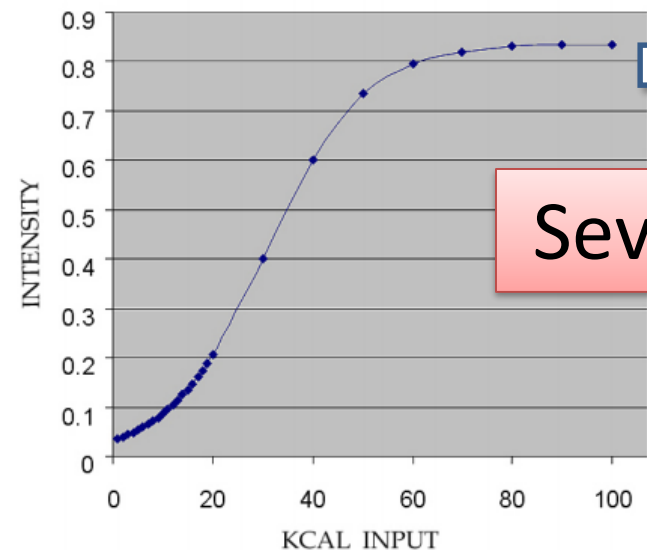
Agricultural Intensity and Influence Buffer Distance Values

| Crop type | Influence buffer distance (meters) | Intensity (Kcal) | Normalized value |
|---|---|---|---|
| Banana | 2000 | 20 | 0.5 |
| Sugarcane plantations | 1000 | 4 | 0.11 |
| Small scale agriculture and grasslands | 500 | 13 | 0.25 |
| Tree crops and agroforestry | 500 | 8 | 0.17 |

Impact distance based on dispersal potential of pesticide…

# Threat: Agriculture



FIGURE 4 Environmental Risk Surfaces depicting agriculture-based activities and corresponding aggregation of intensities for terrestrial (a) and freshwater (b) habitat realms. Each realm exhibits variation based on the intensity and influence distances specified by experts.

Agriculture Intensity
TERRESTRIAL

High (75)

a.

Low (0)
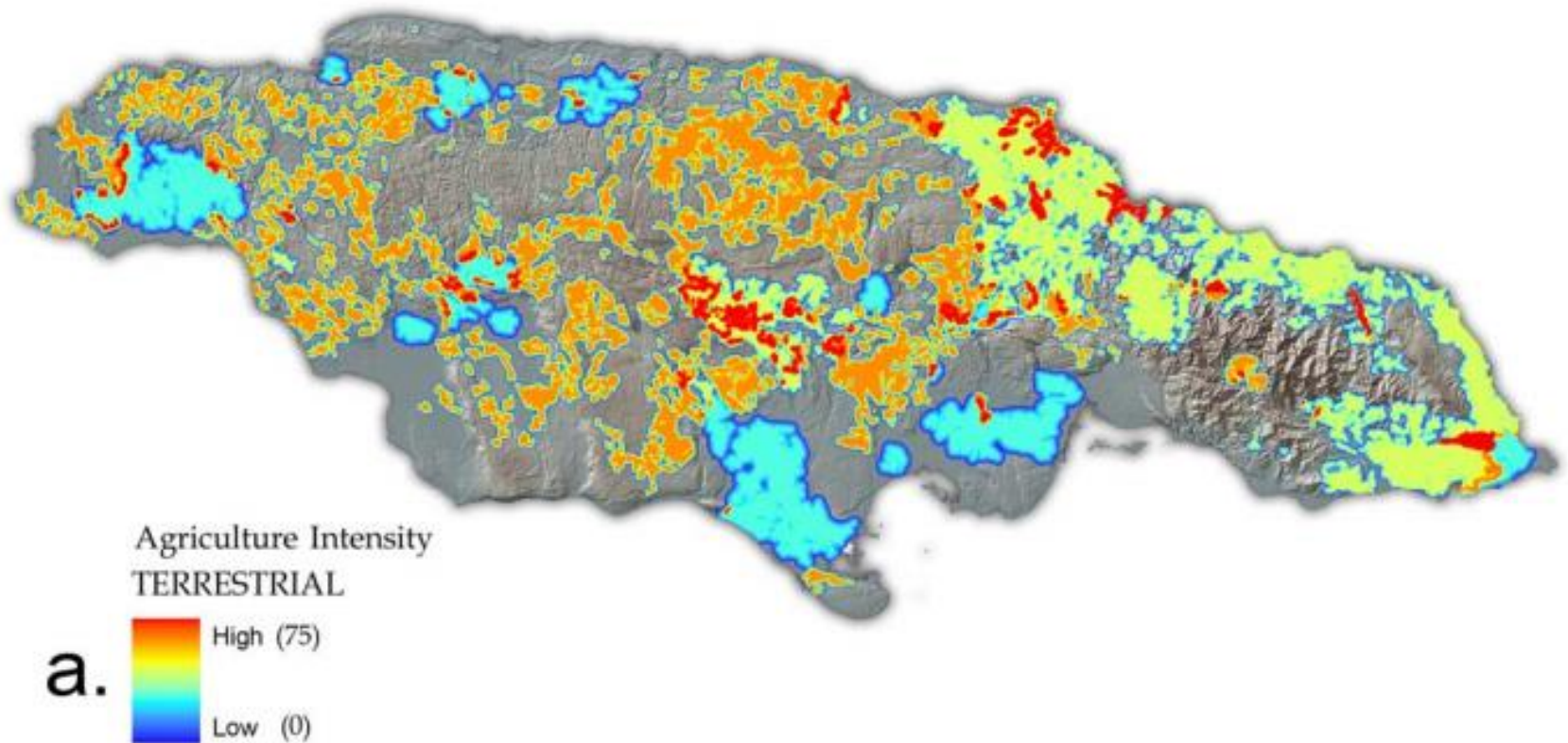
# Threat: Population Density

Intensity of impact $= 0.9217 / (1 + 22.6614 \cdot EXP(-0.0114 \cdot \text{raw cost}))$.



Severity
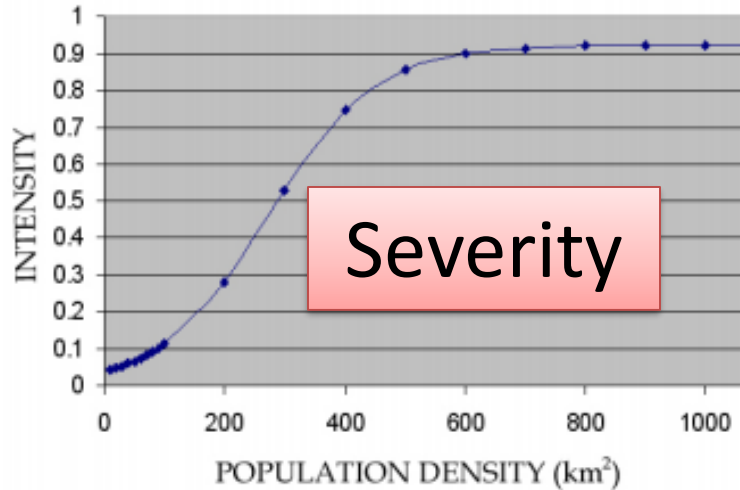
" these polygons were assigned an influence distance of 3 kilometers based on logical rationale to account for impact overlaps "

Scope

Population Density Intensity and Buffer Distance Values

| Population density per km² by section (census data of 2000) | Influence buffer distance (meter) | Intensity | Nomalized intensity (scale 0-1) |
|---|---|---|---|
| 1-9 | 3000 | 5 | 0.05 |
| 10-29 | 3000 | 11 | 0.11 |
| 30-49 | 3000 | 17 | 0.17 |
| 50-99 | 3000 | 25 | 0.25 |
| 100-199 | 3000 | 50 | 0.5 |
| 200-499 | 3000 | 75 | 0.75 |
| 500-999 | 3000 | 87 | 0.87 |
| 1000-19999 | 3000 | 95 | 0.95 |
| 20000 + | 3000 | 100 | 1 |

# Threat: Tourism

Tourism is a driving economic force in the Caribbean. Negative impacts from tourism occur initially when beaches and mangroves are cleared for building hotels and resorts. Hotels and resorts are areas of concentrated resource use, waste disposal, and direct pressures associated with tourist activities. Hotel coverage was mapped to identify the areas most highly affected by tourism development. The tourist zones were derived by creating a buffer of 5 km around hotel clusters.



Severity

Scope
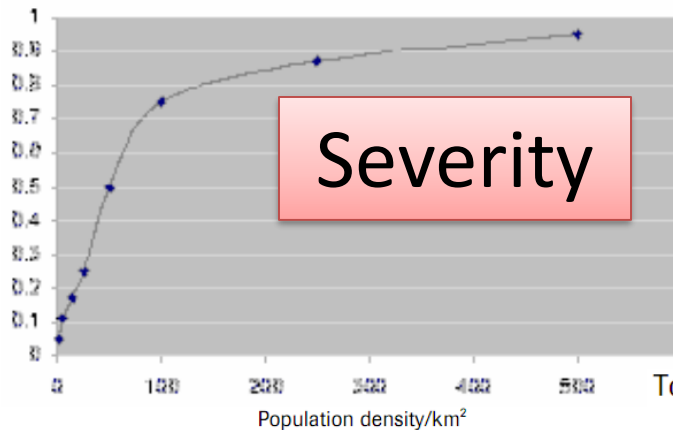
Tourism Intensity and Buffer Distance Values

| Density of tourist population per km² by tourist zone | Influence buffer distance (meter) | Intensity | Nomalized intensity (scale 0-1) |
|---|---|---|---|
| 1 | 3000 | 5 | 0.05 |
| 5 | 3000 | 11 | 0.11 |
| 15 | 3000 | 17 | 0.17 |
| 25 | 3000 | 25 | 0.25 |
| 50 | 3000 | 50 | 0.5 |
| 100 | 3000 | 75 | 0.75 |
| 250 | 3000 | 87 | 0.87 |
| 500 | 3000 | 95 | 0.95 |

# Which buffer distance to pick?

Expert opinion was critical for identifying key threats and developing the intensity and influence distance values incorporated into the models. All final decisions regarding intensity values and influence distances were made by the small core teams of experts responsible for developing the ERS for each habitat realm. When possible, their decisions were substantiated through literature reviews and consultations with other outside experts. Finally, once completed, the freshwater, marine and terrestrial ERS models including all relevant values were verified in workshops of outside experts.



Measuring threats and selecting intensity and influence distance thresholds is not an exact science and is in the early stages of development. For many practitioners, it is a constant struggle to select and justify intensity and distance scores when ranking or aggregating threat data. Careful consideration must be taken when assigning these values, relying heavily on local knowledge of impacts followed by critical expert review. It is useful to convene a workshop of experts who understand the nature of each identified risk element, and who can rank and assign corresponding intensity and influence distance values.

http://www.journalconsplanning.org/2008/JCP_v4_4_McPherson.pdf

# Theobald: Degree of modification in Colorado
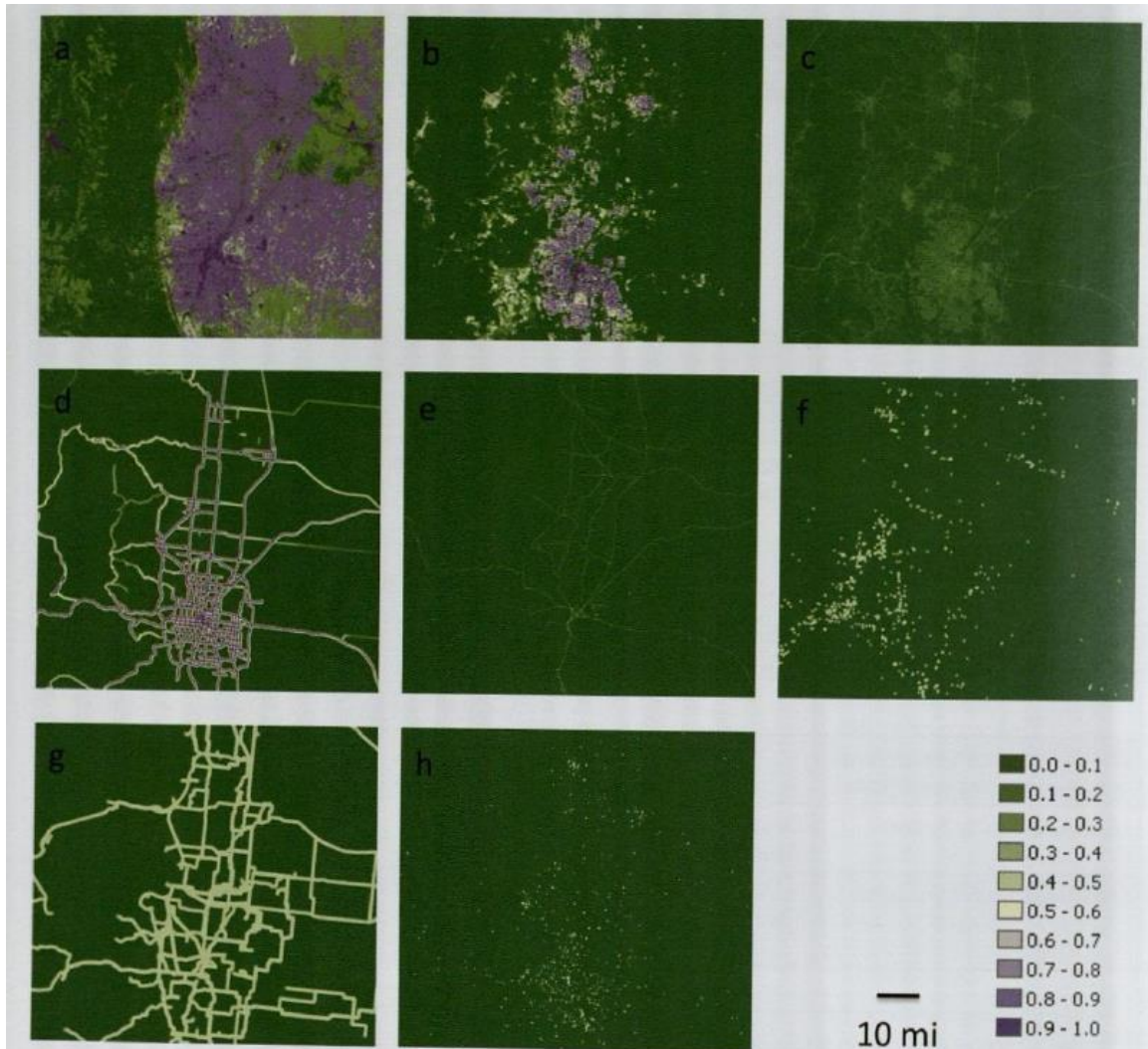


Land cover    Housing density    Road footprint

Highway traffic    Railways    Mines

Power lines    Cell towers

0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0

10 mi

# Theobald: Degree of modification in Colorado

## 1. Create threat layers…

For the physical footprint of various types of roads, I calculated $r$, the proportion of a 30-m cell occupied by a road as represented by Census 2010 data. Based on an ad hoc analysis from high-resolution aerial photography, I estimated that highways occupied 100% of a 30-m cell (or a 1.0 proportion). Secondary roads occupied 50%; local roads, 30%; and dirt/4WD roads, 10%.

To incorporate datasets on oil and gas, I converted the surface location of active wells into a well density surface by converting locations of active wells using a kernel density function (1-km radius). I assigned a human-modification factor for wells of 0.5 for $d > 2.0$ per km$^2$ and 0.25 for 0.1–2.0 per km$^2$ (Copeland et al. 2009).
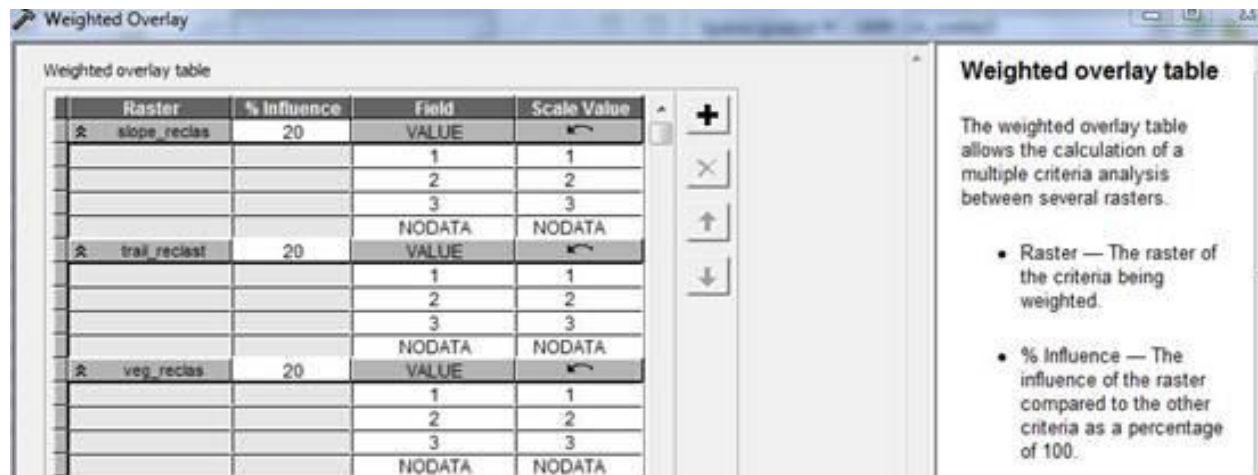
I calculated an index using Defense Meteorological Satellite Program (DMSP) "night lights" values for 2009 (Sutton et al. 2009) using the natural log and then normalized. I also estimate the degree of human modification by power lines by assigning a value of 0.5 and then calculating a kernel density function and for cell and radio towers (using a 0.5-km radius).

# Theobald: Degree of modification in Colorado

## 2. **Combining threat layers…**

A. *Weighted sum/weighted overlay*

- o What if threats not independent?
- o Major threat may be dampened by absence of other threats
- o Not cumulative…



B. *Fuzzy logic…*

# Theobald: Degree of modification in Colorado

## 2. Combining threat layers…

### B. Fuzzy logic…

Table 5.5. Illustration of combination formulas at a single location (or cell) for multi-attribute (multilayer) analysis for three threats with values of 0.1, 0.5, and 0.9

| Threats/Combos | Possible combinations of values, iteration | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| A | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.1 | 0.1 | 0.5 | 0.5 | 0.9 |
| B | 0.1 | 0.1 | 0.1 | 0.5 | 0.5 | 0.5 | 0.9 | 0.5 | 0.9 | 0.9 |
| C | 0.1 | 0.5 | 0.9 | 0.5 | 0.5 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| Sum | 0.300 | 0.700 | 1.100 | 1.100 | 1.500 | 1.500 | 1.900 | 1.900 | 2.300 | 2.700 |
| Average | 0.100 | 0.233 | 0.367 | 0.367 | 0.500 | 0.500 | 0.633 | 0.633 | 0.767 | 0.900 |
| Product | 0.001 | 0.005 | 0.009 | 0.025 | 0.125 | 0.045 | 0.081 | 0.225 | 0.405 | 0.729 |
| Fuzzy And(min) | 0.100 | 0.100 | 0.100 | 0.100 | 0.500 | 0.100 | 0.100 | 0.500 | 0.500 | 0.900 |
| Fuzzy Or (max) | 0.100 | 0.500 | 0.900 | 0.500 | 0.500 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 |
| Fuzzy Sum | 0.271 | 0.595 | 0.919 | 0.775 | 0.875 | 0.955 | 0.991 | 0.975 | 0.995 | 0.999 |

Source: David M. Theobald.

# Theobald: Degree of modification in Colorado
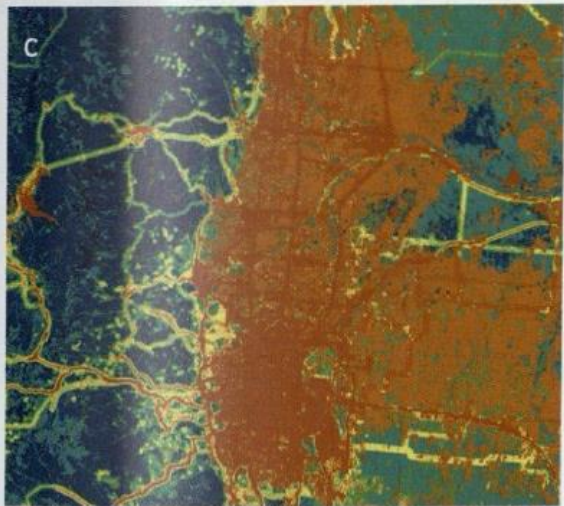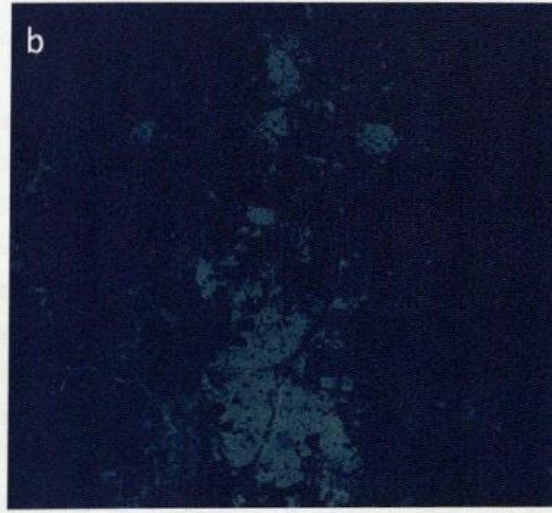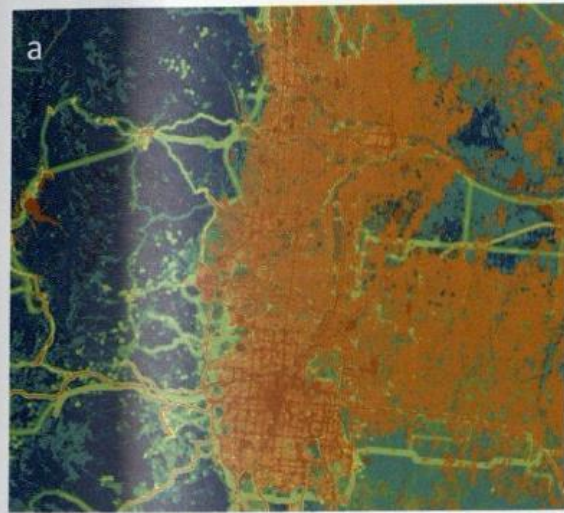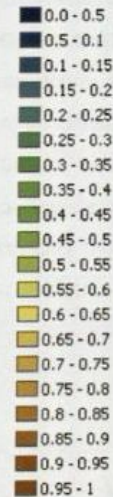


A. Max value

B. Mean value

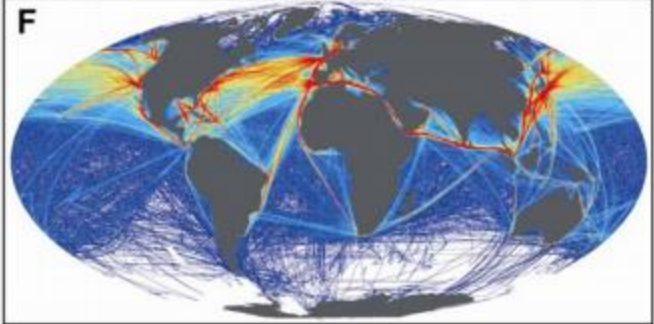C. Fuzzy sum

# Global Map of Human Impact on Marine Ecosystems
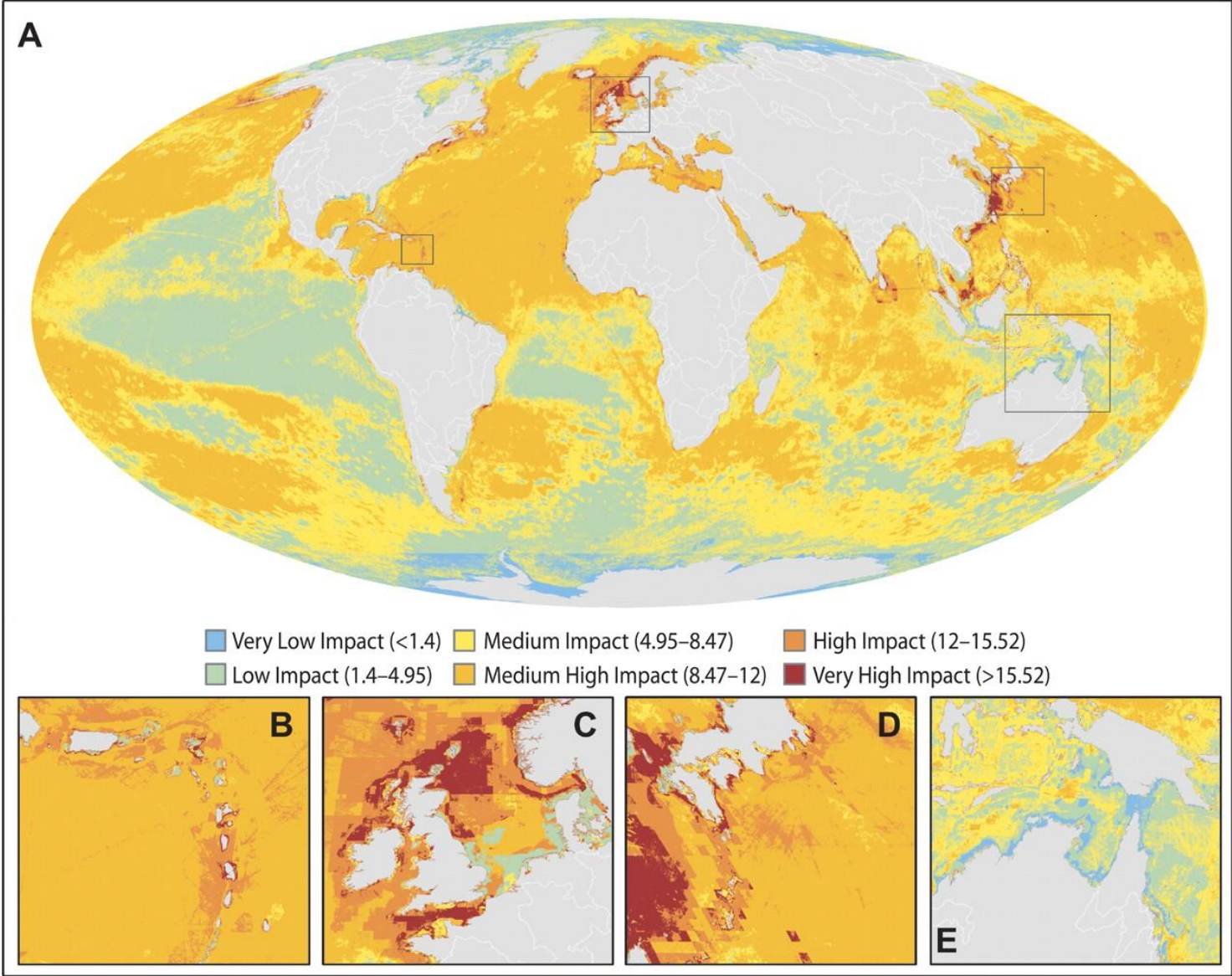
# Global Map of Human Impact on Marine Ecosystems
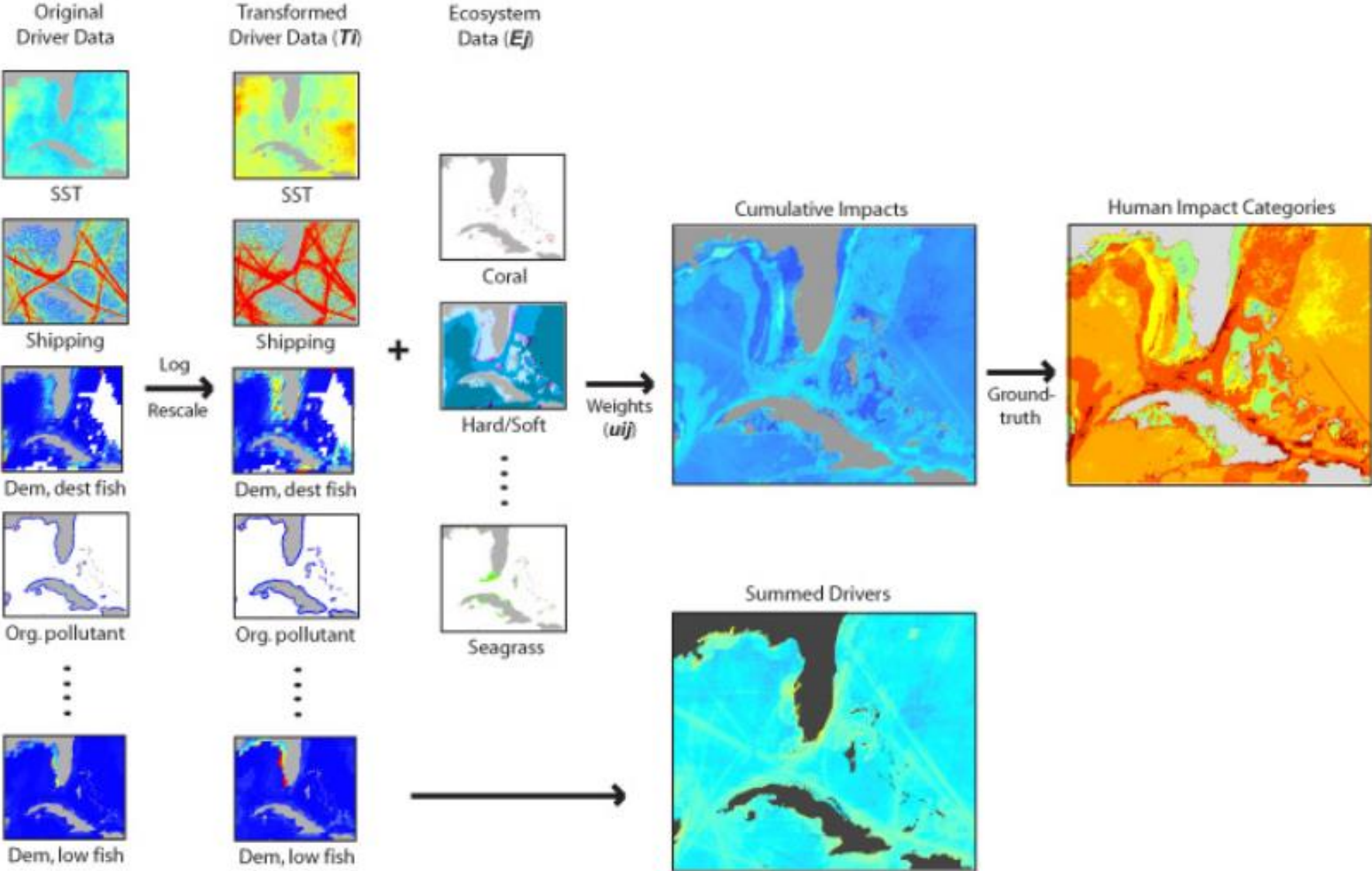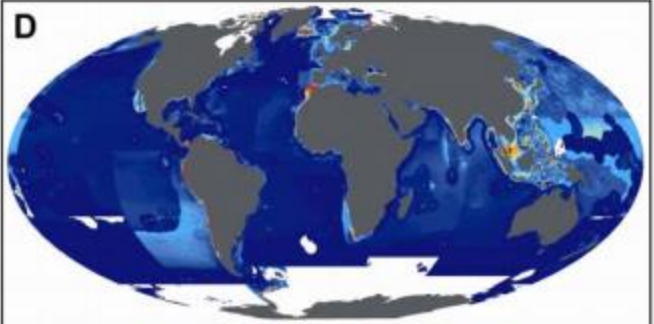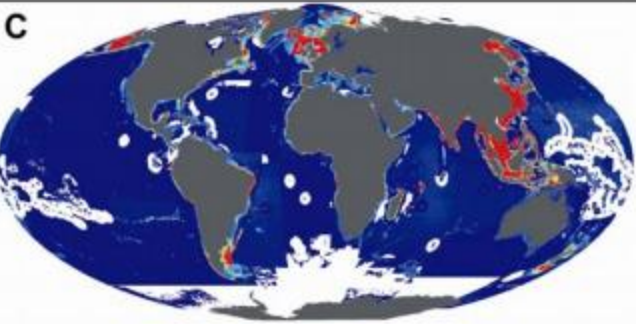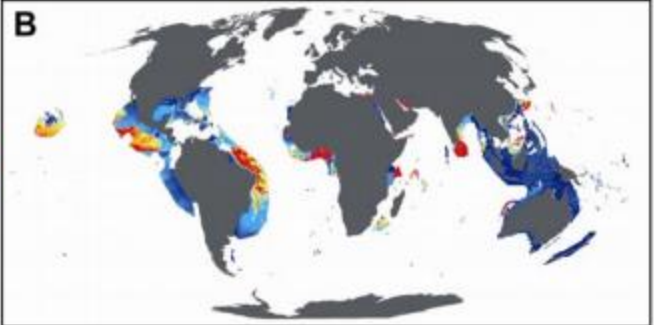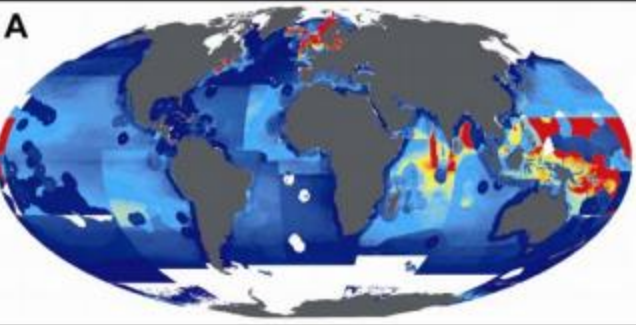
# Global Map of Human Impact on Marine Ecosystems
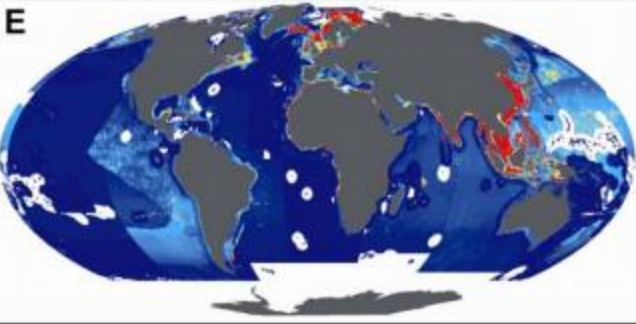


A) pelagic, low-bycatch fishing

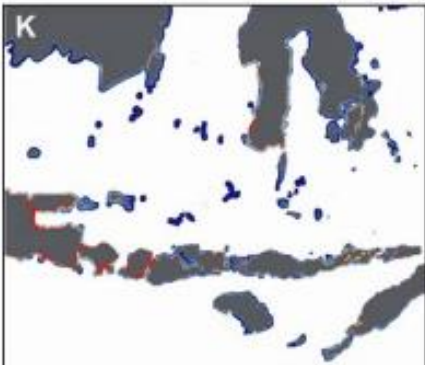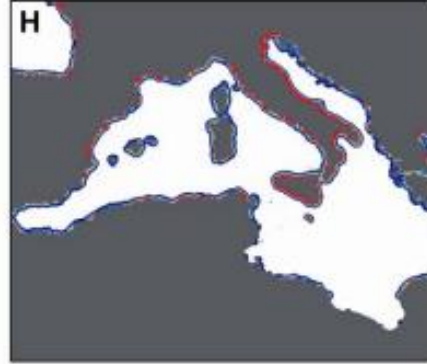B) pelagic, high-bycatch fishing

C) demersal habitat-modifying fishing

D) demersal non-habitat-modifying, low-bycatch fishing

E) demersal non-habitat-modifying, high-bycatch fishing

F) shipping

# Global Map of Human Impact on Marine Ecosystems



G) nutrients (Western Mediterranean),

H) organic pollutants (Western Mediterranean),

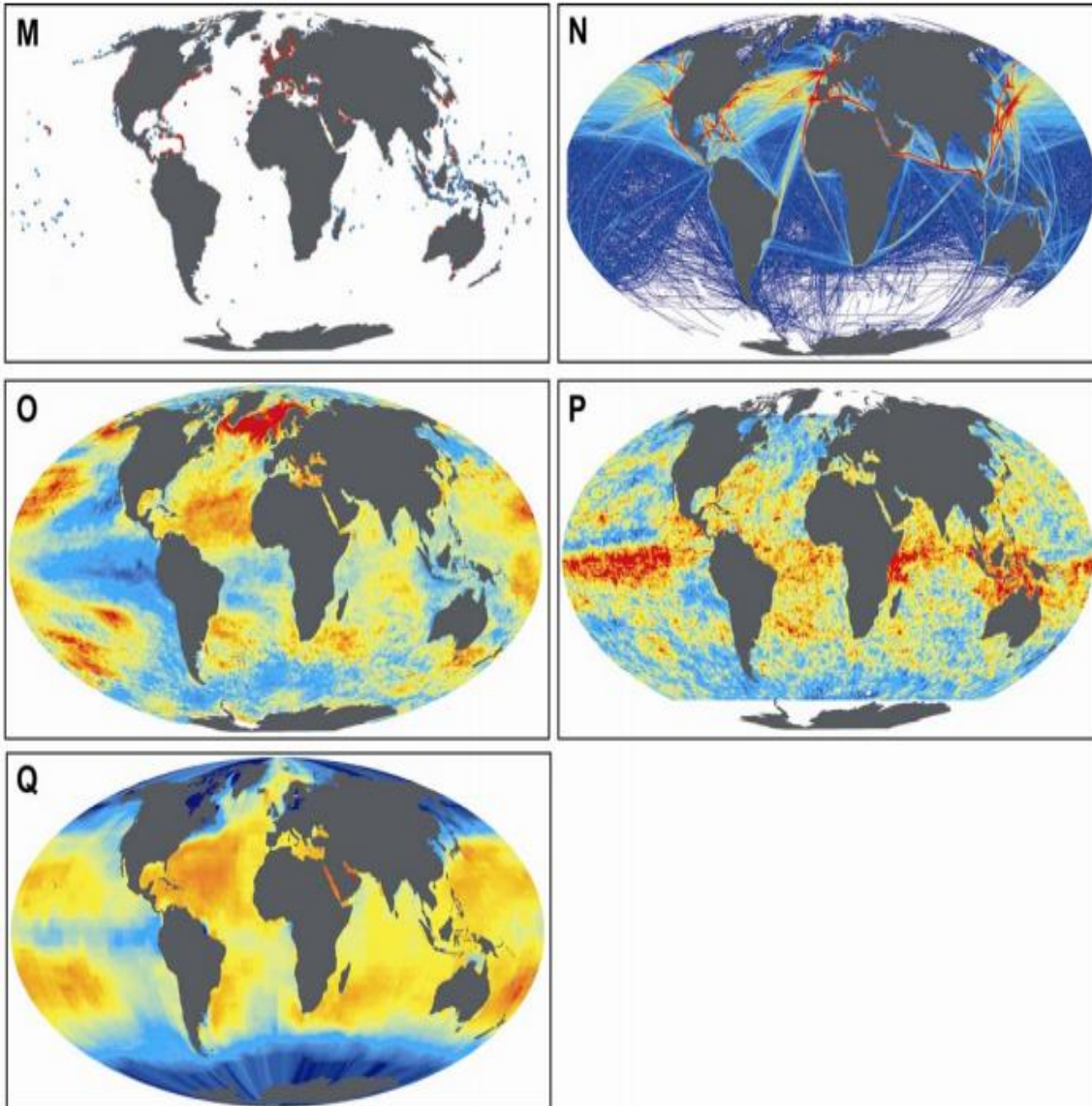I) inorganic pollutants (Western Mediterranean),

J) direct human impact (Western Mediterranean),

K) artisanal fishing (central Indonesia),

L) oil rigs (Gulf of Mexico)

# Global Map of Human Impact on Marine Ecosystems
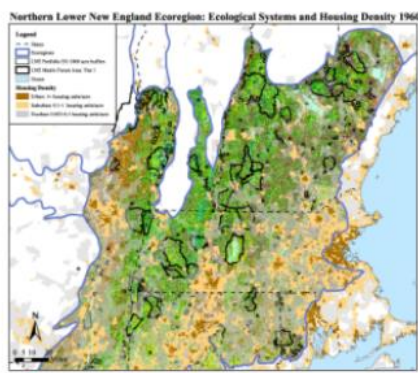


M) invasive species

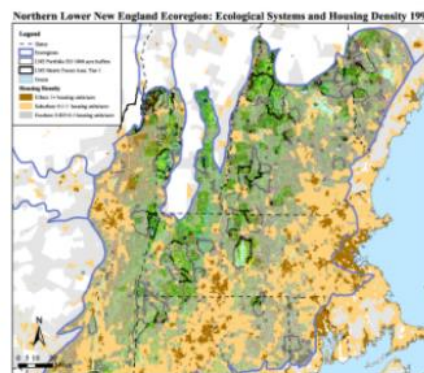N) ocean pollution

O) sea temperature changes

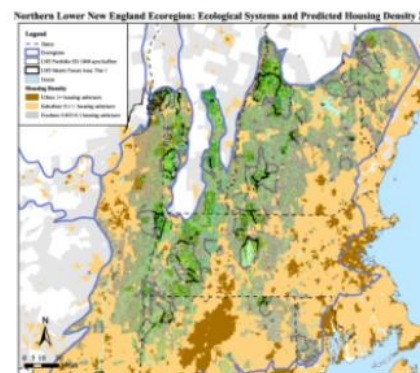P) UV changes

Q) ocean acidification

# Threat forecasting



**Example 1: Predicting housing development using census data in the Northeast**
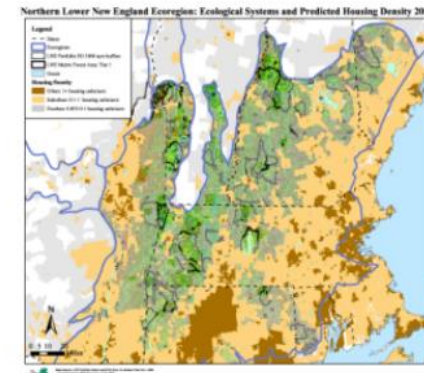
1960    1990    2020    2050

In this example from the US Northeast (showing lower New England), census data from 1960 and 1990 are projected into the years 2020 and 2050. This information can then be compared with areas of conservation importance, enabling planners to prioritize conservation actions, based on the likely risk from development. This approach, called *hindcasting*, uses past threats data to predict the intensity and distribution of future threats.

# Threat forecasting



**Example 2: Using cost surfaces to estimate current and future threats in the Caribbean**

*sedimentation*          *overfishing*          *aggregate threat surface*
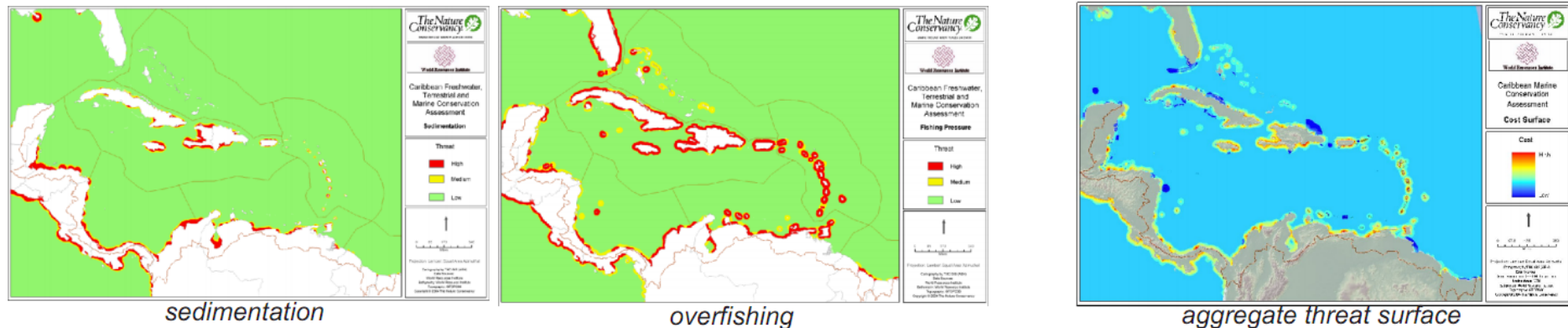
In this example from the Caribbean, models that approximate the intensity and spatial distribution result in threat "cost surfaces." Specific threats included sedimentation, overfishing, road development, land conversion, among others. These models were derived from regional data sets (remote sensing, census, GIS) as well as expert opinion. All threats were combined to create an aggregate threat surface. This type of analysis can be run for both existing as well as future threats.
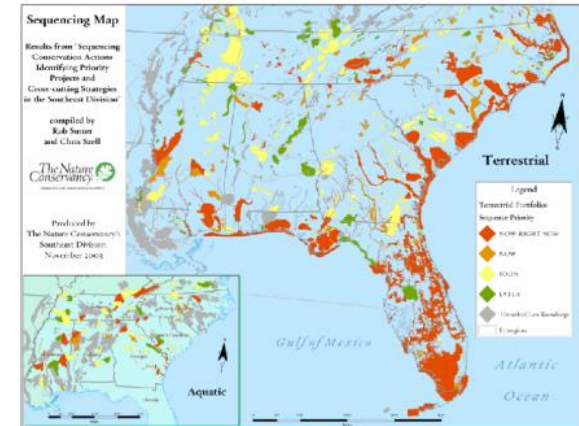
# Threat forecasting



## Example 3: Assessing risk to conservation areas in the Southeast
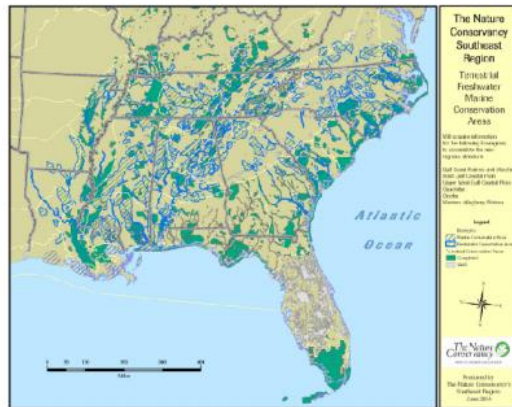
*areas of conservation importance*

*example of fire assessment*

*prioritized areas, based on total risk*

In this example from the US Southeast, the risks to biodiversity from 37 different threats are identified and mapped, using areas of conservation importance as the basic unit of analysis. These threats are ranked in severity, ranging from very high (the threat will likely destroy or eliminate key biodiversity features), to low (the threat will cause only minor impairment to key biodiversity features). The most common and destructive threats included altered fire regime, water withdrawal, suburban development, incompatible forestry, forest conversion, road development, invasive species. The resulting analysis enables conservation planners to sequence their conservation actions, based on threat urgency.

# Summary: Threat Analysis & Mapping

- It's harder than you might have thought!
  - Getting at root causes is a challenging task…
  - Severity and scopes are hard to determine and are different for different species….
  - Digested threat maps bury a lot of assumptions…

# Summary: Threat Analysis & Mapping

- Moving forward:
  - Progress toward classifying threats (via taxonomy)
  - More insightful understanding of threats in terms of stresses and sources

- Where GIS fits in:
  - Need to be able to map the sources as features
  - Spatial relationships of scales
    - Movement across landscape (e.g. air/water transport)
    - Decay from source
    - Density functions