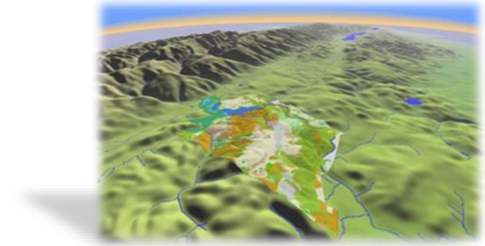
NICHOLAS SCHOOL OF THE
ENVIRONMENT AND EARTH SCIENCES
DUKE UNIVERSITY



ENVIRON 761: Threat Mapping

Instructor: John Fay

Overview

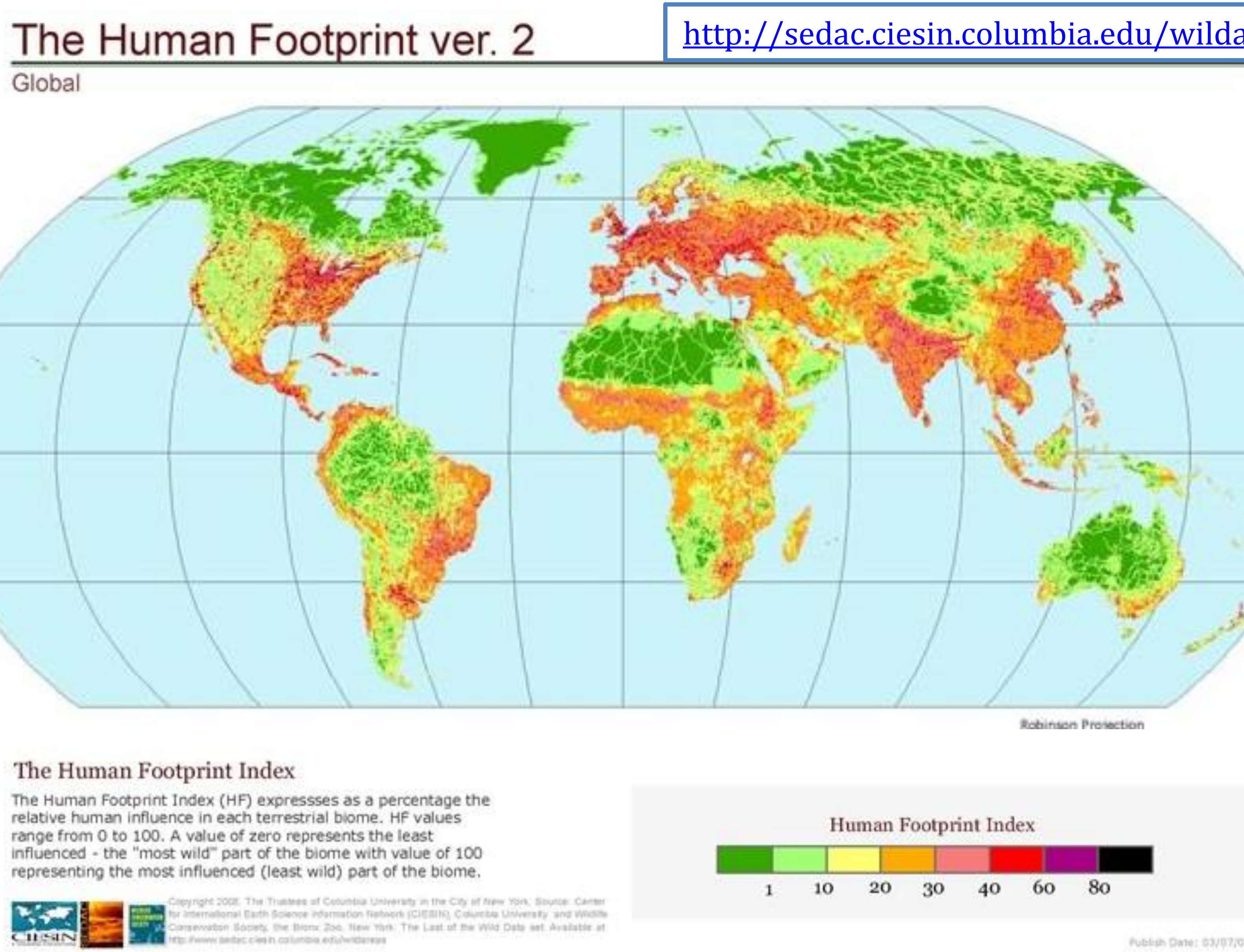
- Threats to biodiversity
- Classifying threats
- Incorporating threats in conservation planning
- State of spatial analysis in threat mapping

The "Original Conservation Crisis"

Threat = Flood

Today's Conservation Crisis…

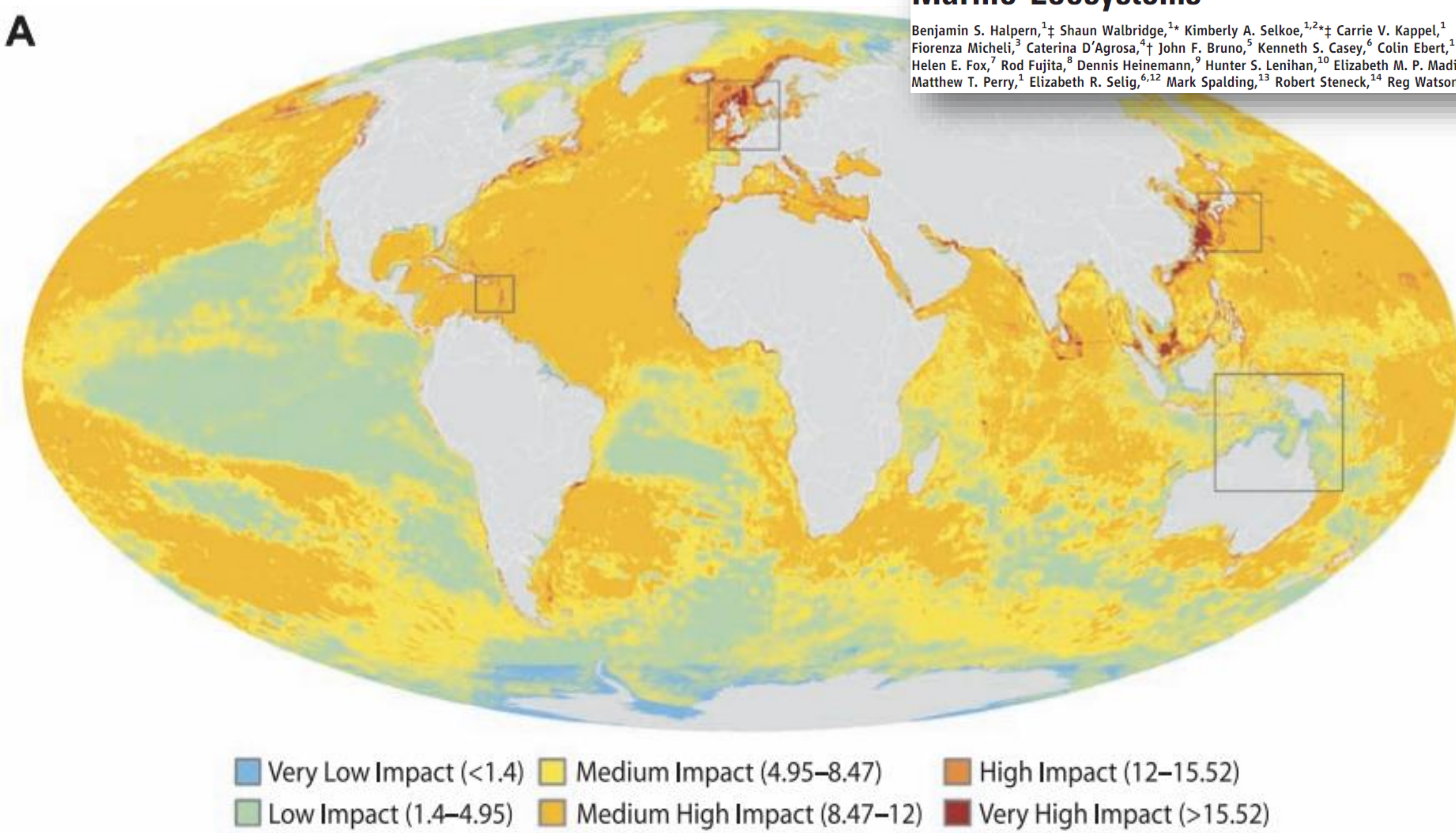
http://sedac.ciesin.columbia.edu/wildareas/



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]



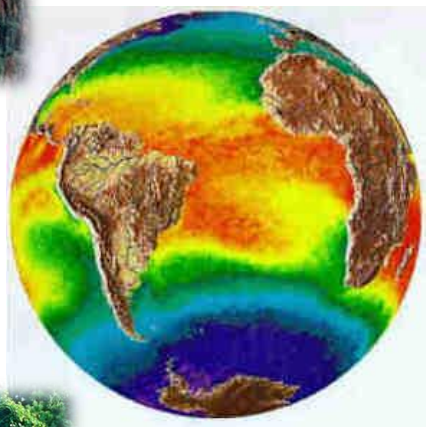
Threat analysis: *Central questions*

- How does one create these "threat maps"?
- What *is* a threat?
- Are threats more severe in selected locations?

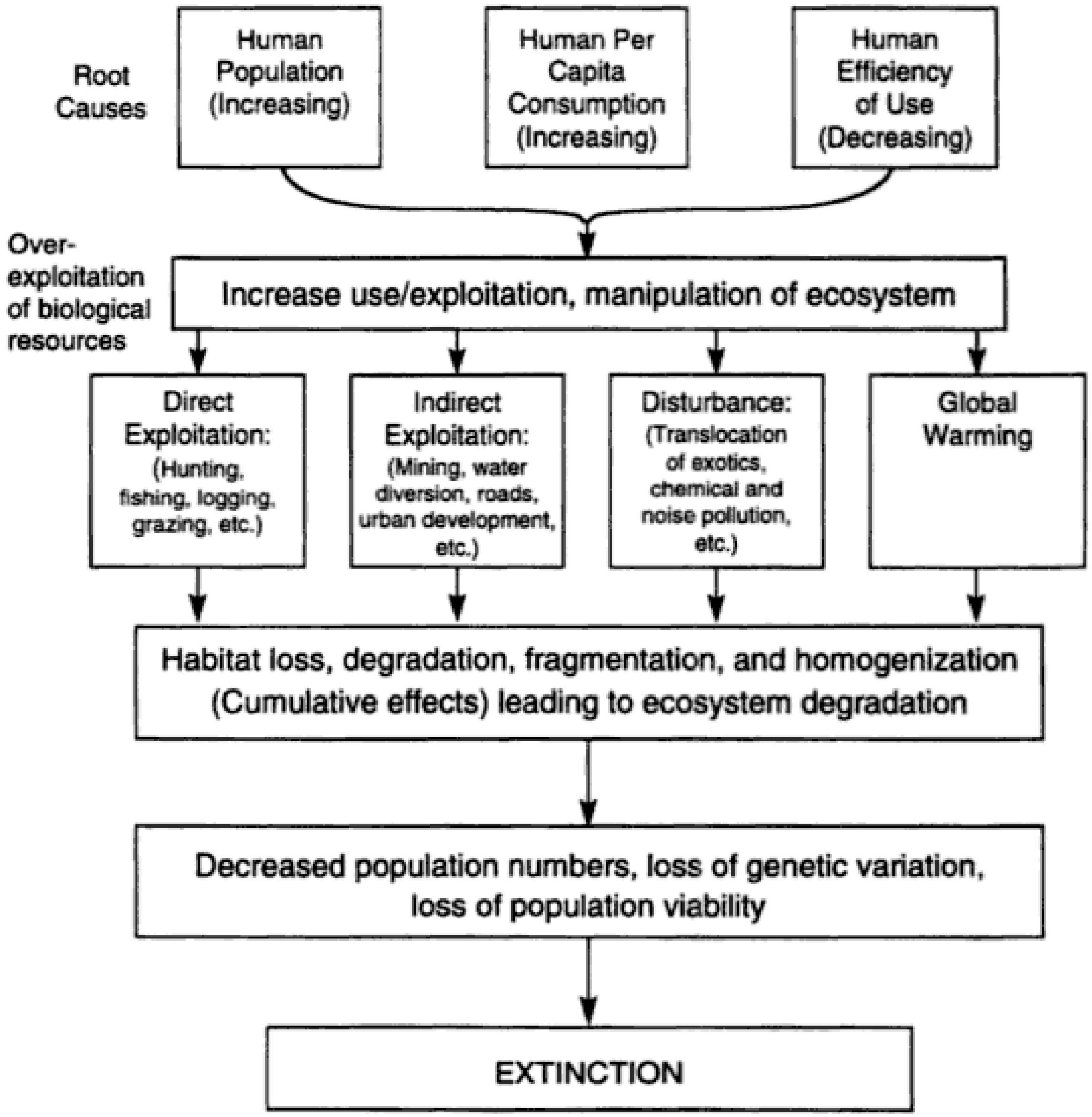
- What role does GIS play in evaluating the impacts of threats in conservation planning?

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

Stedman-Edwards (1997)

- 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

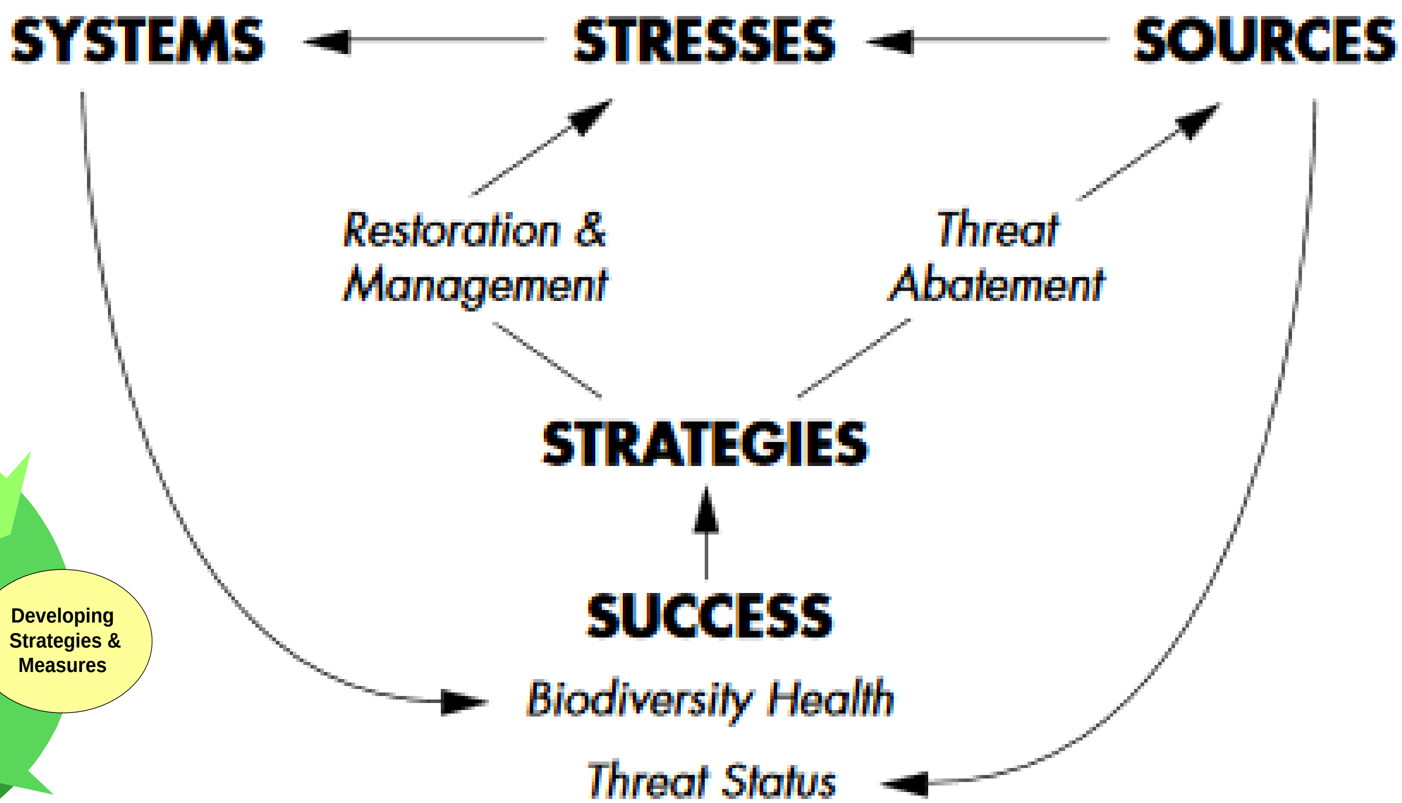
The Five-S Framework for Site Conservation:

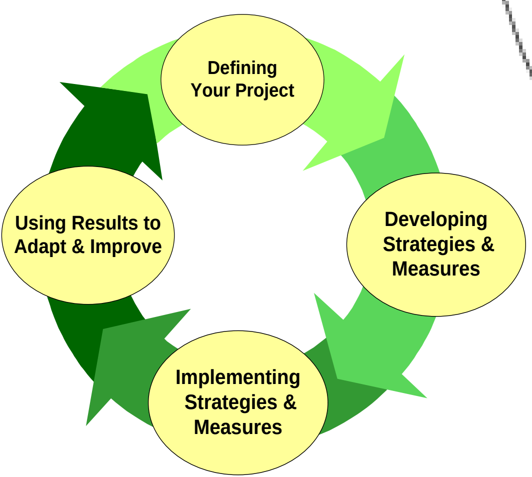
A Practitioner's Handbook for Site Conservation Planning and Measuring Conservation Success

Conservation GATEWAY

The Nature Conservancy

Protecting nature. Preserving life.





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

- Habitat destruction -- affects area of habitat or occurrence area *(Size)*

- Altered vegetation structure or composition -- affects characteristic native species *(Condition)*

- Altered fire regime -- 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 stresses for each focal conservation target.*
- *Ratings of the scope and severity of each stress.*
- *A list of sources of stress for each focal conservation target.*
- *Ratings of the contribution and reversibility for each source.*
- *A ranking of the sources of stress 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 stress rank
4. Identify sources of stress (Use IUCN-CMP taxonomy)
5. Apply source of stress rating criteria & calculate threat rank

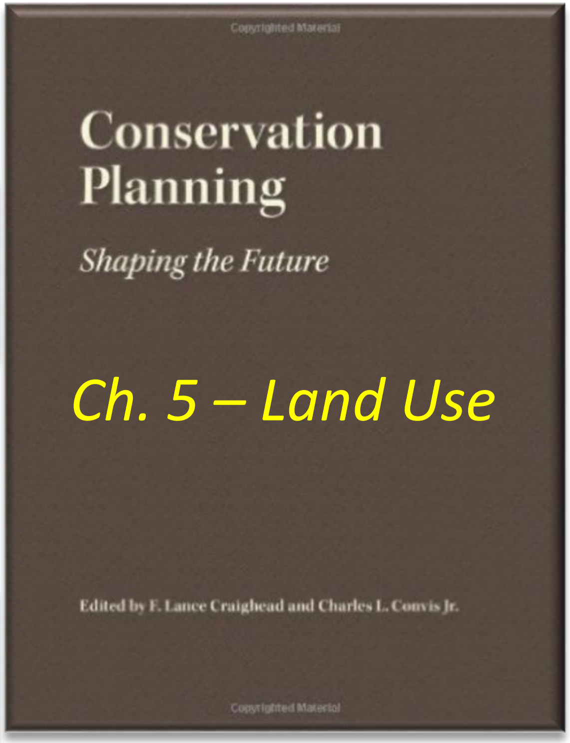
…repeat for other targets

…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.

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)

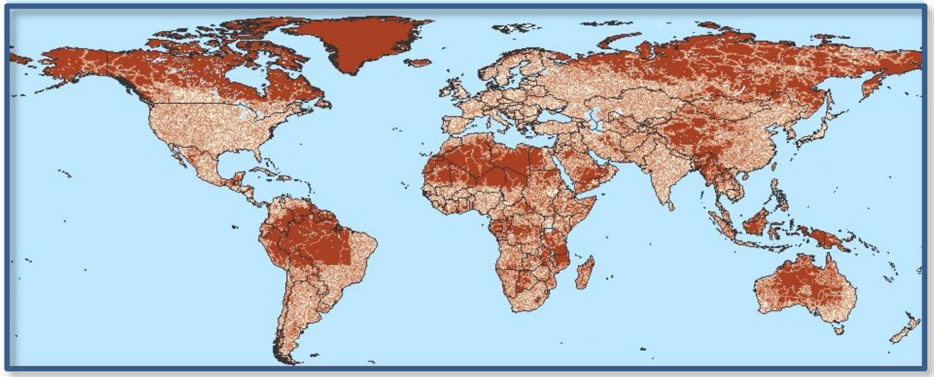
- Use multiple sources of threat information
  - *Experts…*
  - *Literature, reports, databases:*
    - IUCN
    - Natural heritage programs
    - NatureServe
    - LCCs
    - Conservation data centers
    - Government agencies
  - *Spatial data…*

NatureServe

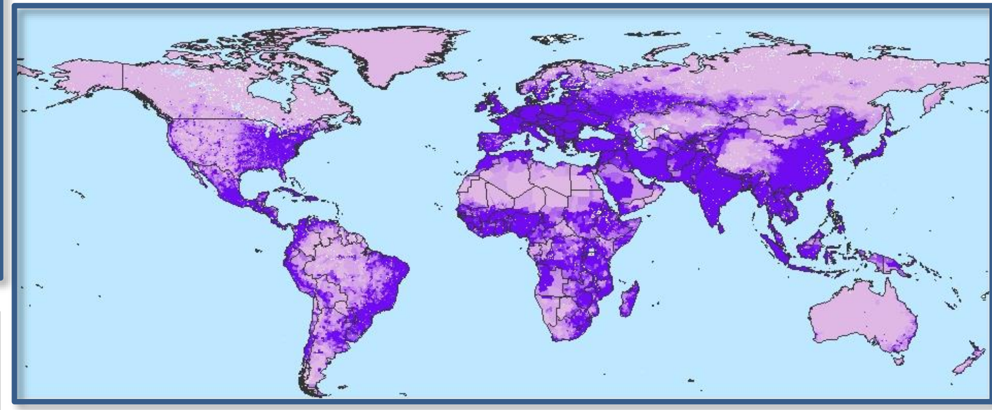
Gauging Ecological Threats in the Southeastern United States

Analysis will help guide the South Atlantic Landscape Conservation Cooperative

TNC: Spatial data to identify threats…



DISTANCE TO NEAREST ROAD



POPULATION DENSITY

LIGHTS AT NIGHT

1. Identify threats to include in analysis…

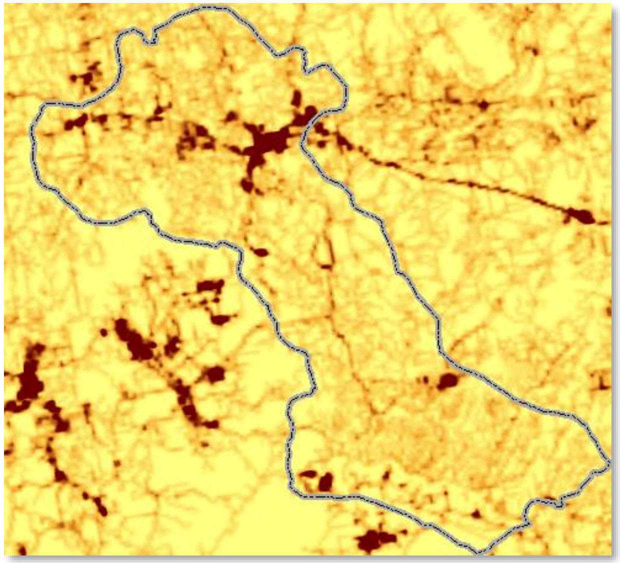
Theobald (Ch. 5): Integrating land use and landscape change with conservation planning

Identify relevant threats to include, striving for comprehensiveness and avoiding redundancy when identifying each indicator.

2. Obtain spatial data to represent threats

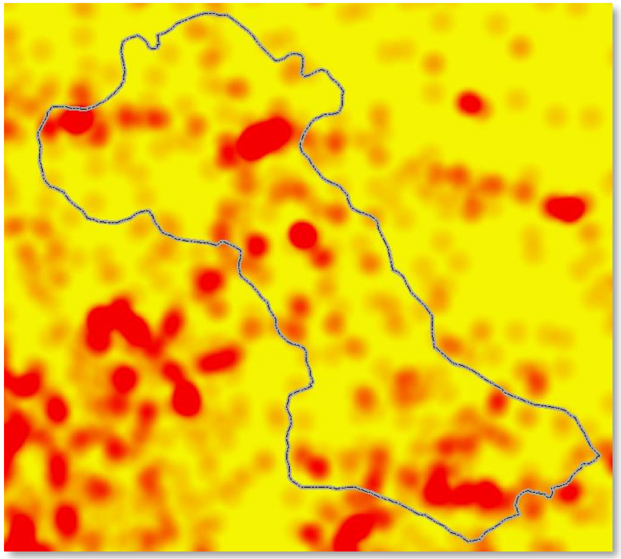
Theobald (Ch. 5):

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.



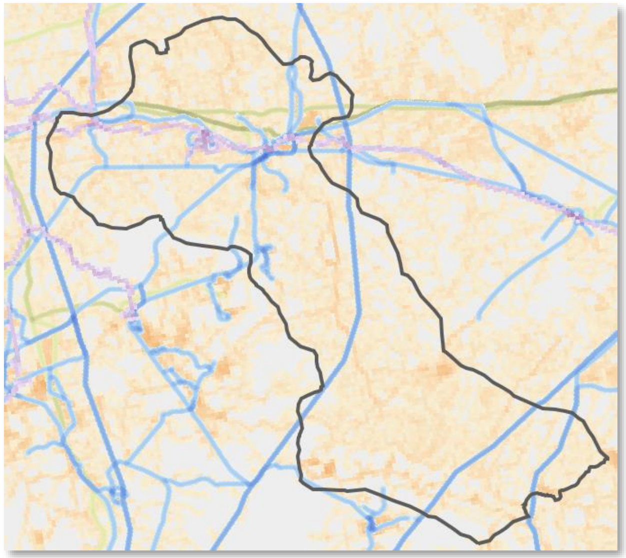
Road density

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

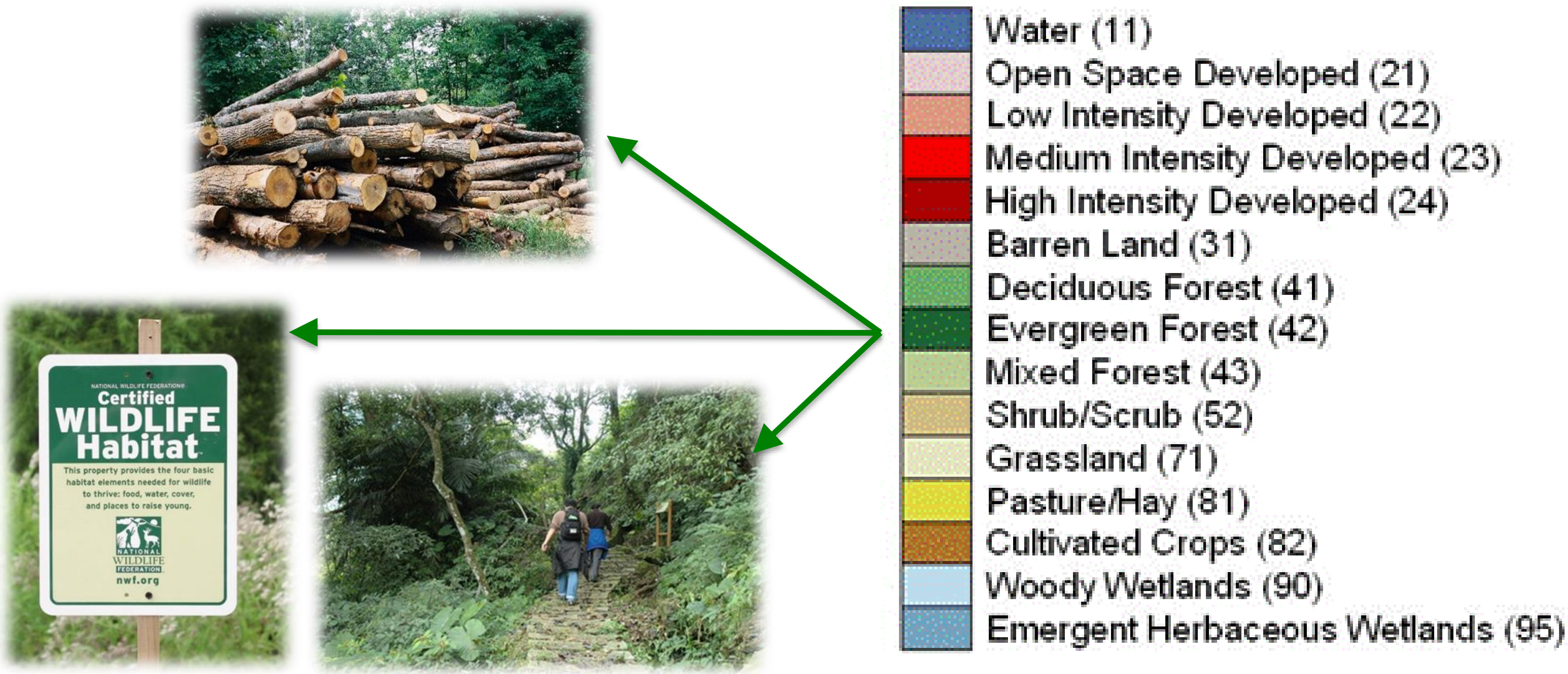
Table 5.2. Commonly used and readily available datasets on global land use/land cover

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…*



Land use & Conservation Planning

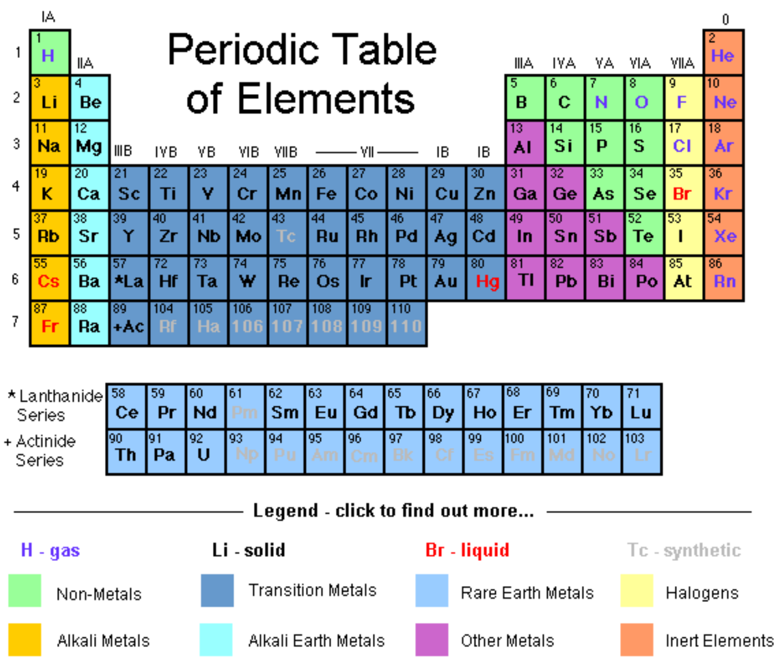
Modification Types

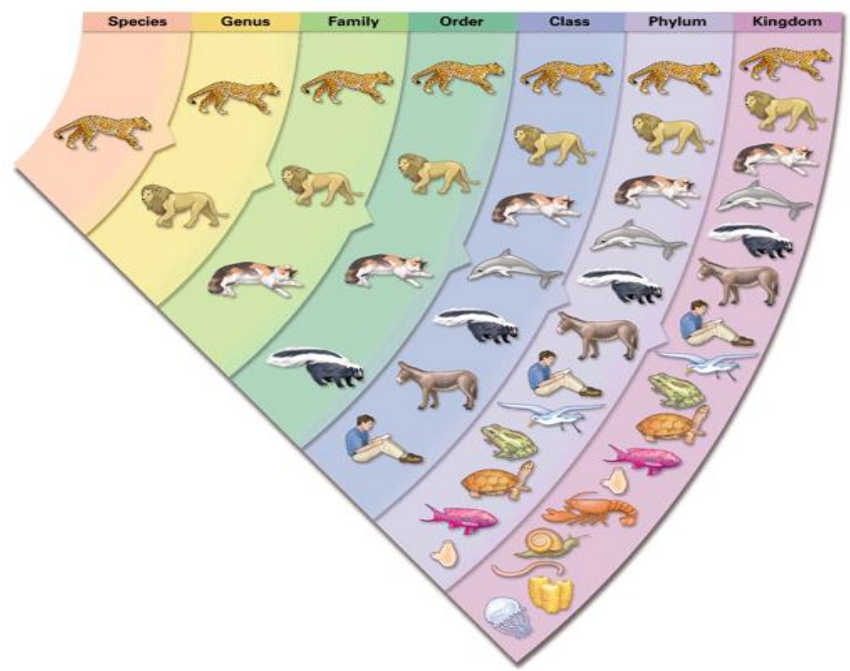
- Development, habitat alteration*
  - *For residential and commercial land uses…*
- Extractive resource use
  - *For agriculture, mining, energy production…*
- Transportation infrastructure*
- Invasive species
  - *Purposeful or unknowingly (seeds, plants, pests)*
- Hunting, collecting

** 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

IUCN
The World Conservation Union

+

CMP
The Conservation Measures Partnership

- 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) US Geological Survey Gap Land Cover v1 (http://gapanalysis.usgs.gov/data/land-cover-data/) LANDFIRE (http://www.landfire.gov) Housing density from census blocks (e.g., ICLUS/SERGoM)	Standard product and multidate allows change detection Distinguishes semicultural classes (e.g., plantations) Can compare to "potential natural" vegetation (biophysical settings) Quantifies patterns of disturbance beyond urban fringe	Urban cover misses residential <1 dwelling unit per acre Coarser and variable sized analytical unit	Age of development 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

WWF for a living planet®

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"

http://www.panda.org/standards/1_4_threats_ranking/

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 destroy or eliminate 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 seriously degrade/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 moderately degrade/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 slightly degrade/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 scope, severity, and irreversibility 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

	TARGET: Sharks					TARGET: Coral Reefs					TARGET: Intertidal Systems					TARGET: Seabirds					SITE RANKING	
DIRECT THREAT	SCOPE	SEVERITY	IRREVER SIBILITY	TOTAL	CLASSIFICATION	SCOPE	SEVERITY	IRREVER SIBILITY	TOTAL	CLASSIFICATION	SCOPE	SEVERITY	IRREVER SIBILITY	TOTAL	CLASSIFICATION	SCOPE	SEVERITY	IRREVER SIBILITY	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 scope and severity of threats and understand their causes

1. Organize information on threats
2. Use multiple sources of threats information
3. Describe/diagram their root causes and stresses

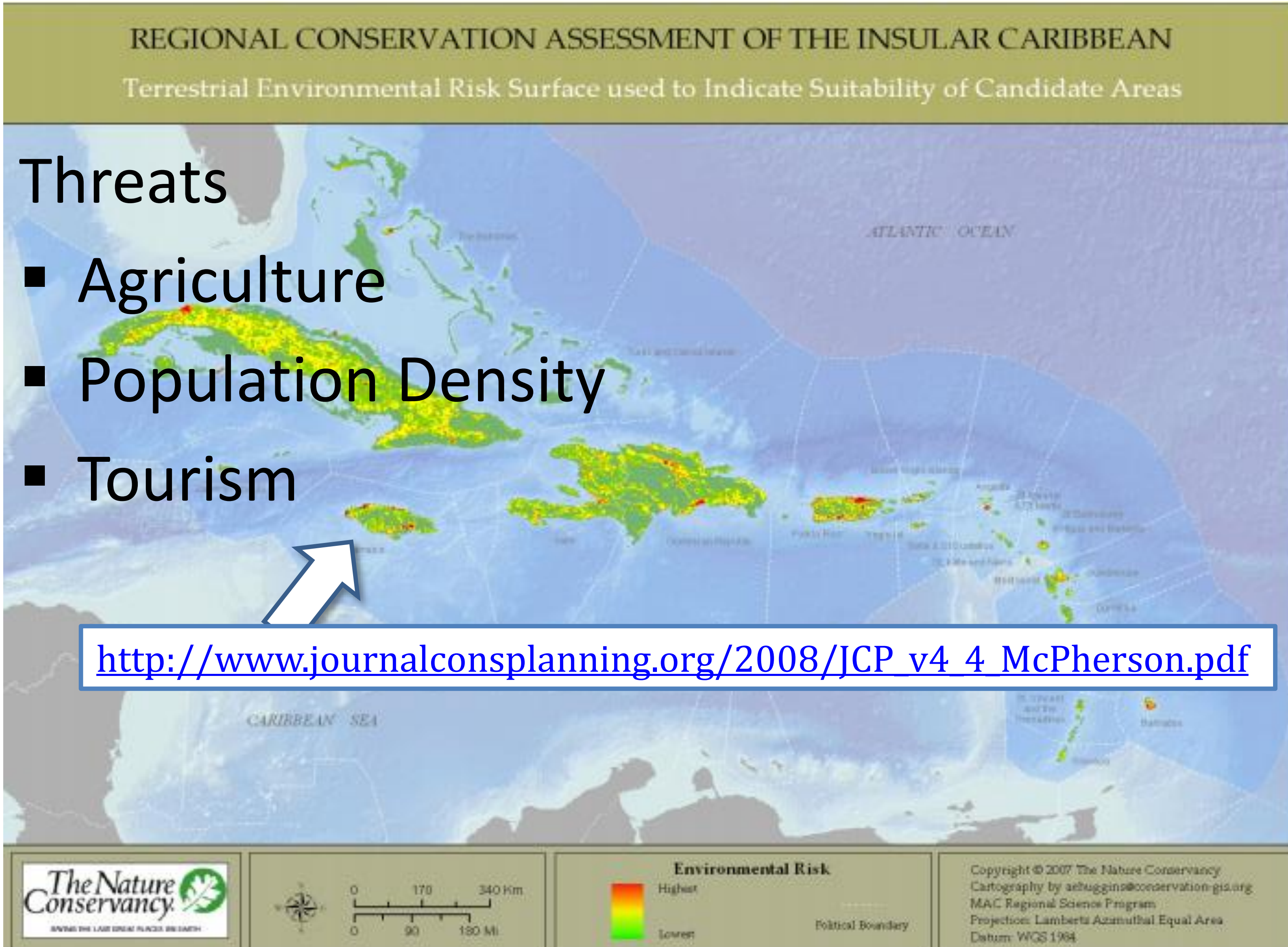
What role does spatial analysis play?

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



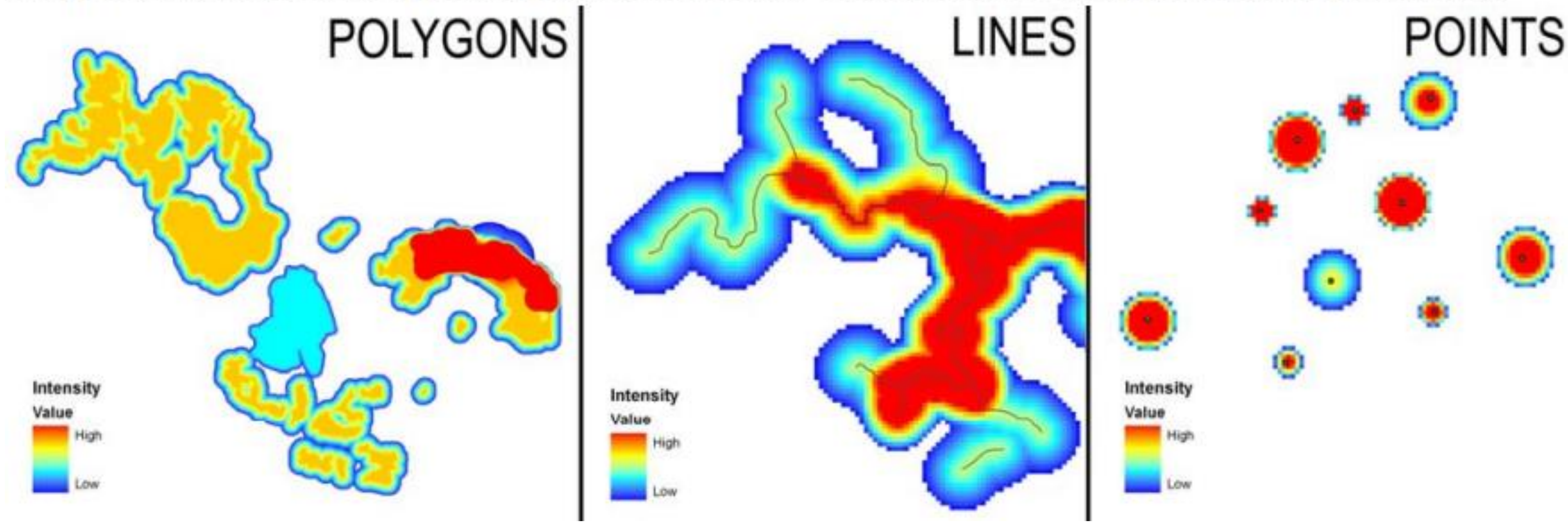
Threats

- 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).

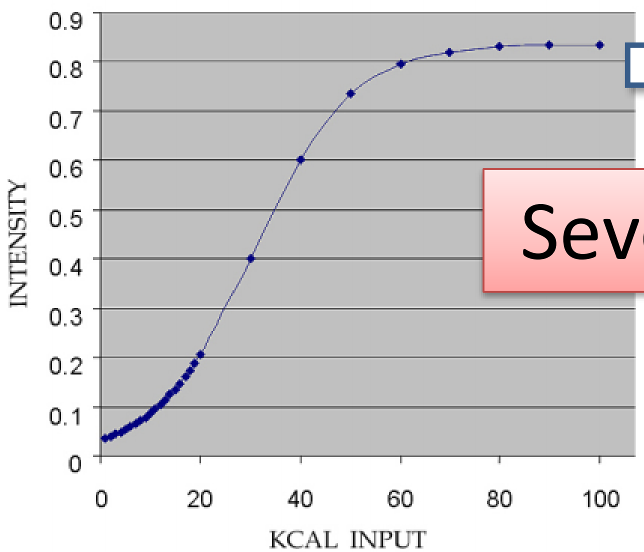


1. Assemble data that best represent risk elements
2. Assign intensity and influence distances
3. Develop risk tables listing targets and their level of risk

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)).



Severity

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

Agricultural Intensity and Influence Buffer Distance Values

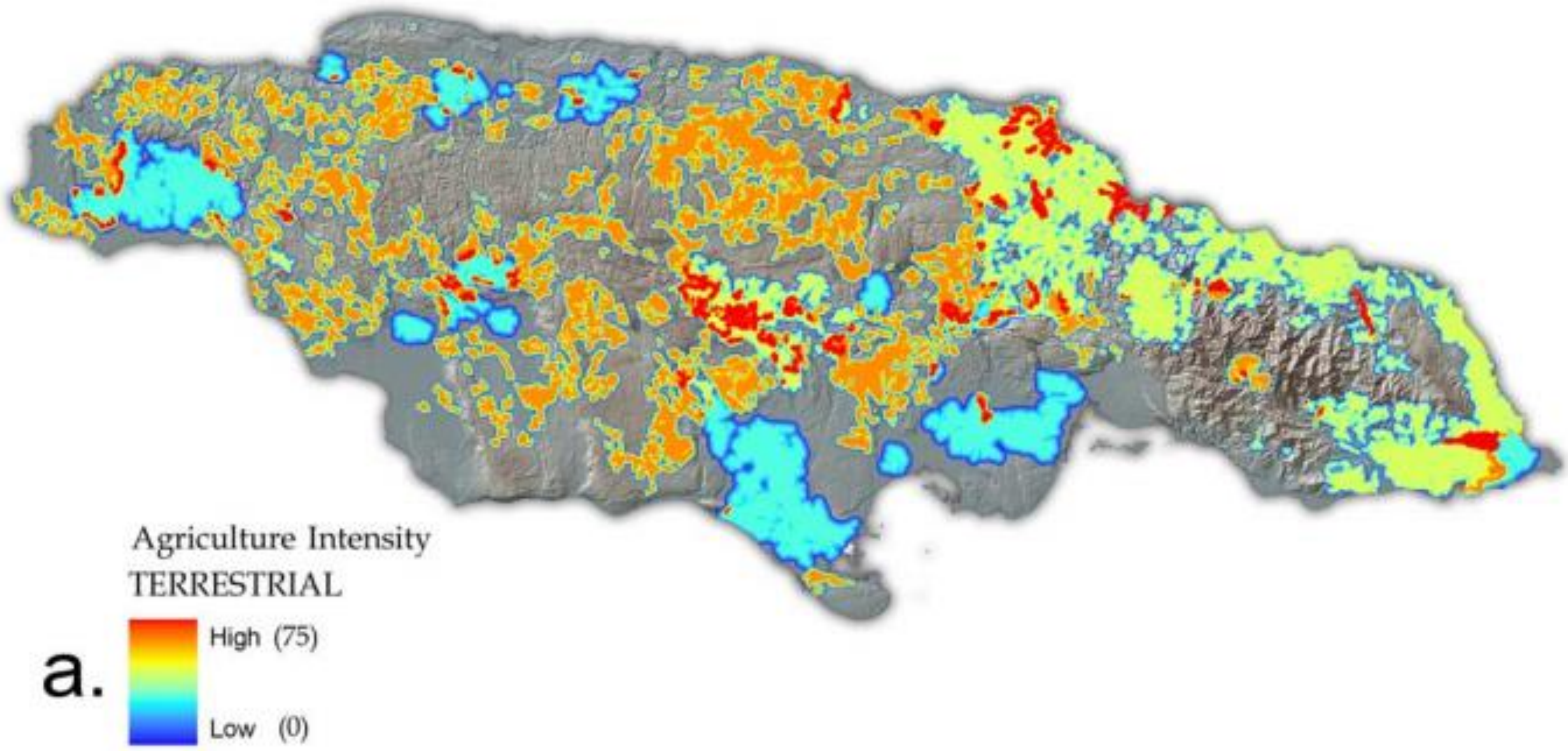
Crop type	Influence buffer distance (meters)	Intensity (Kcal)	Normalized value
Banana	2000	20	0.5
Sugarcane plantations	1000	4	0.11
Small scale agriculture and grasslands	500	13	0.25
Tree crops and agroforestry	500	8	0.17

Scope

Impact distance based on dispersal potential of pesticide…

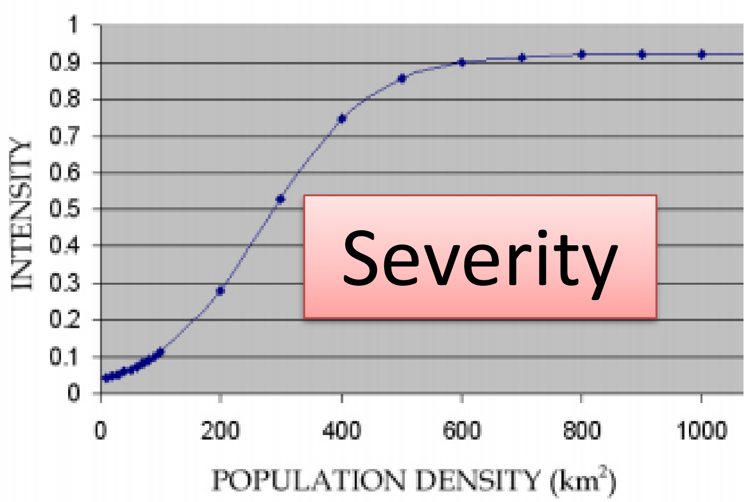
Threat: Agriculture

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.



Threat: Population Density

Intensity of impact =0.9217/ (1 +22.6614*EXP(-0.0114*raw cost)).



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

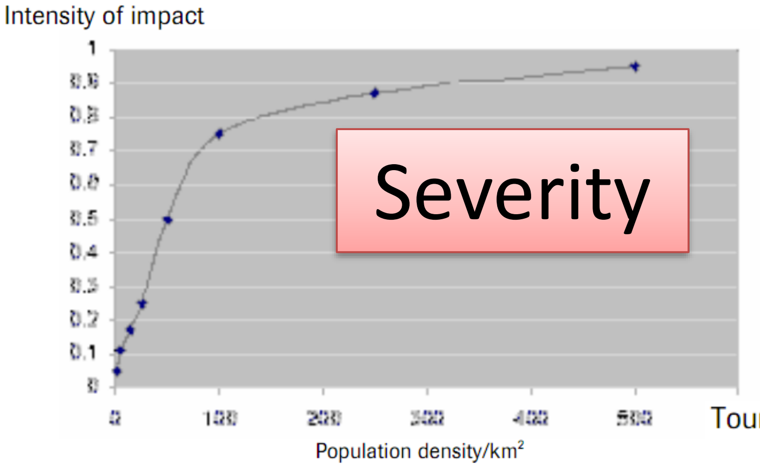
Population Density Intensity and Buffer Distance Values

Scope

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.



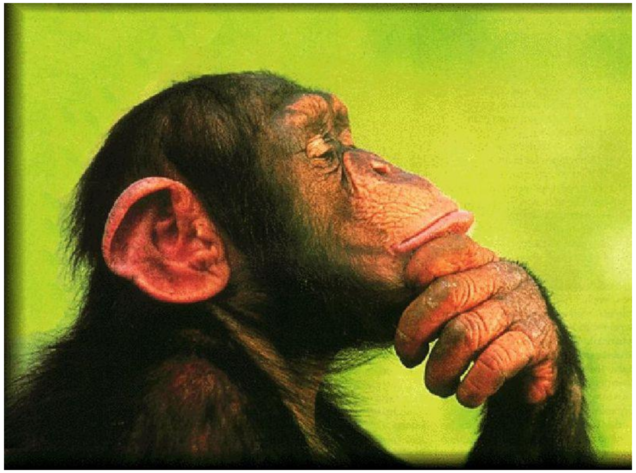
Tourism Intensity and Buffer Distance Values

Scope

Density of tourist population per km^2 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?

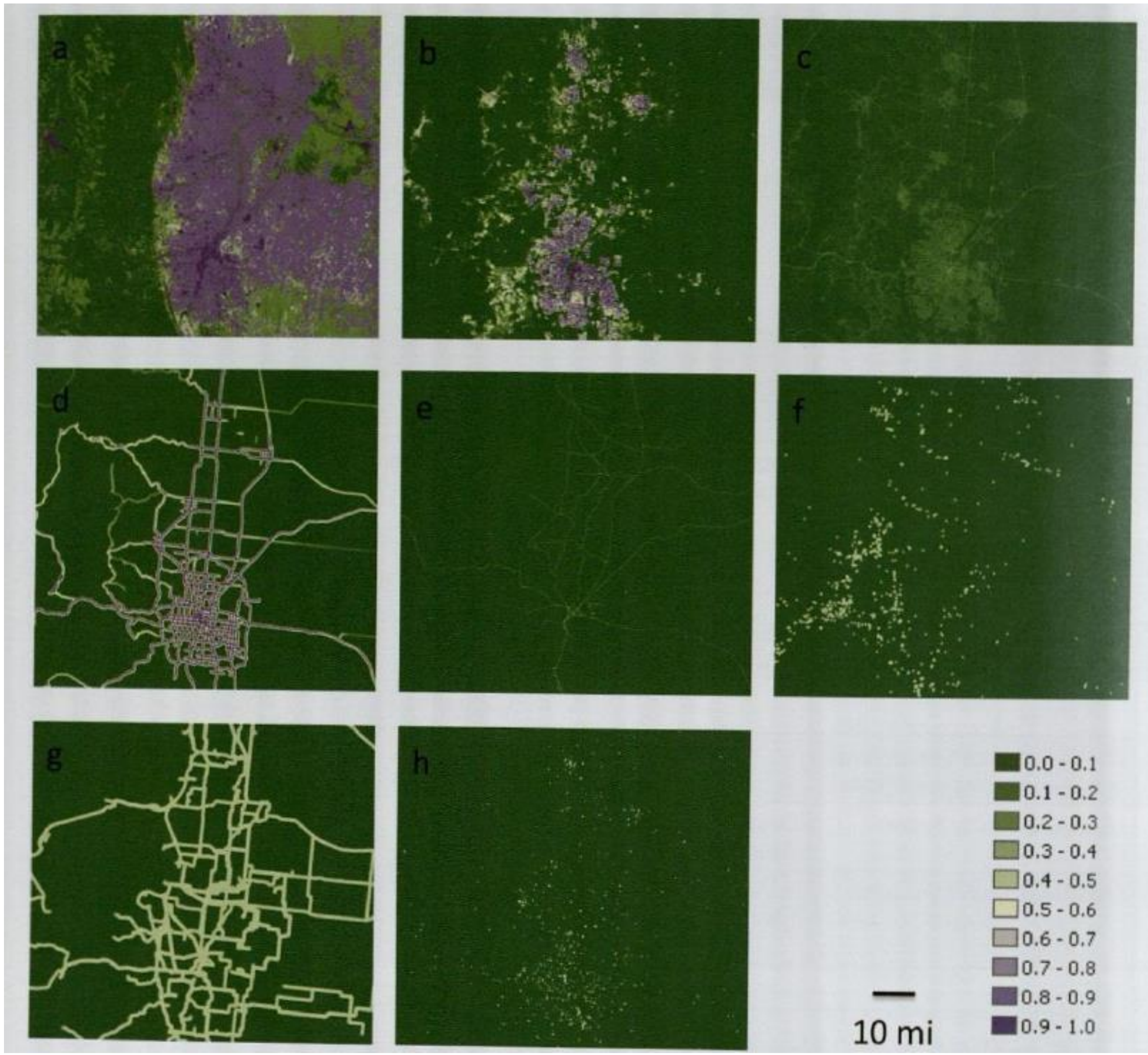
Expert opinion was critical for identifying key threats and developing the intensity and influence distance values incorporated into the models. All final decisions regarding intensity values and influence distances were made by the small core teams of experts responsible for developing the ERS for each 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

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).

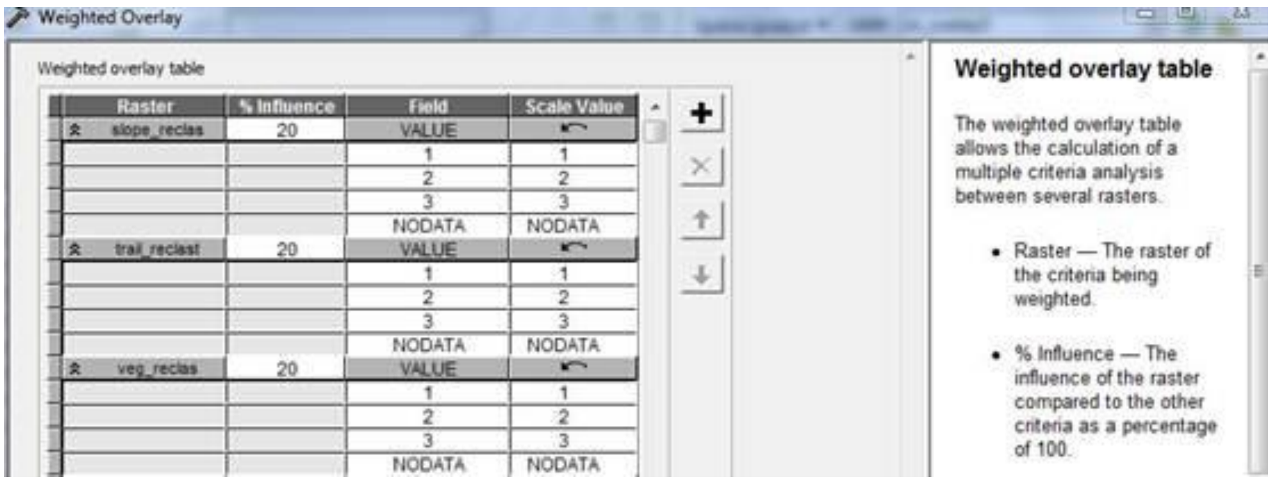
I calculated an index using Defense Meteorological Satellite Program (DMSP) "night lights" values for 2009 (Sutton et al. 2009) using the natural log and then normalized. I also estimate the degree of human modification by power lines by assigning a value of 0.5 and then calculating a kernel density 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

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



B. Fuzzy logic…

Theobald: Degree of modification in Colorado

2. Combining threat layers…

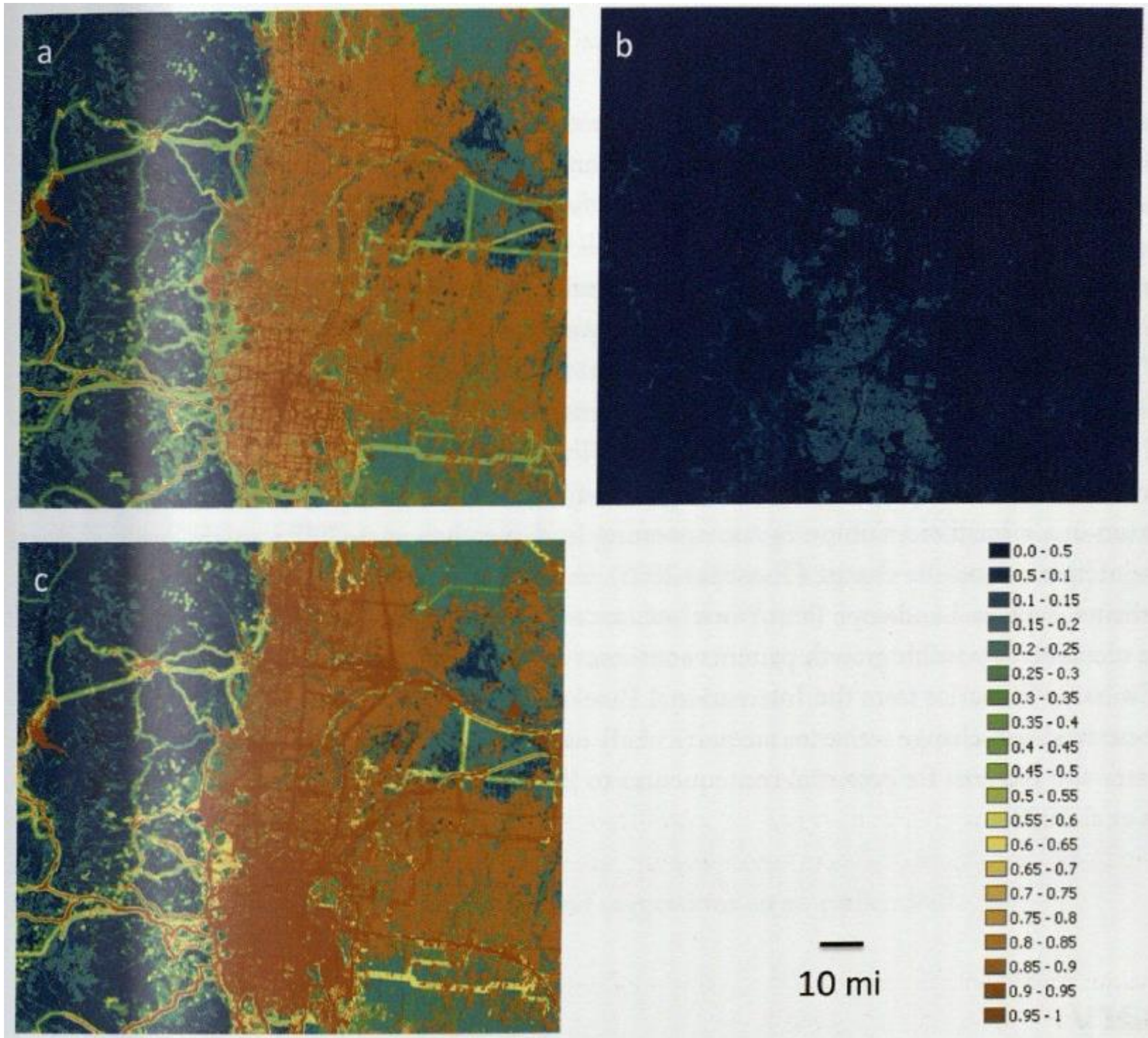
B. Fuzzy logic…

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

	Possible combinations of values, iteration									
Threats/Combos	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

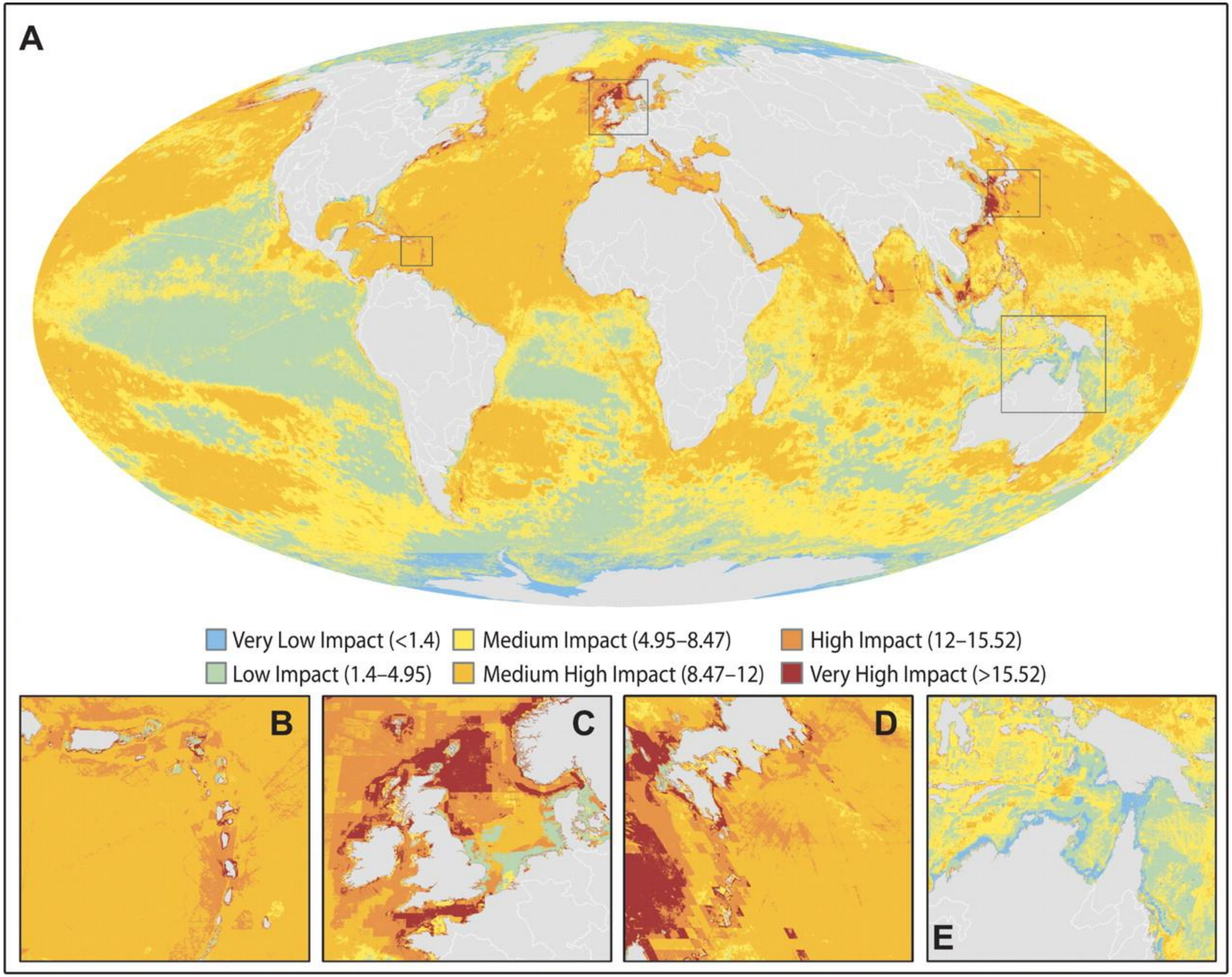
Source: David M. Theobald.

Theobald: Degree of modification in Colorado

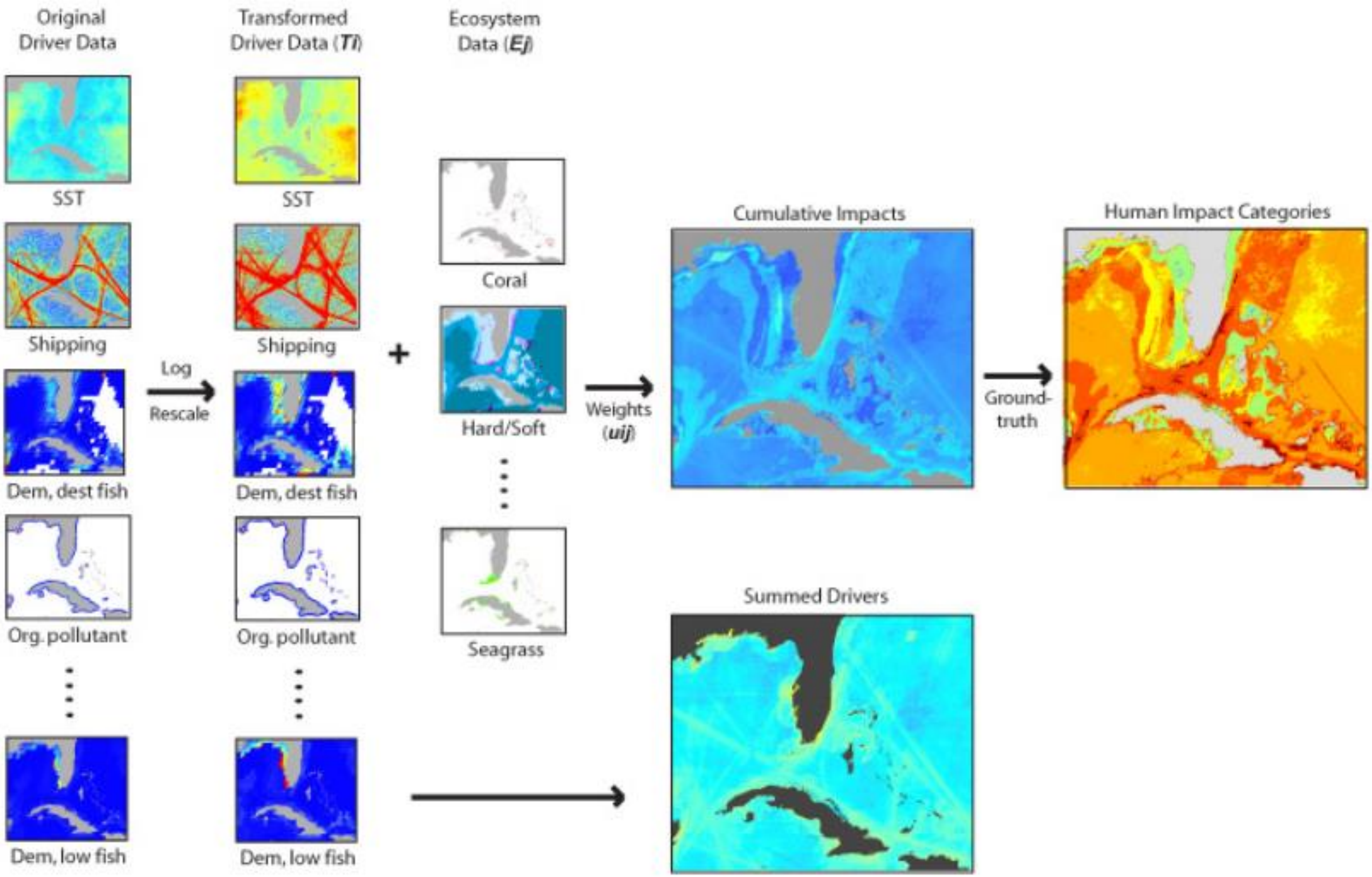


A. Max value
B. Mean value
C. Fuzzy sum

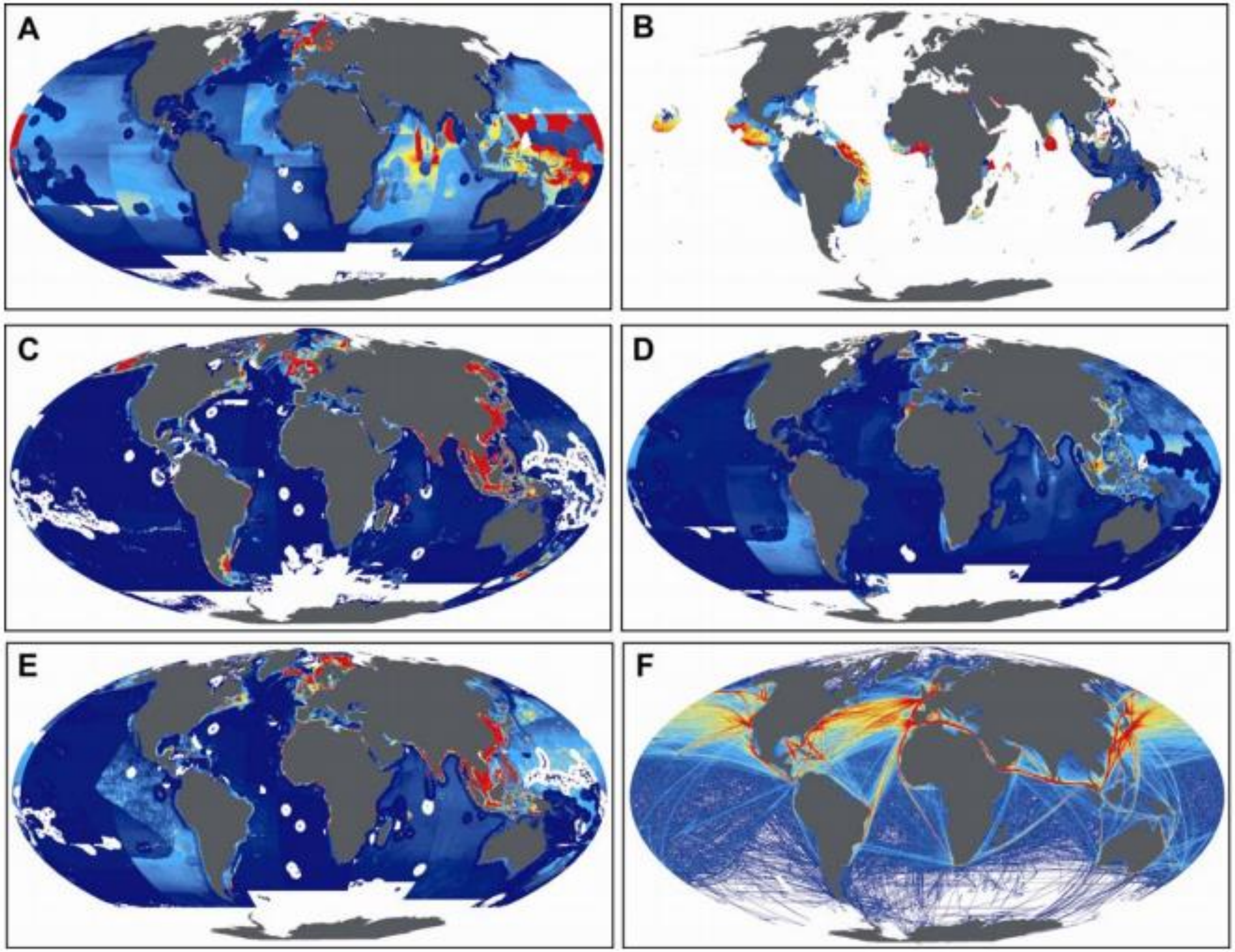
Global Map of Human Impact on Marine Ecosystems



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

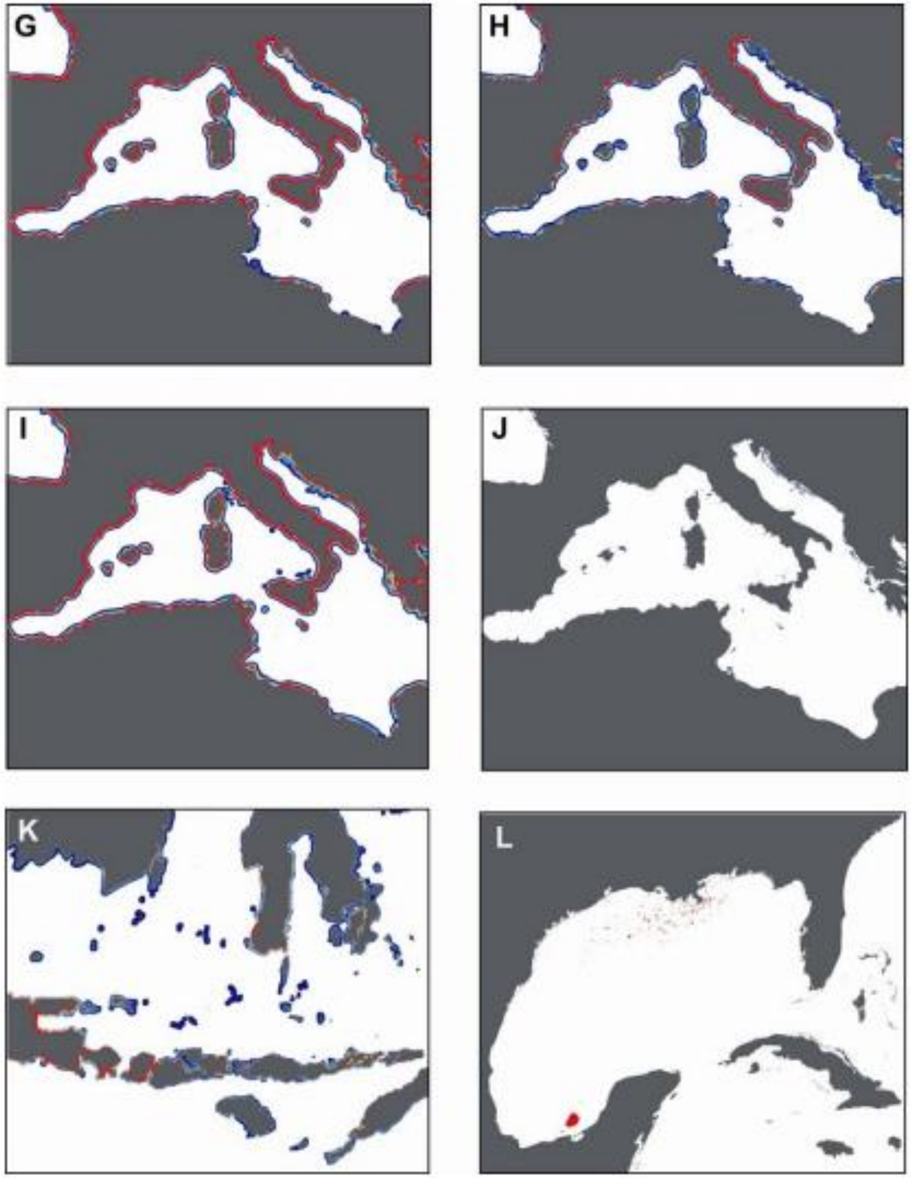
C) demersal habitat-modifying fishing

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),

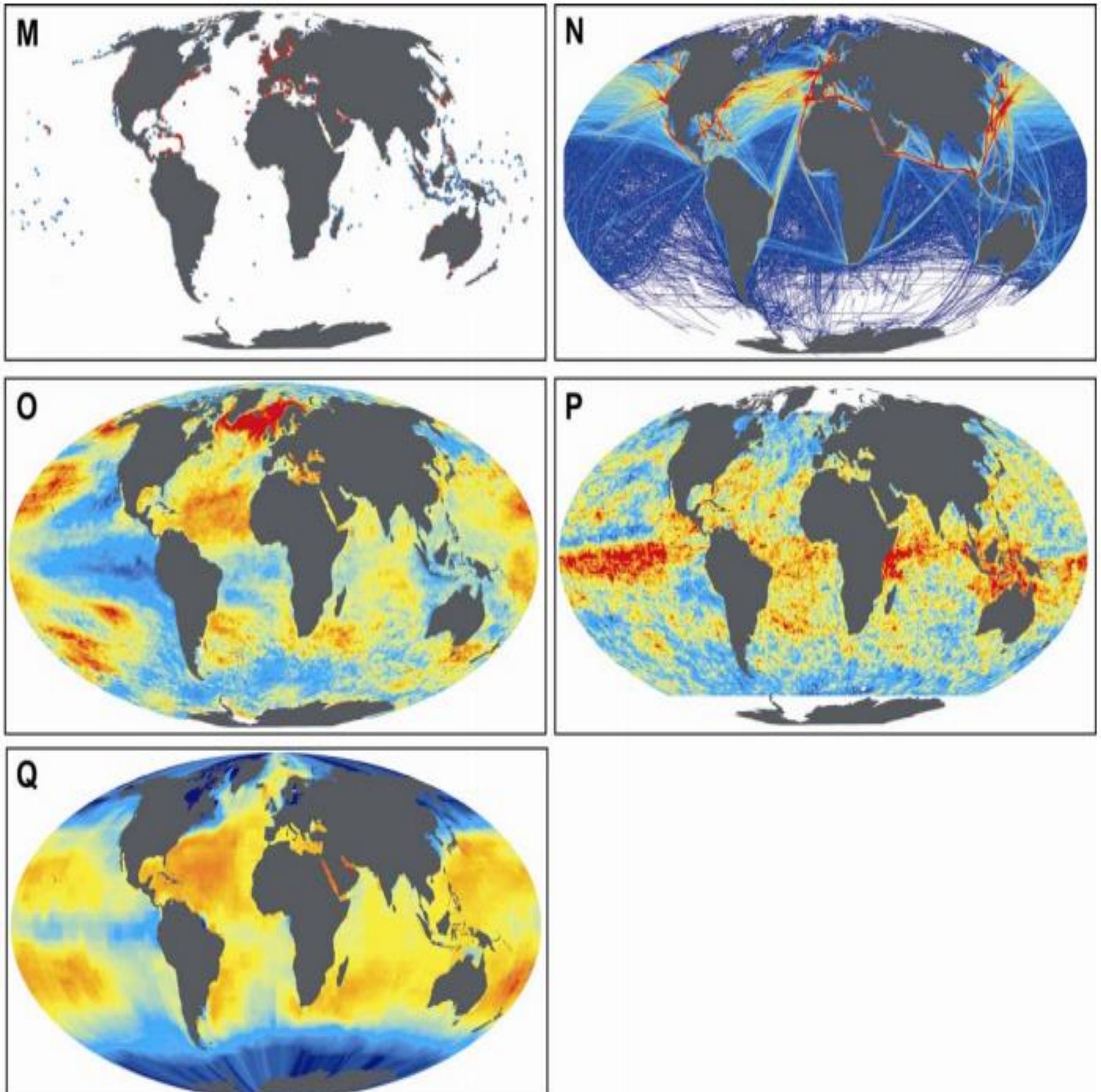
I) inorganic pollutants (Western Mediterranean),

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

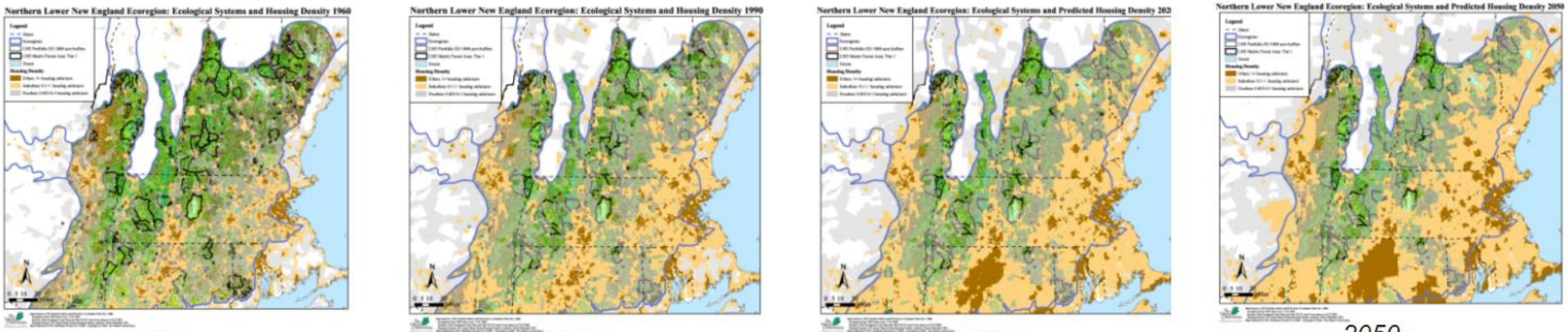
O) sea temperature changes

P) UV changes

Q) ocean acidification

Threat forecasting

Example 1: Predicting housing development using census data in the Northeast

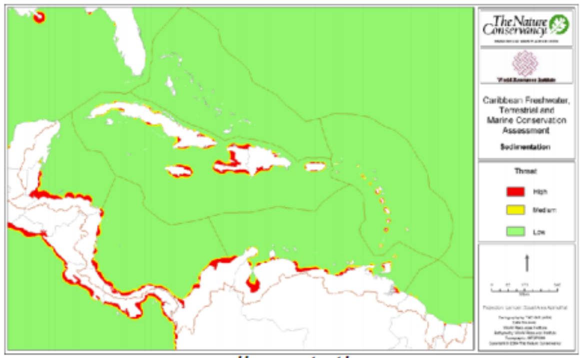


1960 1990 2020 2050

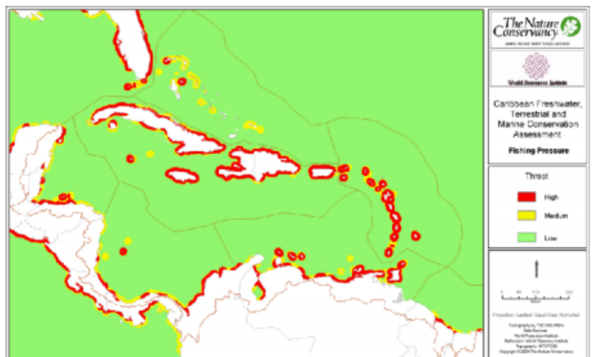
In this example from the US Northeast (showing lower New England), census data from 1960 and 1990 are projected into the years 2020 and 2050. This information can then be compared with areas of conservation importance, enabling planners to prioritize conservation actions, based on the likely risk from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

Threat forecasting

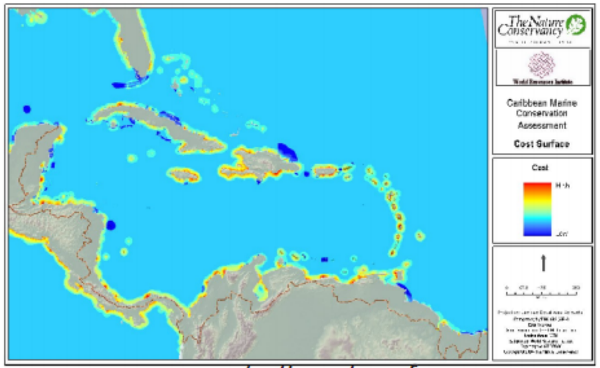
Example 2: Using cost surfaces to estimate current and future threats in the Caribbean



sedimentation



overfishing

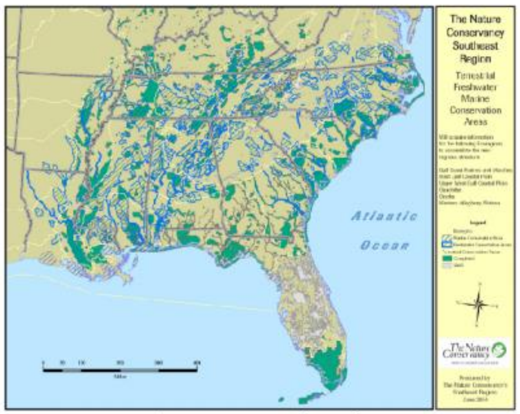


aggregate threat surface

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.

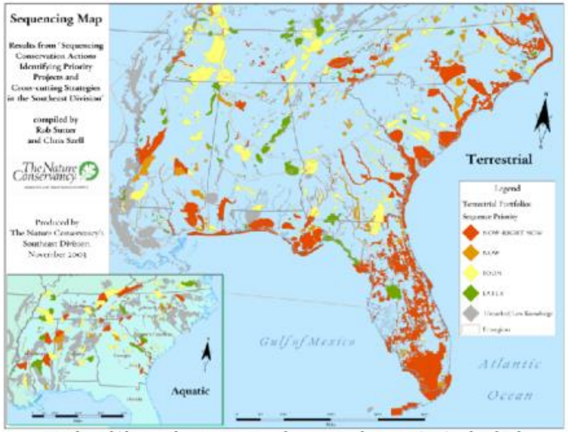
Threat forecasting

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