Roles and limitations of artificial intelligence (AI) and machine learning (ML) for the management of natural resources

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Society of Decision Professionals

April 17th, 2024, Arlington, VA.

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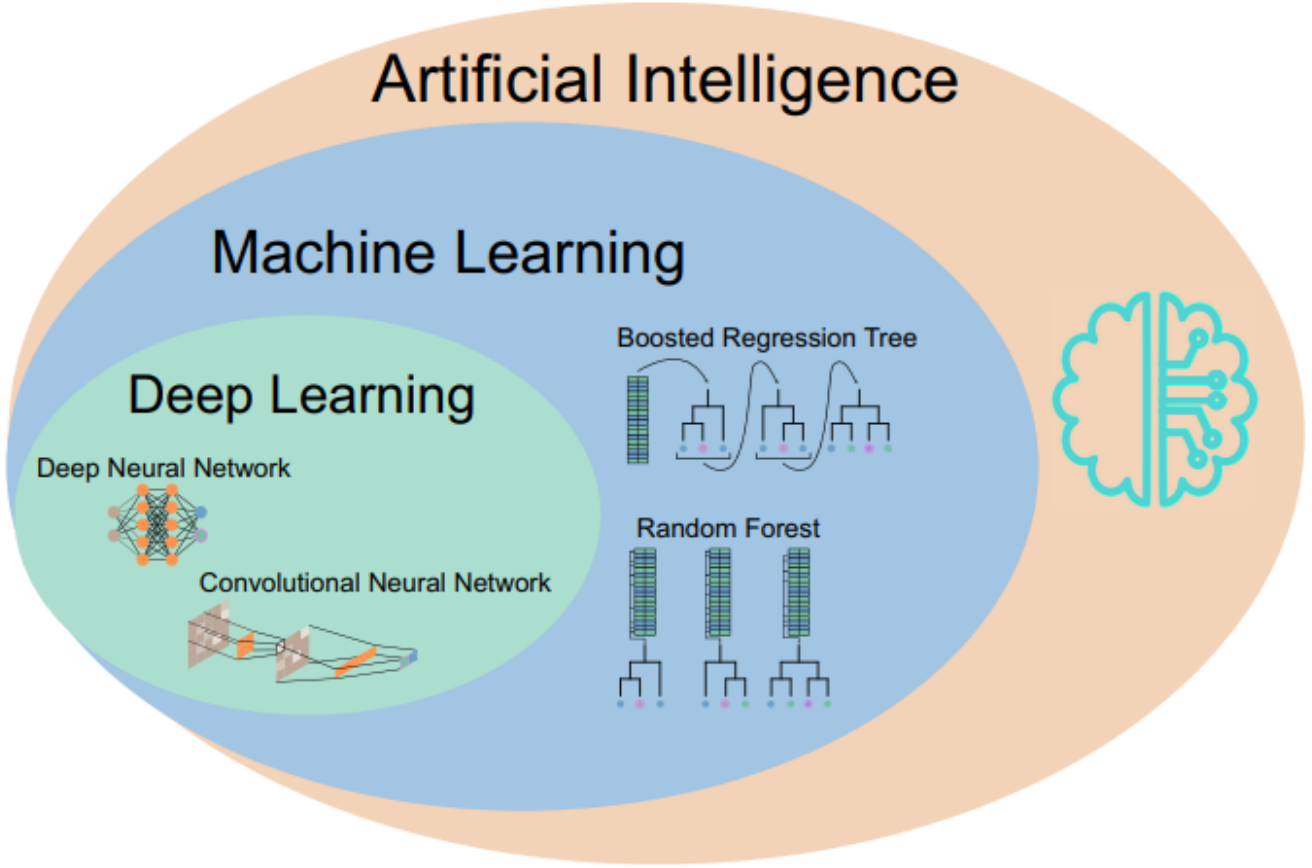
Outline

- Definition of AI, ML and DL
- Structured Decision Making (SDM).
- Role of ML/DL for each component of SDM.
- Potential limitations of AI/ML/DL.

Artificial Intelligence, Machine Learning and Deep Learning



Pichler et al. (2023). Meth. Ecol. Evol. 14, 994–1016

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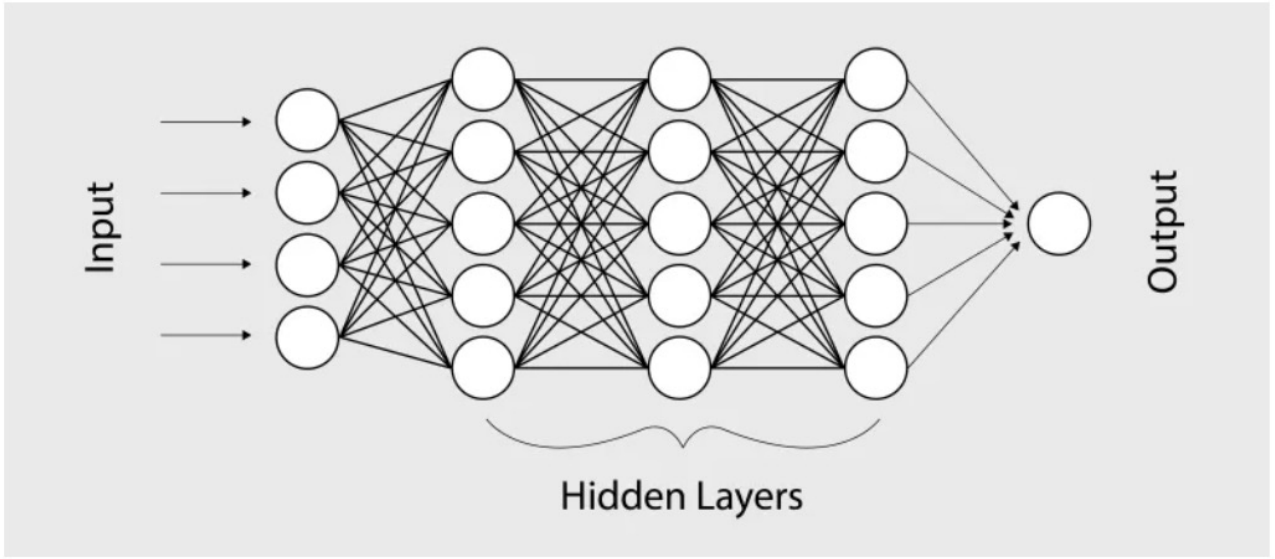
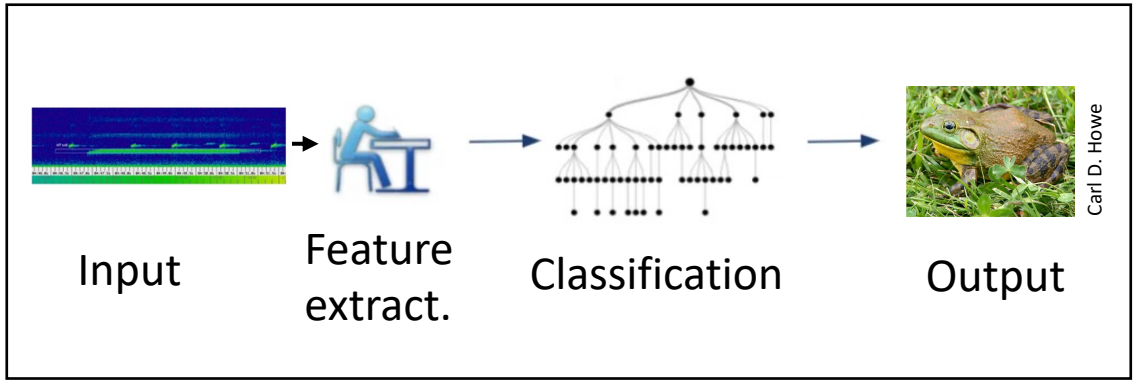
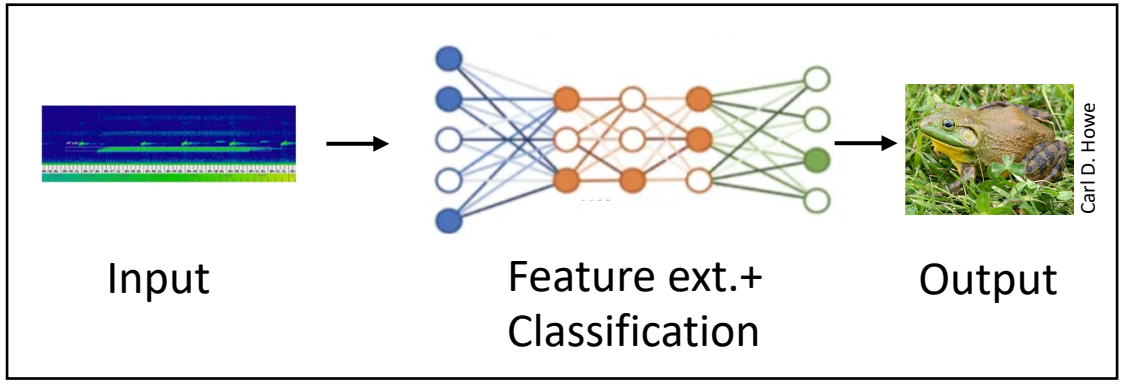
Machine learning and deep learning



Western sandpiper

Modified from Arun Addagatla





Modified from Arun Addagatla and Andy Royle (2019)

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Modeling flow from images

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EcoSHEDS

Flow Photo Explorer

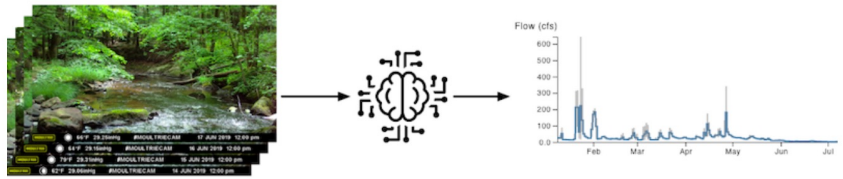
HOME | ABOUT | USER GUIDE | PHOTO EXPLORER | ACCOUNT

Welcome to the Flow Photo Explorer

https://www.usgs.gov/apps/ecosheds/fpe/#/

The **Flow Photo Explorer** is an integrated database, machine learning, and data visualization platform for monitoring streamflow and other hydrologic conditions using timelapse images.

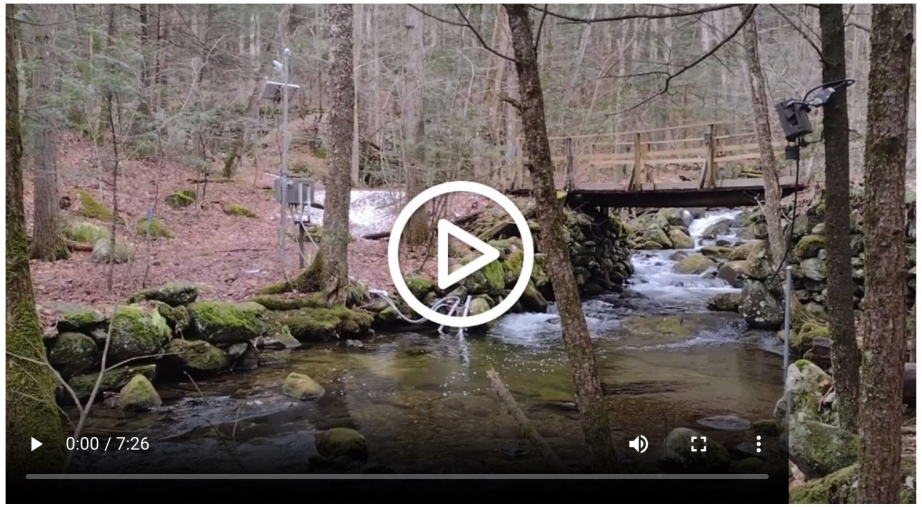
The goal of this project is to develop new approaches to hydrologic monitoring in streams and rivers where flow data are historically sparse or non-existent.



Timelapse Photos | Machine Learning Models | Continuous Streamflow

START EXPLORING >

Do you have flow photos to contribute? Request an account to upload your photos.
Already have an account? Log in.
Questions? You can reach us at ecosheds@usgs.gov.



Video produced by the USGS MD-DE-DC Water Science Center

The Flow Photo Explorer project is a collaboration between U.S. Geological Survey, U.S. Environmental Protection Agency, Walker Environmental Research, Microsoft Research, and many contributing partners. Funding was provided by U.S. Geological Survey, U.S. Environmental Protection Agency, and National Geographic Society. See About for more information.

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Structured decision making (SDM) AKA Decision analysis

SDM: Formal method for analyzing a decision

- Problem
- Objectives
- Potential management actions
- Models
- Tradeoff & optimization
- Monitoring

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Potential management actions

- Fish sorting with AI

  + *Help preferred species cross obstacles.*

  + *Automatically sort "undesirable" species.*

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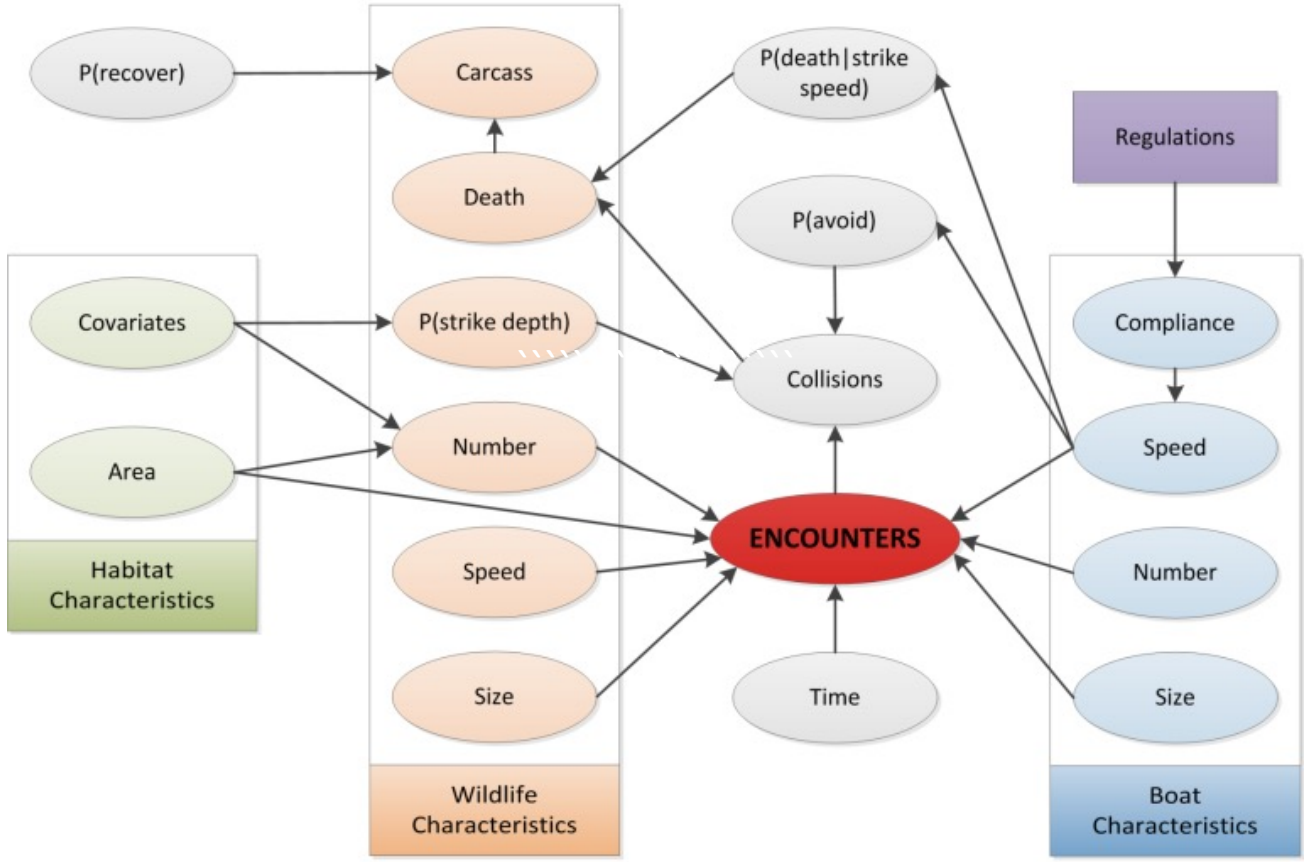
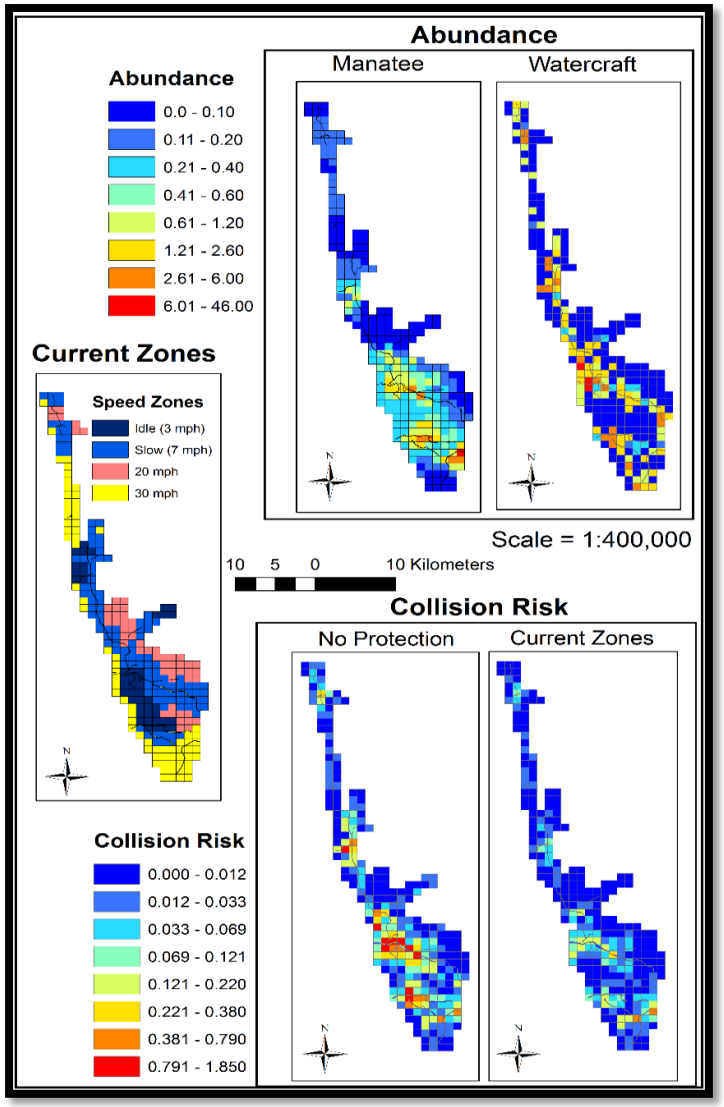
Models project consequences of actions

Model expected mortality



Martin et al. (2016) Meth. Ecol. Evol. 7: 42–50

Udell et al. (2019) J Appl Ecol. 2019; 56: 1050–1062



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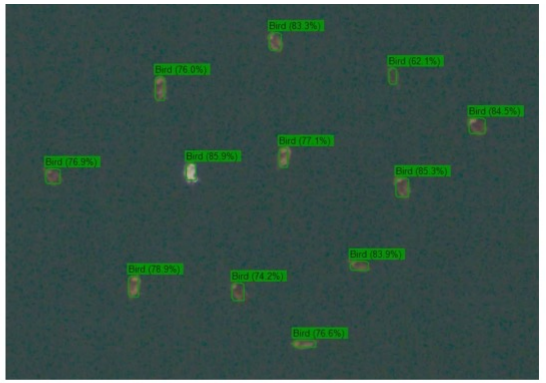
Monitoring techniques and image classification

https://www.pexels.com/photo/quadcopter-flying-on-the-skey-1034812

Edwards (2021) Sci Rep 11, 12920



Augustine et al. (2023) bioRxiv 2023.02.20.529272

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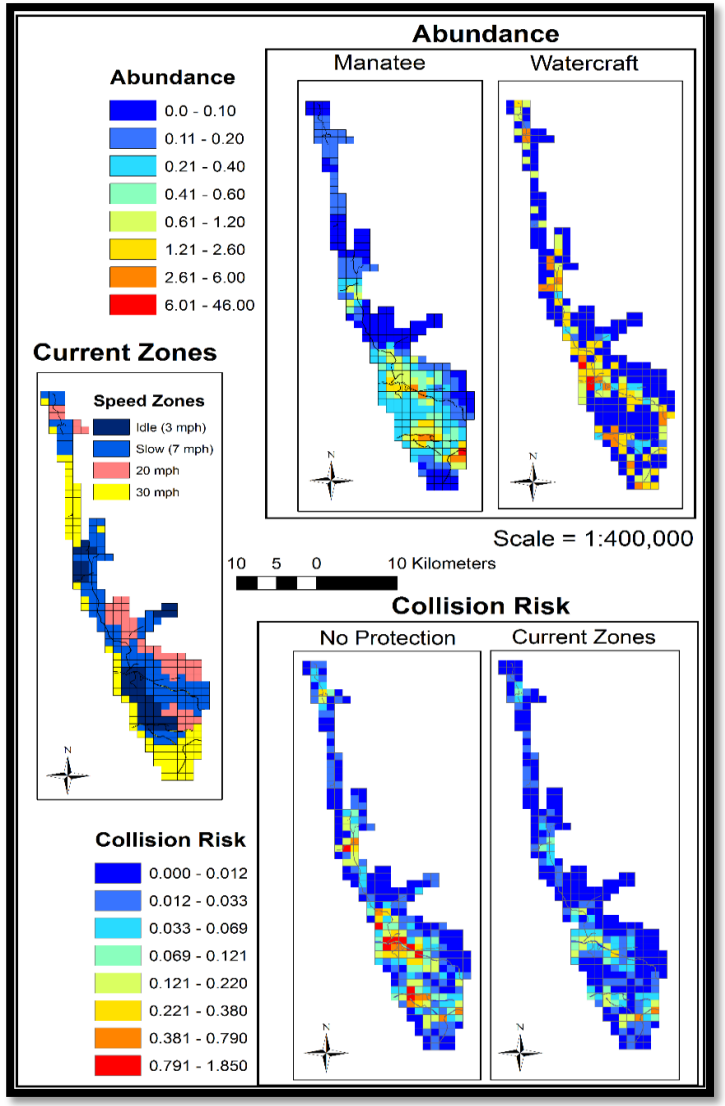
Abundance and imperfect detection

"Repeated count data"

Site	-- occasion --
site 1	0 2 0 1 3
site 2	0 0 1 0 0
site 3	5 6 5 4 6
site 4	0 0 1 1 0
…	
site M	**0 0 0 0 0**

Edwards (2021) Sci Rep 11, 12920



Udell et al. (2019) J Appl Ecol. 2019; 56: 1050–1062

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Matching individuals and population dynamics

"Enc. history data"

Indiv.	-- occasion --
Ind. 1	0 1 0 1 1
Ind. 2	0 0 1 0 0
Ind. 3	1 1 0 0 0
Ind. 4	0 0 1 1 0
…	
Ind. Y	0 0 0 0 0

1 = detected
0 = not detected

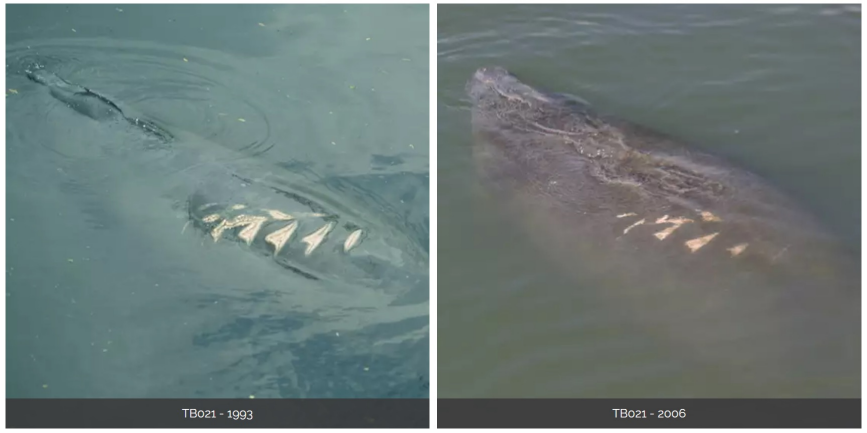
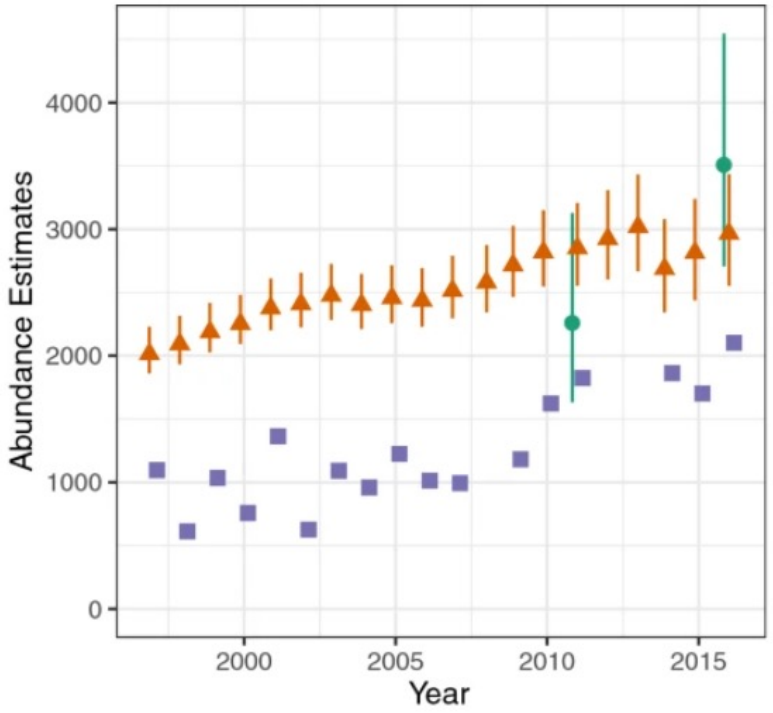


Image from FWC



Hostetler et al. (2021) Sci Rep 11, 2702

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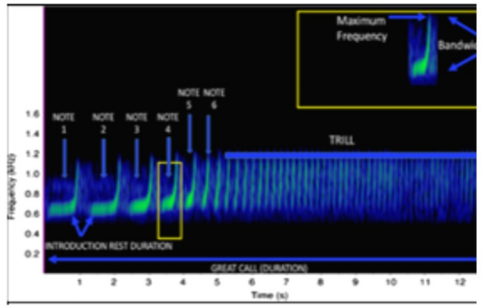
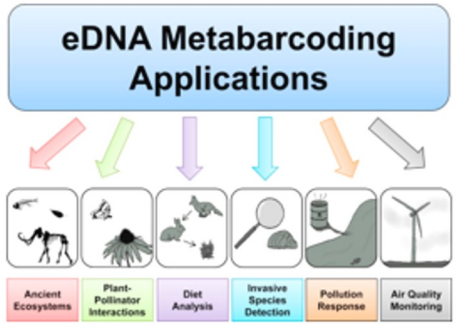
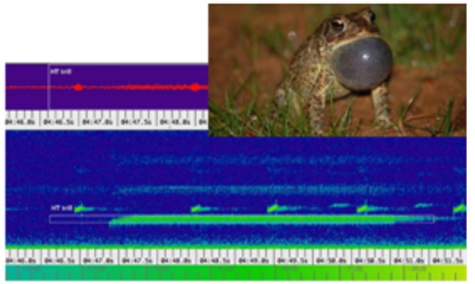
Other examples of monitoring techniques

	Genetics	Camera Trapping	Bioacoustics
• Individual identification + capture-recapture	 Detector dog searching for mink scat		 "vocal fingerprinting"
• Species determination +species distribution	 Ruppert et al. (2019) Glob. Ecol. Cons.17, e00547.		 Species determination

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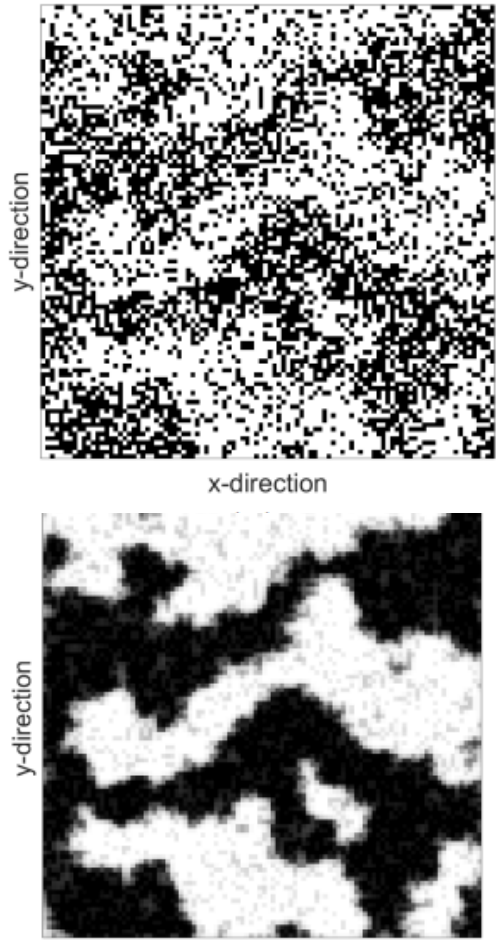
Imperfect detection and misclassification errors

- Probability of occurrence
  - + *False negative*
  - + *False Positive*
- Note ML/DP for estimation
- *Where to treat Melaleuca?*
  - + *Spatial optimization*

"occupancy data"

Site	-- occasion --
site 1	0 1 0 1 1
site 2	0 0 1 0 0
site 3	1 1 0 0 0
site 4	0 0 1 1 0
…	
site M	0 0 0 0 0

1 = detected at site
0 = individual not detected



Bonneau et al. 2019. Ecol. Mod.,392, 108-116

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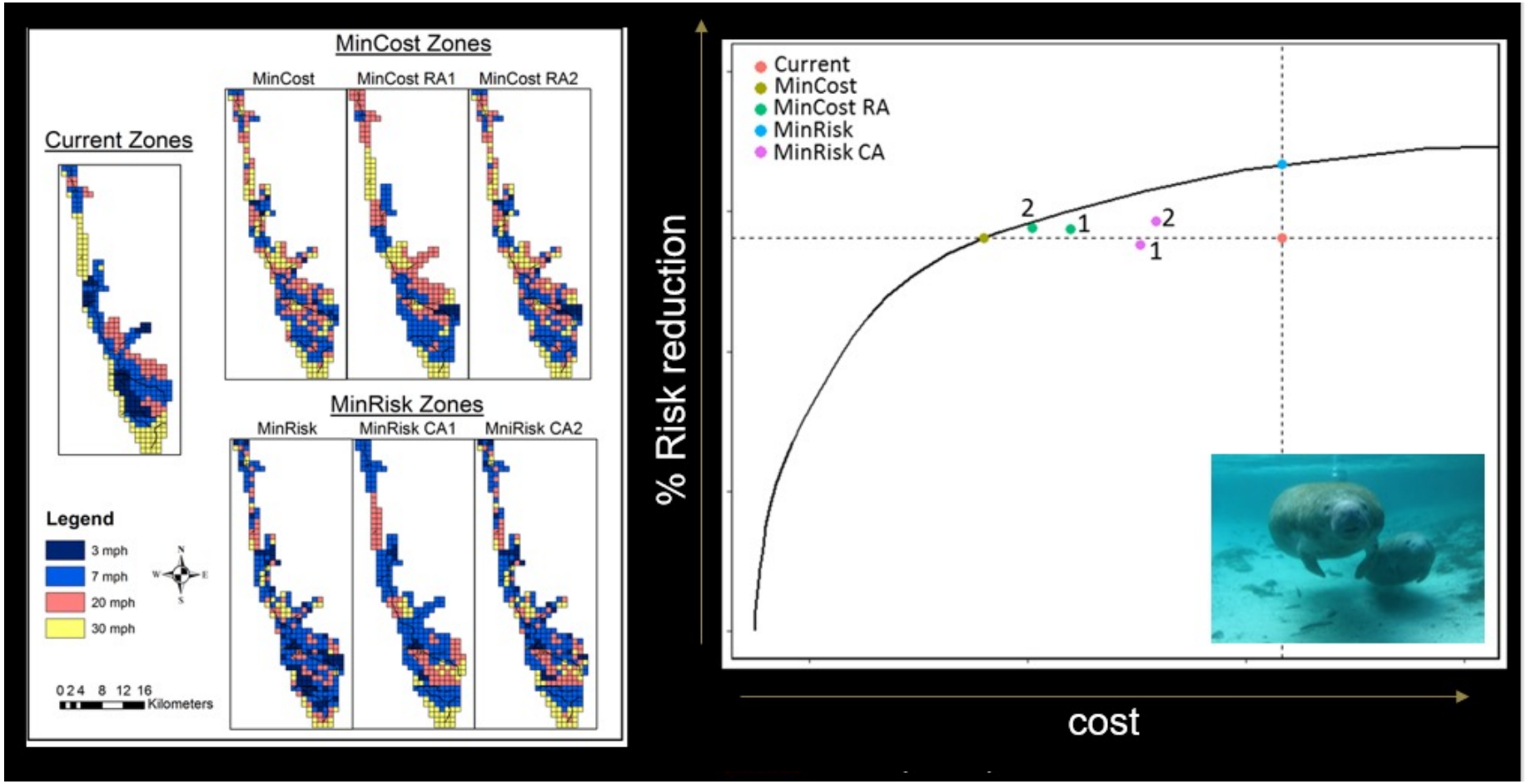
Spatial optimization



Udell et al. (2019) J Appl Ecol. 2019; 56: 1050–1062

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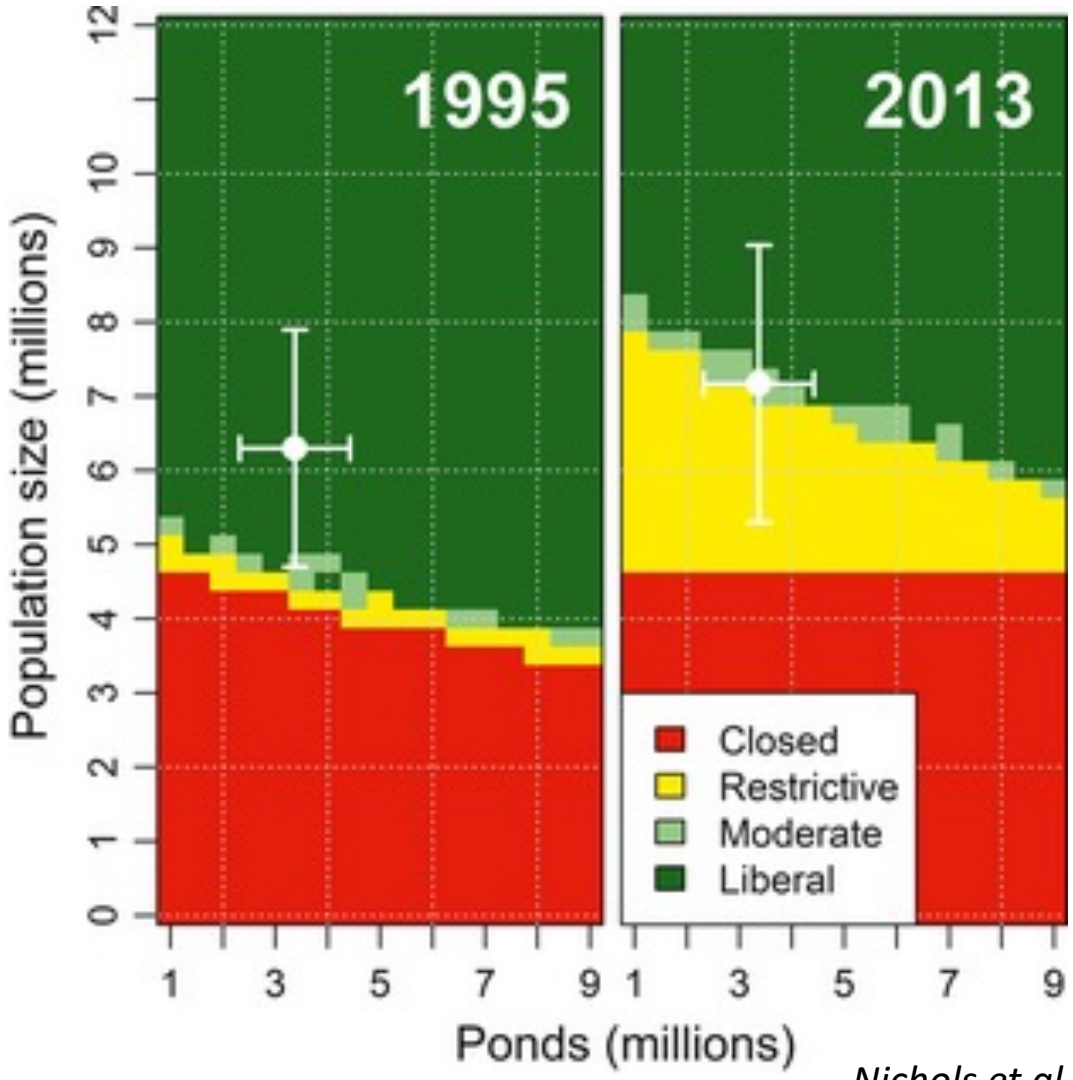
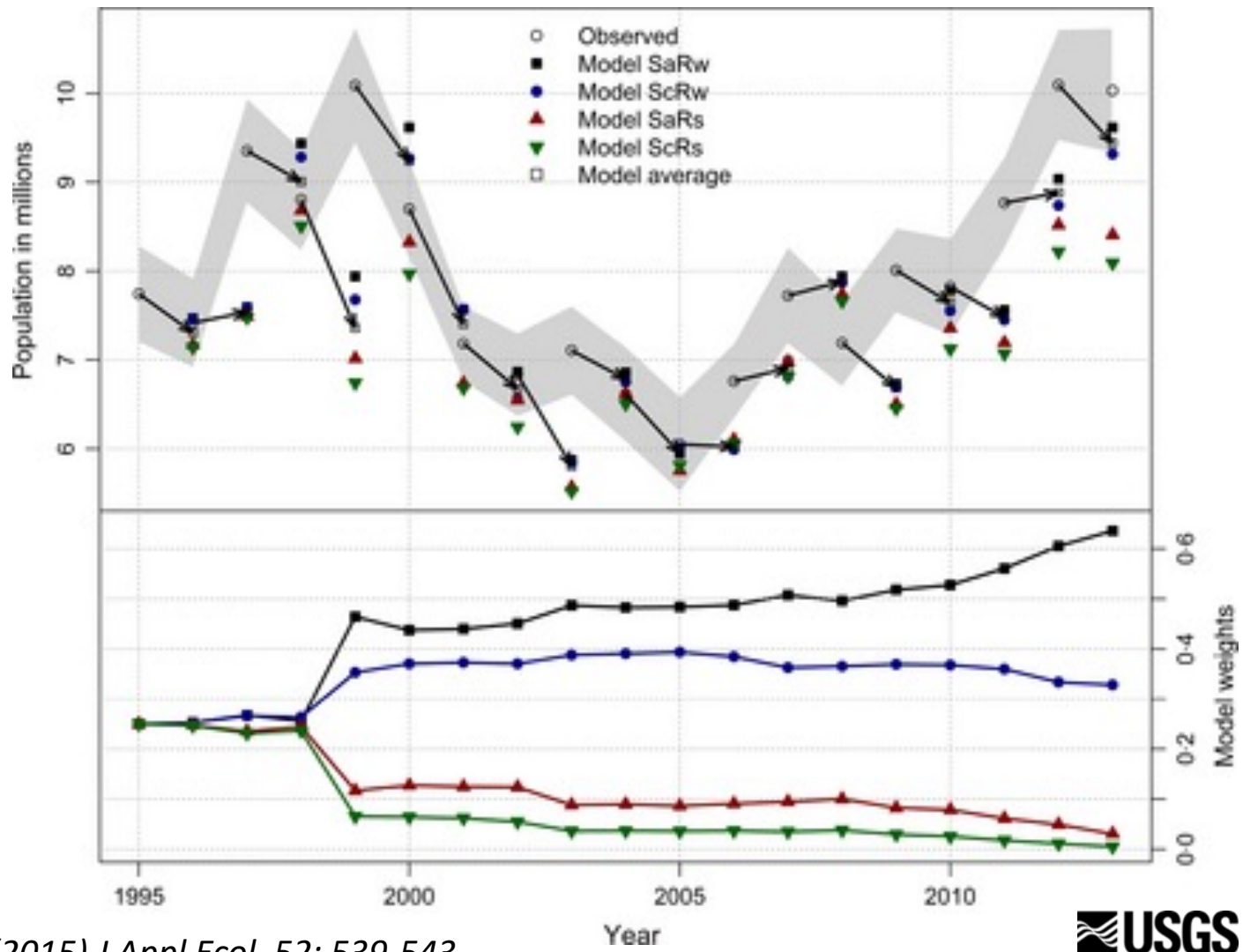
Adaptive management





Nichols et al. (2015) J Appl Ecol, 52: 539-543

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Adaptive optimization and AI

Optimization for linked decisions with scientific uncertainty

- Not ML: Stochastic Dynamic Program

  + Optimal solutions

  + Small dimension-problems

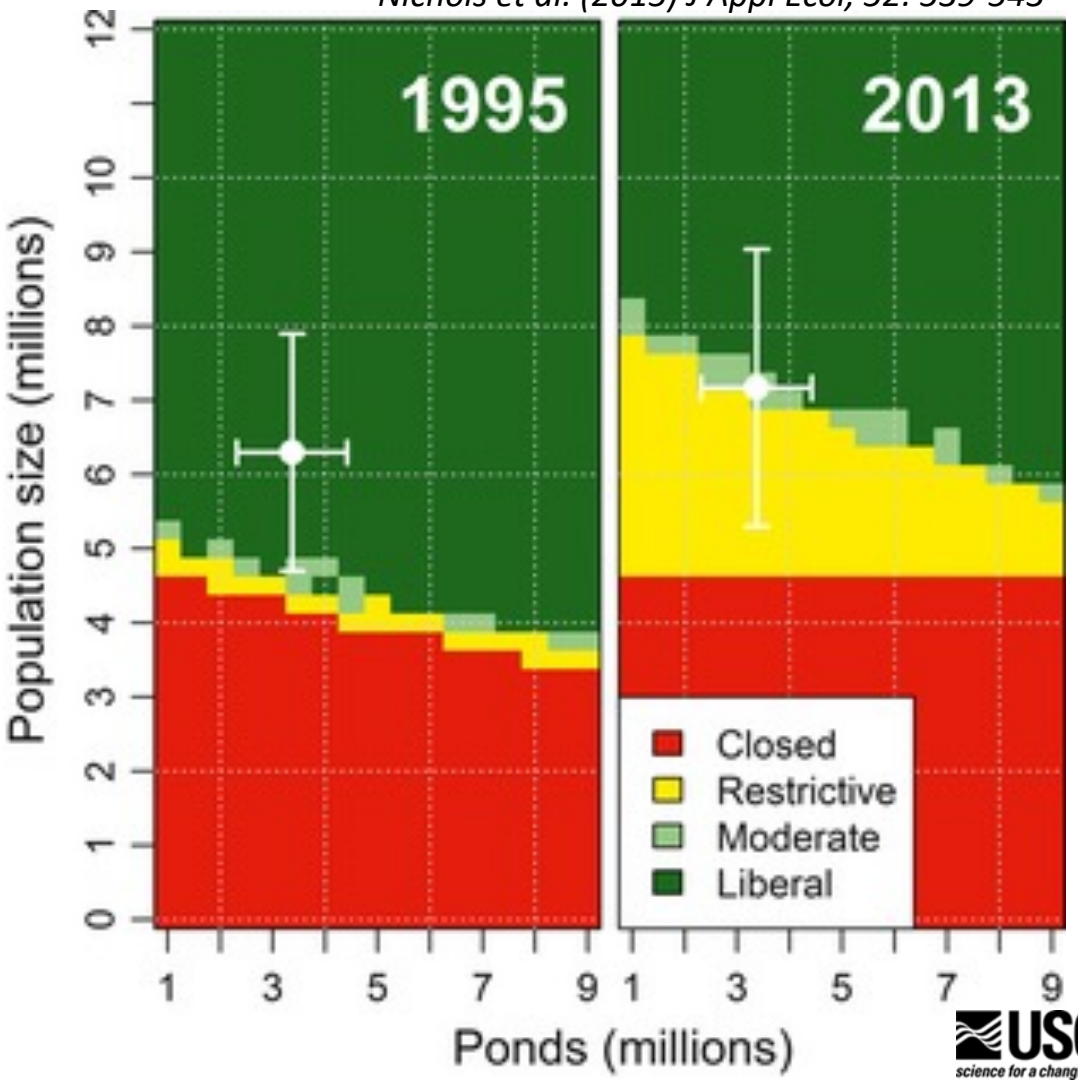
- ML: Reinforcement Learning

  + No guarantee of optimal solutions

  + Large dimension-problems

See Fonnesbeck et al. (2005) Nat. Res. Modeling, 18: 1-40.

Nichols et al. (2015) J Appl Ecol, 52: 539-543



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Potential risks and limitations of AI/ML/DL

- Complexity of algorithms
- Need for supercomputers
  + *Training times can be weeks*
- Data hungry
- Phenomenological modeling
- Risk of overfitting
  + *Accurate predictions with training data*
  + *Inaccuracy with new data*

Michelangelo Buonarroti

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Acknowledgements

The work presented was in collaboration with Brad Udell, Holly Edwards, Mathieu Bonneau, Fred Johnson, Christina Romagosa, Quentin Sabatier, the Florida Fish and Wildlife Conservation (FWC), Commission, the U.S. Fish and Wildlife Survey (USFWS), the National Oceanic and Atmospheric Administration (NOAA). Slides 4 (bottom figure) and 12 were modified from A. Royle et al. The Wildlife Society Conference 2019 and from an article by Arun Addagatla *https://arunaddagatla.medium.com/the-deep-learning-bc4db7959cbd.*

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