Marine Life Protection Act Initiative

Adult Movement, Larval Dispersal and Connectivity

Presentation to the MLPA Blue Ribbon Task Force
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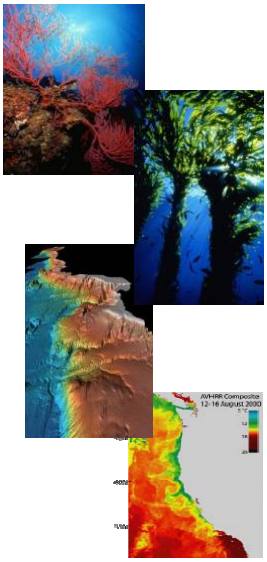
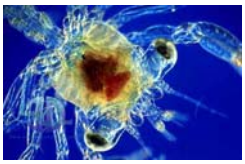
Summary of MLPA Goals

1. To protect the natural diversity and function of **marine ecosystems**.
2. To help sustain and restore **marine life populations**.
3. To improve **recreational, educational, and study opportunities** in areas with minimal human disturbance.
4. To protect representative and unique **marine life habitats**.
5. Clear objectives, effective management, adequate enforcement, sound science.
6. To ensure that MPAs are designed and managed as **a network**.

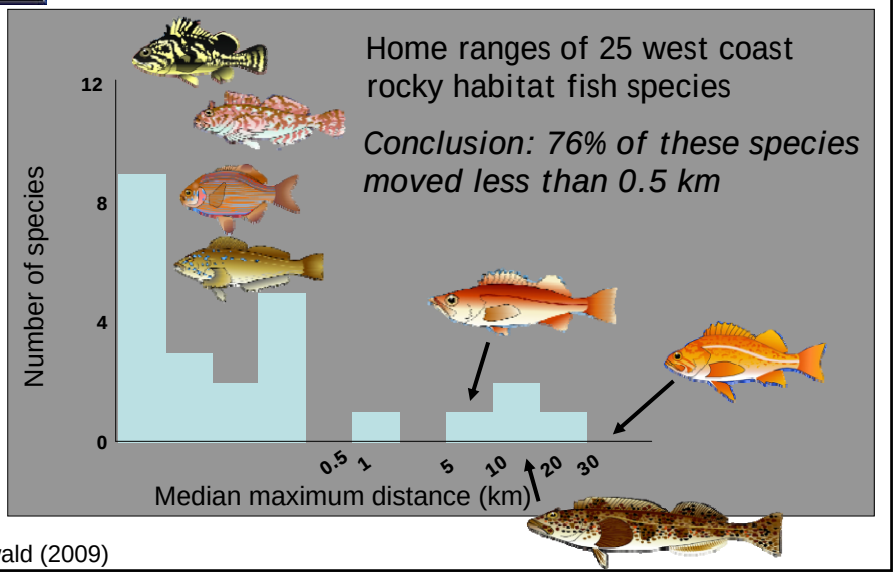


Protecting Populations: Goals 2 & 6



- MPAs should be large enough that adults do not move out of them too frequently and become vulnerable to fishing
  - Effective MPAs have a size greater than the average adult home range size (Moffitt et al. 2009)
- Movement can be alongshore or between shallow to deep habitats

Scales of Adult Movement



Freiwald (2009)

Scales of Adult Movement

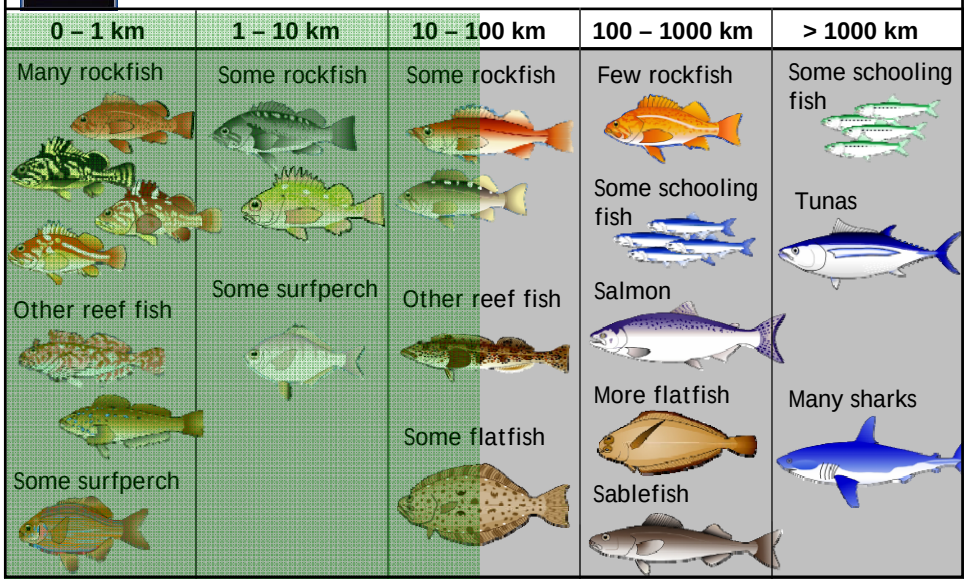
0 – 1 km	1 – 10 km	10 – 100 km	100 – 1000 km	> 1000 km
Many rockfish Other reef fish Some surfperch	Some rockfish Some surfperch	Some rockfish Other reef fish Some flatfish	Few rockfish Some schooling fish Salmon More flatfish Sablefish	Some schooling fish Tunas Many sharks

MPA Size Guidelines

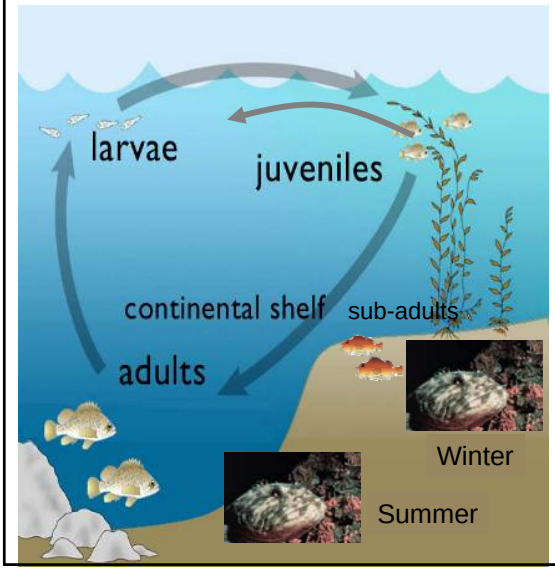
To effectively protect adult populations of a broad range of species, **MPAs should minimally span 5-10 kilometers (3-6 miles) of coastline, and preferably span 10-20 kilometers (6-12.5 miles)**

- Guideline based on adult neighborhood sizes and movement patterns
- Increasing MPA size increases range of species protected
- Much larger MPAs would be required to fully protect marine birds, mammals and migratory fish

Scales of Adult Movement



Species Use Different Depths, Times



Species use different depths at different times:

- **Seasonal shifts**
- **Changing habitats over the course of the life cycle**

MPA Size Guidelines

- **MPAs should extend from the intertidal zone to deep waters offshore** to protect species that move onshore or offshore over the course of their life cycle, and to protect species that differ in preferred depth ranges.

MPA Size Guidelines

MPA size guidelines, combined and simplified:

Minimum range: 3 to 6 miles alongshore

x 3 miles cross-shelf

9 to 18 square miles

Preferred range: 6 to 12* miles alongshore

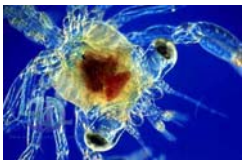
x 3 miles cross-shelf

18 to 36 square miles

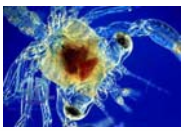
*12.5 miles rounded down

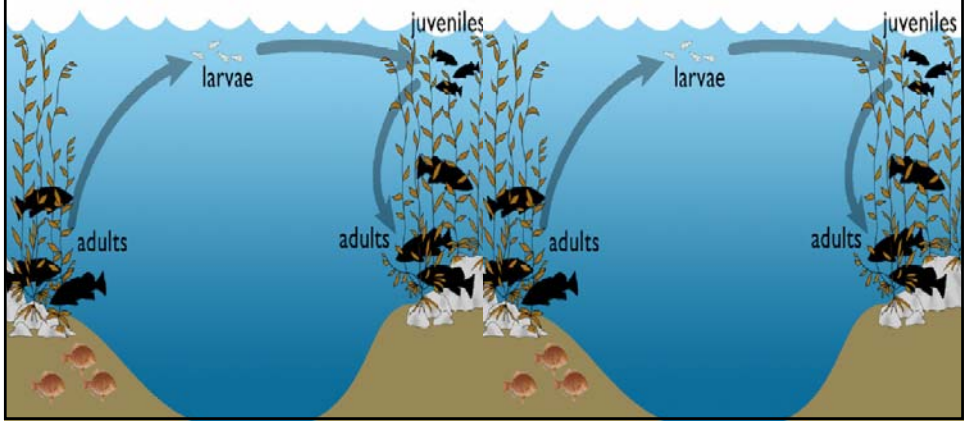
Protecting Populations: Goals 2 & 6

- MPAs should be large enough that adults do not move out of them too frequently and become vulnerable to fishing
- MPAs should be spaced so that sufficient larvae can move from one to the next



Reserves Connected by Larval Dispersal

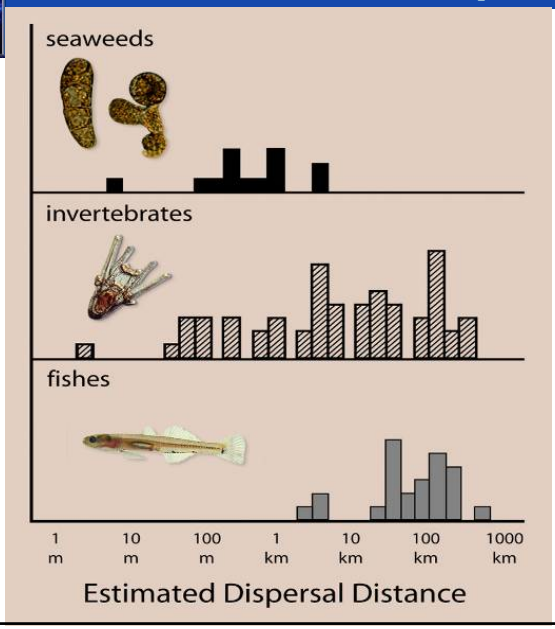




Factors that Affect Larval Dispersal

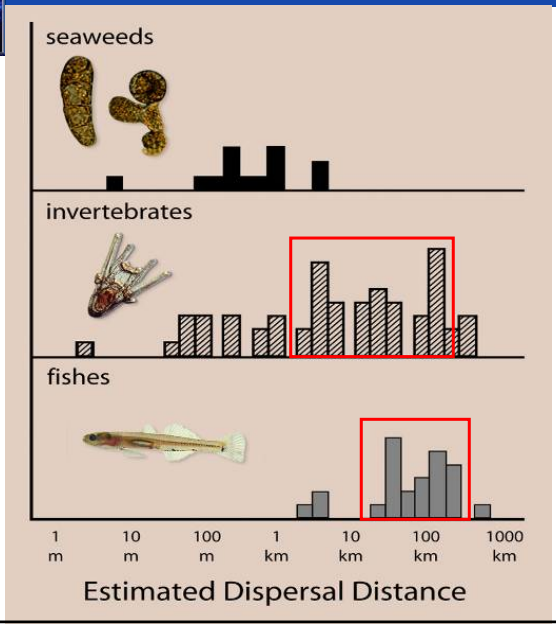
- **Numerous factors affect dispersal patterns:**
  - Ocean circulation
  - Time and location of spawning
  - Duration of planktonic-pelagic life history
  - Larval ecology and behavior
- **Understanding of these processes is limited, so we use simplifying assumptions to predict dispersal and connectivity**
- **Where possible, we use additional information (e.g., ocean circulation models) to inform predicted dispersal patterns**

Scales of Larval Dispersal



Palumbi (2003)
Kinlan and Gaines (2003)

Scales of Larval Dispersal



Inverts: < 100 km

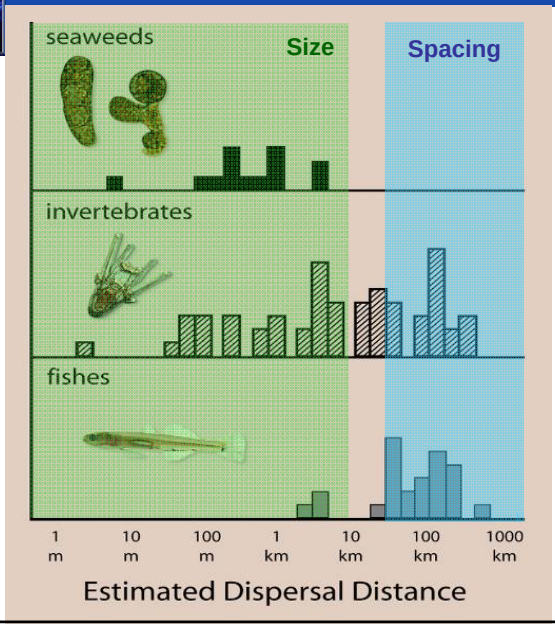
Fish: 10 - 200 km

Palumbi (2003)
Kinlan and Gaines (2003)

MPA Spacing Guidelines

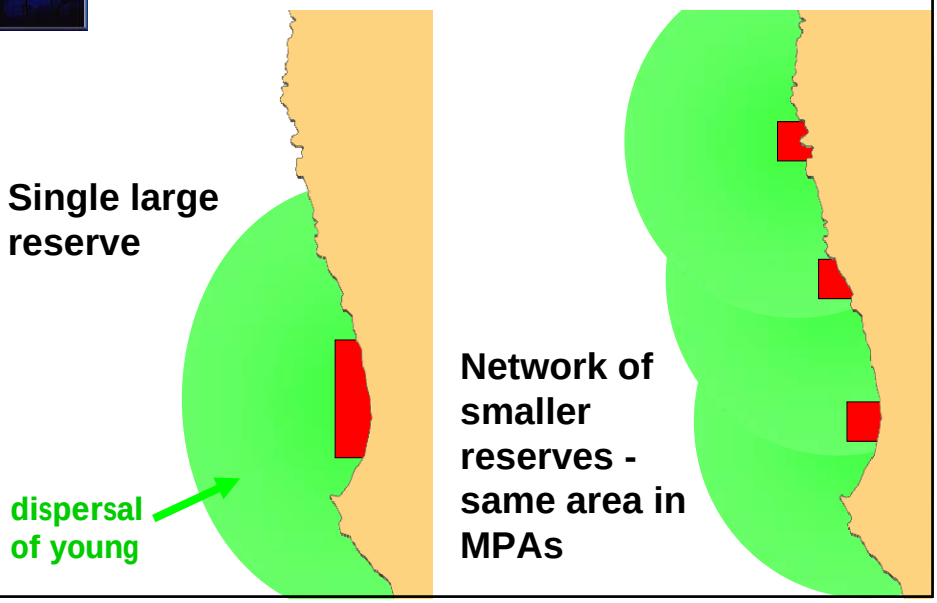
- **MPAs should be placed within 50-100 kilometers (31-62 miles) of each other** to maintain connectivity among MPAs for important bottom-dwelling fishes and invertebrates.
- Because many populations are habitat-specific, spacing is evaluated separately **for each habitat** encompassed within MPAs.

Scales of Larval Dispersal



Kinlan and Gaines (2003)

Characteristics of Networks



Roles of Multiple Connected MPAs

- Increase area over which larval export from MPAs is realized
- Reduce negative and increase beneficial impacts to local fisheries along the coast
- Enhance connectivity and replenishment among MPAs
- Reduce dependency of populations inside MPAs on replenishment by populations outside MPAs
- Buffer against local catastrophes (e.g., oil spill, storms)
- Encompass the diversity of habitats and associated species

What Bioeconomic Models Do

INPUT	OUTPUT
Biology Oceanography Habitat Fishery Management MPAs (Fleet Response) (Weather)	Adult Biomass Larval Supply Fishery Yield (Connectivity)

Why Models?

- Size and spacing guidelines are presented as ranges of values that are minimum or maximum thresholds
- Spatially explicit models augment size and spacing guidelines by:
  a) counting benefits of MPAs that are larger or closer to each other than size and spacing guidelines,
  b) evaluating contribution of MPAs that do not meet size and spacing guidelines,
  c) simultaneously assessing conservation and economic consequences of MPAs, and
  d) accounting for context (e.g., fleet dynamics, fishery management, location of habitat within MPAs).

Model Inputs

- **Geographic**
  - Habitat maps
  - Ocean circulation
  - Proposed MPA boundaries and regulations
- **Species-specific**
  - Life history (growth, natural mortality, fecundity)
  - Adult movement (home range diameter)
  - Larval dispersal (pelagic larval duration, spawning season)
  - Egg-recruit or settler-recruit relationship
- **Fleet response**
  - Spatial abundance of fish
  - Distance from port

North Coast Model Species

- Black rockfish
- Brown rockfish
- Cabezon
- Burrowing shrimp
- Dungeness crab
- Red abalone
- Red sea urchin

Model Outputs

- All outputs are based on long-term steady states—*What will the system look like 30 to 50 or more years from now?*
- Each output is calculated for a range of assumptions about future fishery management outside MPAs:
  - Conservative management
  - Maximum sustainable yield (MSY)-type management
  - Unsuccessful management

Model Outputs

- **Conservation**
  - Maps of larval settlement and biomass
  - Total settlement and biomass (summed over study region, weighted sum across species)
- **Economic**
  - Maps of fishery yield
  - Total fishery yield (summed over study region, weighted sum across species)
- **Other Model Outputs**
  - Maps of fishing effort
  - Connectivity patterns that integrate larval production, dispersal, and settlement

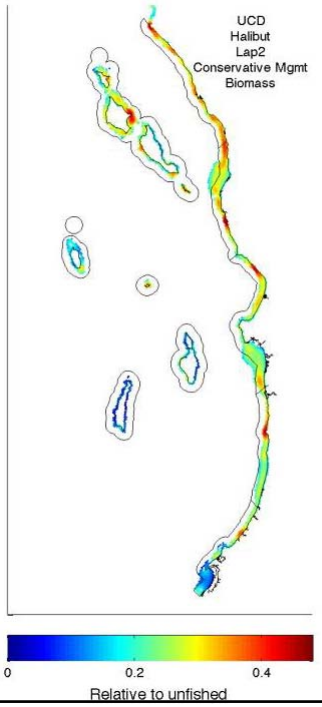
Example Results

Spatial Distribution of Biomass

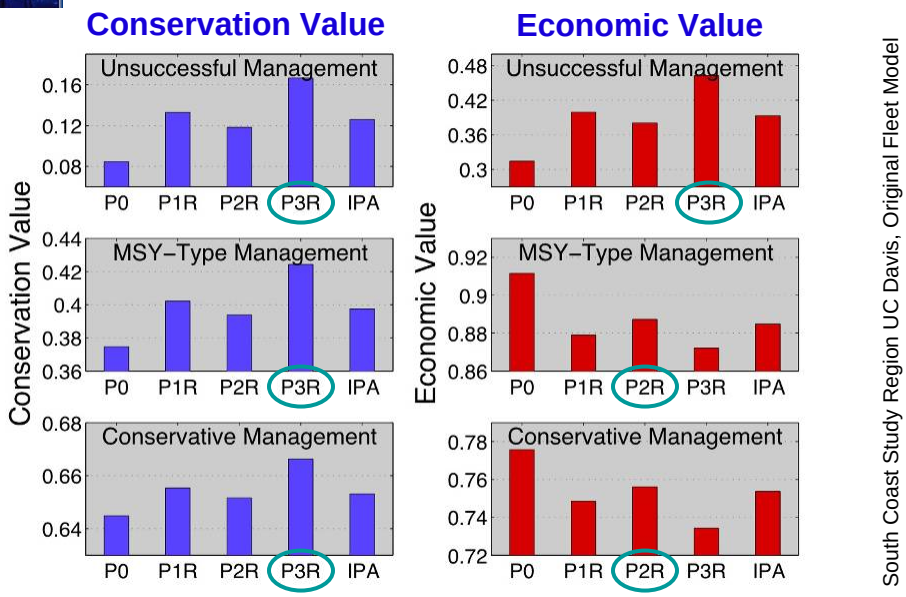
(Maps also available for recruitment, fishery yield and fishing effort)

- **Example species**: Halibut
- **Example proposal**: Lapis 2
- **Management assumption***: Conservative management outside MPAs

*Also run for "unsuccessful management" and "Maximum Sustainable Yield" (MSY-type) management

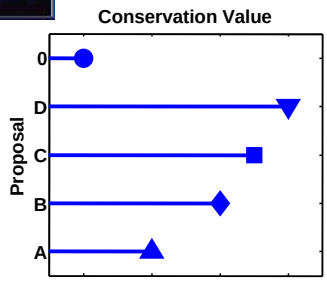


Proposal Rankings



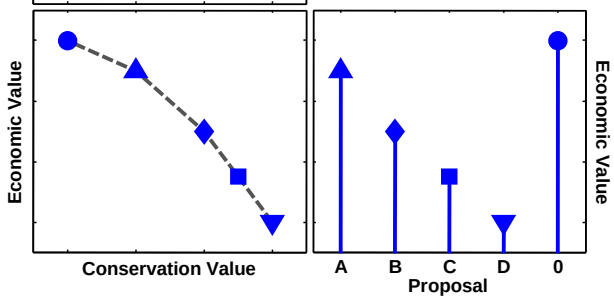
South Coast Study Region UC Davis, Original Fleet Model

Model Results: Rankings in Context



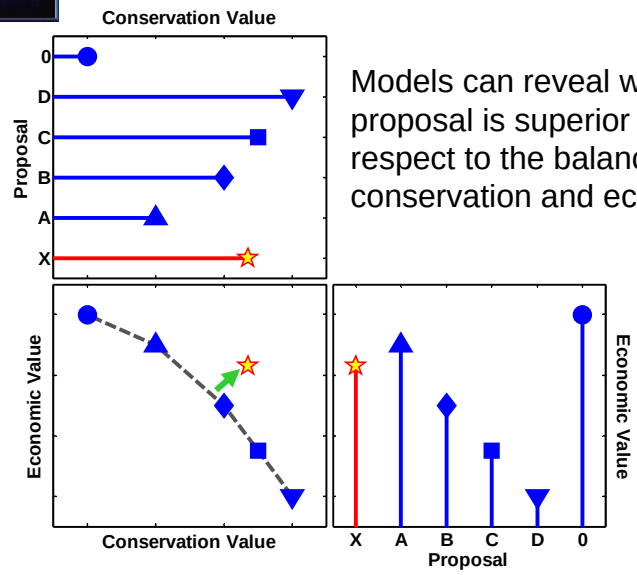
Conservation and economic values vary together; plotting them together puts proposals in context.

Choice of location along the conservation-economics curve is a matter of policy priorities.



Hypothetical example under MSY-type fishery management

Model Results: Rankings in Context



Models can reveal whether a proposal is superior to others with respect to the balance between conservation and economic values.

Hypothetical example under MSY-type fishery management

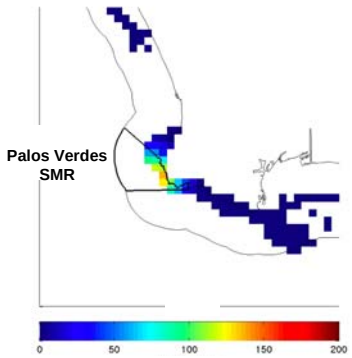
Model Results: Individual MPAs

- **How does removal of an individual MPA from an MPA network affect the expected consequences of the network?**
  - Spatial distribution of biomass and larval production
  - Overall conservation and economic measures
  - Connectivity

Model Results: Individual MPAs

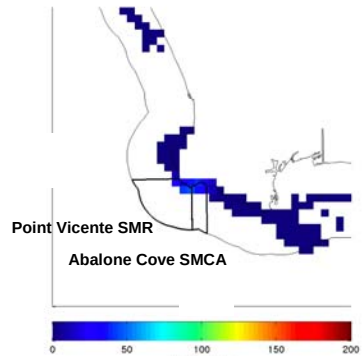
Does the MPA cause more larvae to be produced?

Proposal: P3R



Percent change in larval production (P3R compared to P0)

Proposal: IPA and P2R



Percent change in larval production (IPA and P2R compared to P0)

South Coast Study Region, UC Davis, original fleet model

Summary

- **Size guidelines**
  - Focus on protection of adult populations
- **Spacing guidelines**
  - Focus on connectivity and network characteristics of MPA arrays
- **Bioeconomic models**
  - Synthesize spatial information, biology, and harvest to predict conservation and economic consequences of MPA arrays
- **Size and spacing guidelines motivate design; models augment evaluation**