From prediction to practice: Integrating forecasting models into public health education and response

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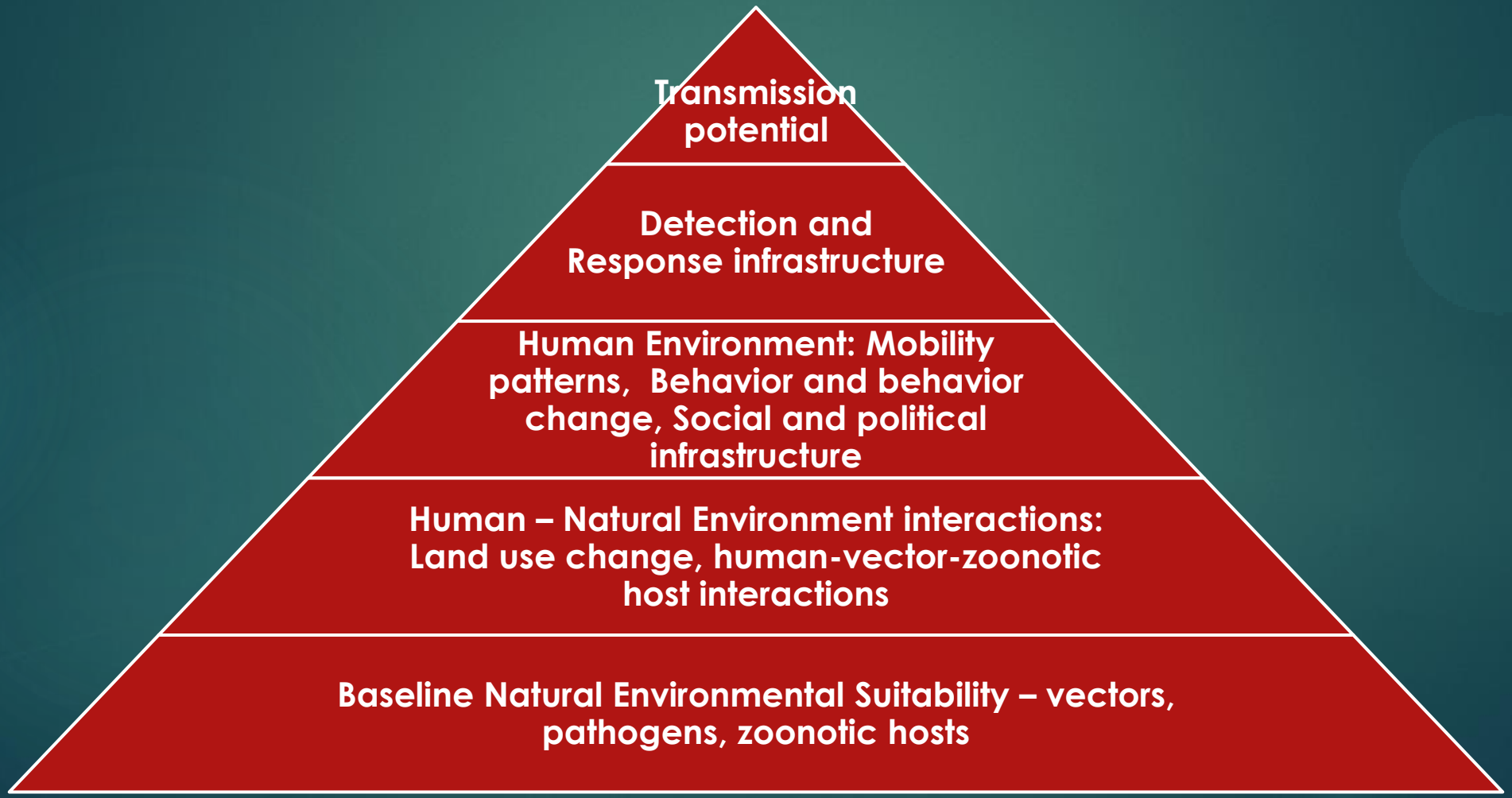
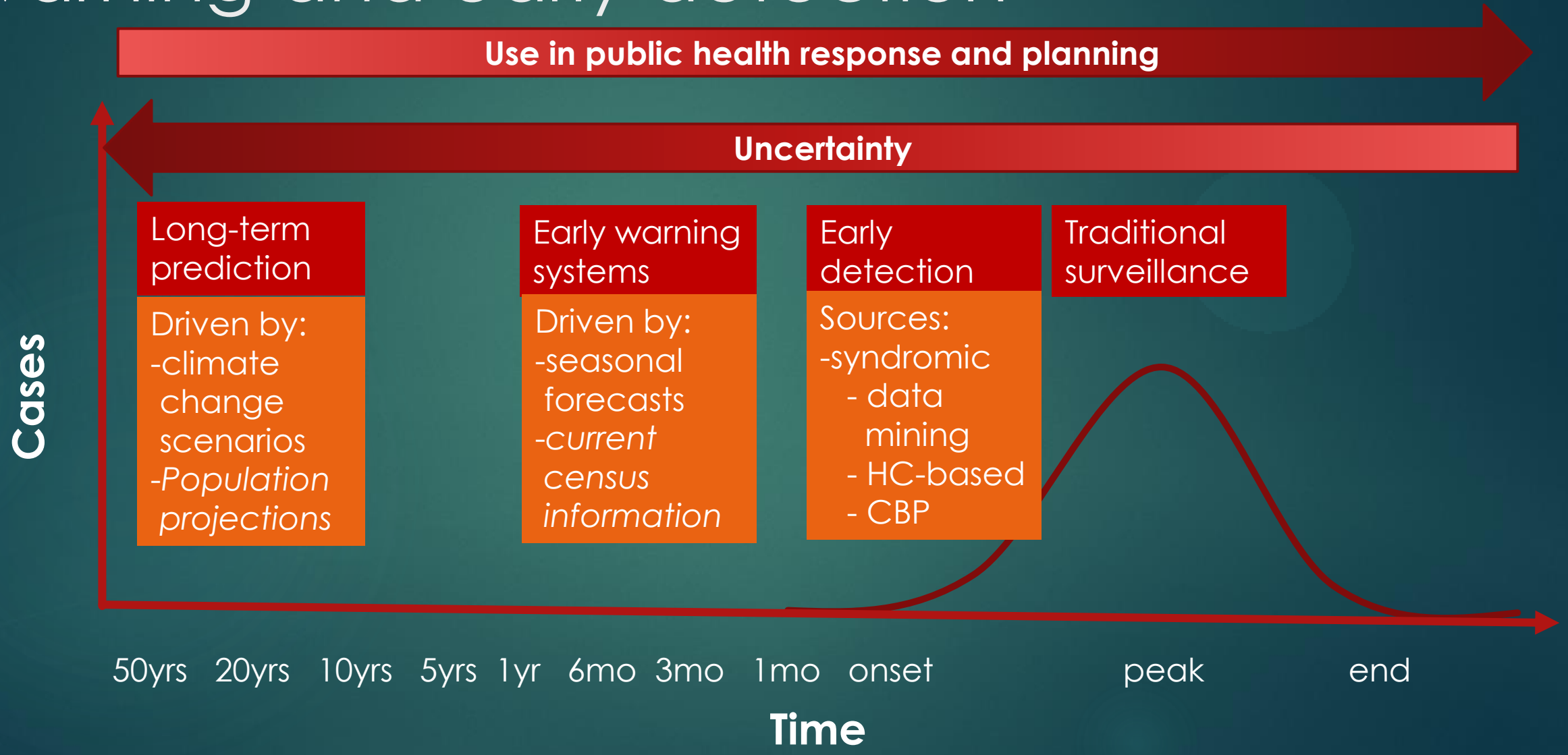
Transmission risk in a given geographic area



Some key concepts identified from: Arthur RF, Gurley ES, Salje H, Bloomfield LS, Jones JH. Philos Trans R Soc Lond B Biol Sci. 2017 May 5;372(1719).

Long term predictions to early warning and early detection



Projecting long-term epidemic potential

Understand the system

What is the process that climate/weather influences the infectious disease potential?

Determine patterns of seasonality

Conduct correlations across differing geographies

Laboratory experimentation

Mitigating factors

If all are exposed, who are the vulnerable?

Examine risk factors for the transmission

Determine the current and projected distribution of these risk factors

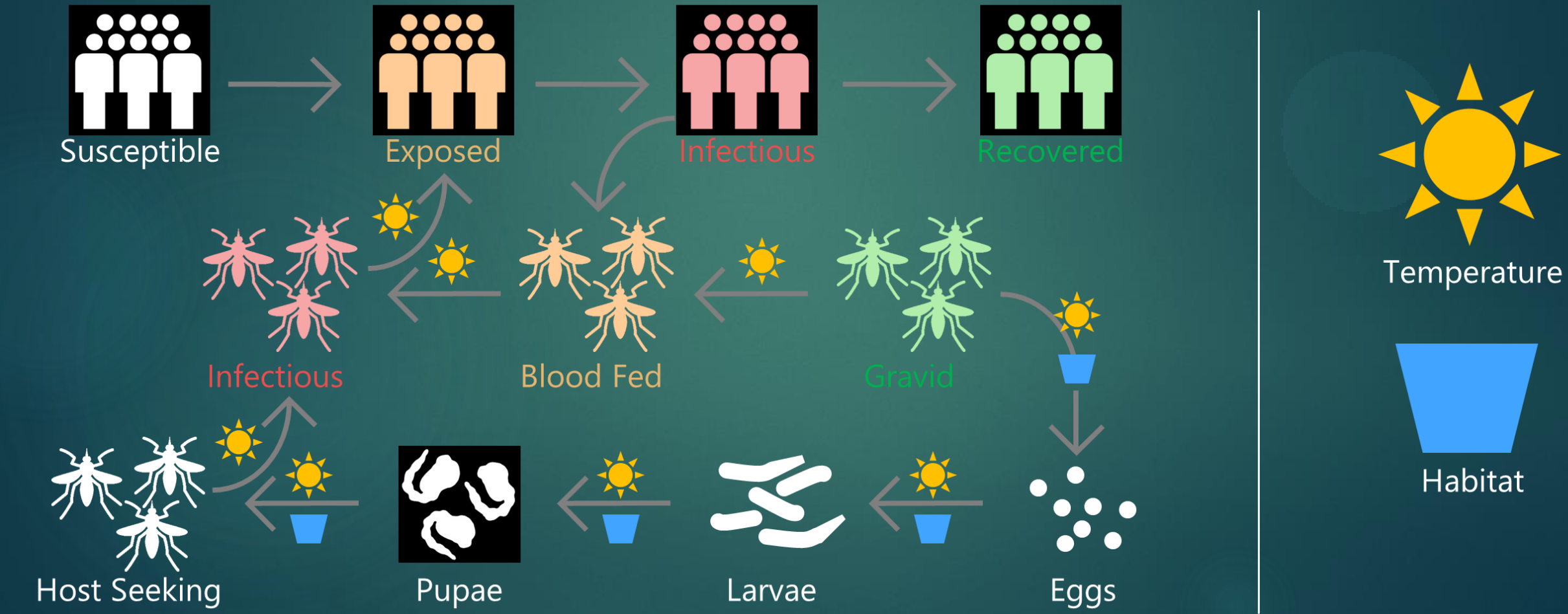
Compile into projections

If we drive process models with projected climate data coupled with data on the human dimension, what happens?

Determine complex interactions among all the determinants of the process *and* the potentially mitigating risk factors

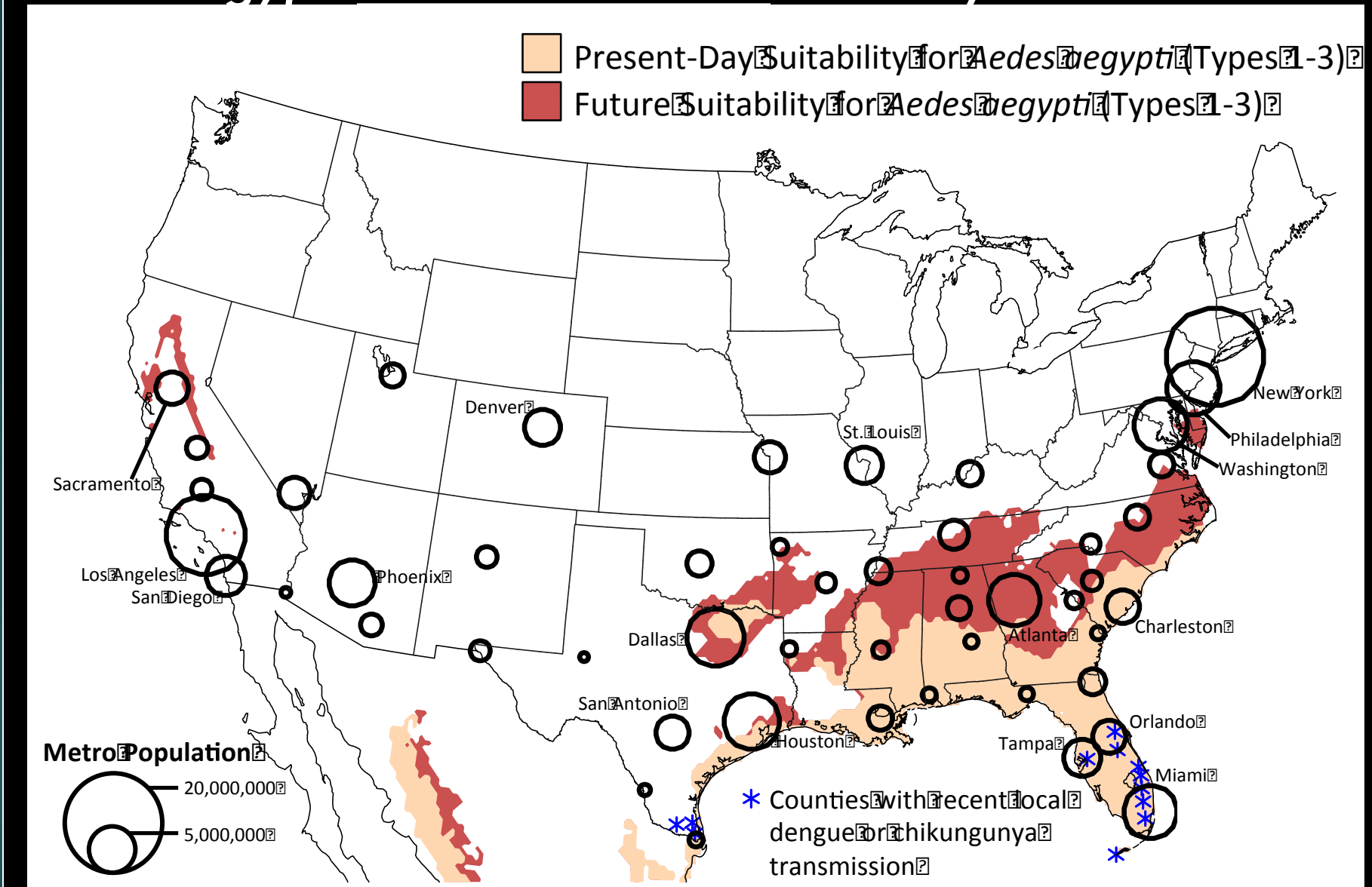
Integration of data

- As more about the dynamics are learned in the field they are integrated into a dynamic model of disease risk



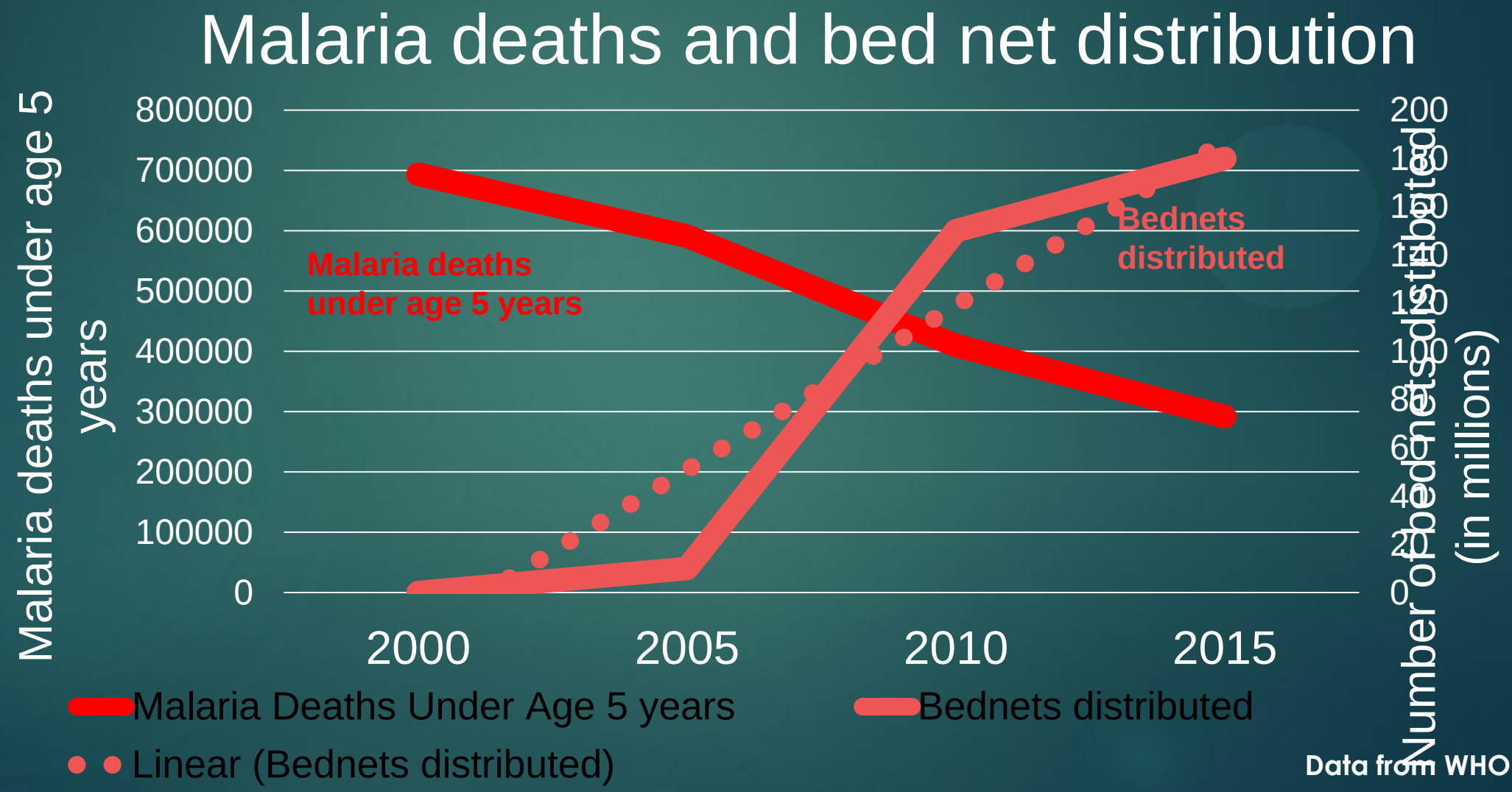
Morin, C. W., A. J. Monaghan, M. H. Hayden, R. Barrera, and K. C. Ernst, 2015:. *PLoS Neg. Trop. Dis*

Ae. aegypti virus transmission suitability



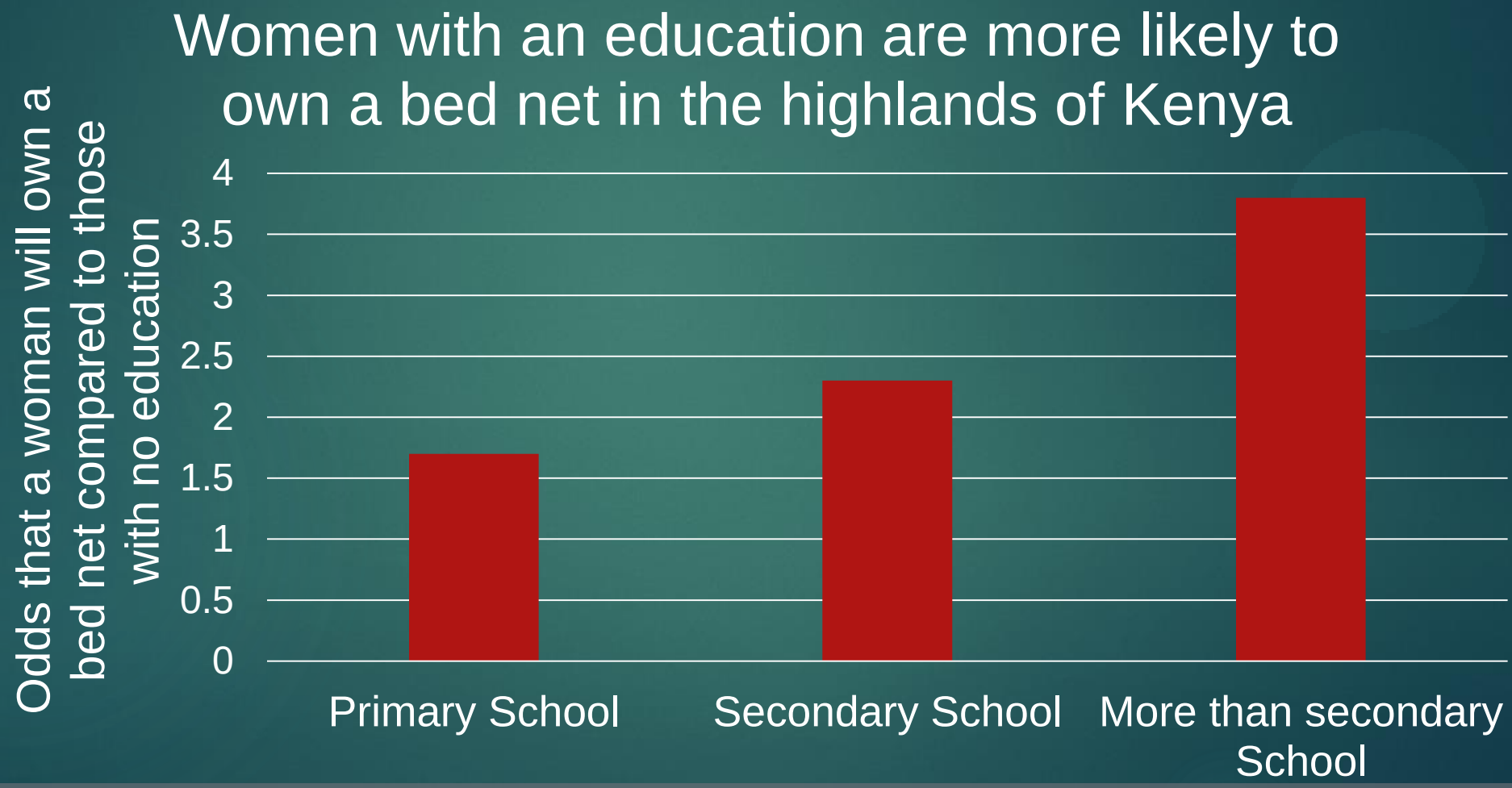
Map shows the range of the *Aedes aegypti* mosquito for present-day (1950-2000) and future (2061-2080; RCP8.5) conditions. Larger cities have higher potential for travel-related virus introduction and local virus transmission. Adapted from: Andrew J. Monaghan, K. M. Sampson, D. F. Steinhoff, K. C. Ernst K. L. Eb B. Jones, M. H. Hayden, Climatic Change (2016)

Predicting risk must account for changing human factors



Data from WHO

Risk influenced by socially-determined behaviors



Ernst KC, Hayden MH, Olsen H, Cavanaugh JL, Ruberto I, Agawo M, Munga S. Malar J. 2016 Apr 14;15:217.

Developing Early Warning systems for infectious disease transmission

- Frameworks for early warning systems have been developed that include stages for:
  - Watch: Developing prior assessment of risk of emergence event
  - Warning: Human disease has been detected
  - Emergency: Epidemic or outbreak is underway
- Key challenges
  - Integration of data streams
  - Changing landscapes of risk
    - Human: behaviour and available control strategies, response capacity
    - Biological: phylodynamics, environmental conditions
  - Communication and adoption of early warning systems by key stakeholders
  - Investment in ongoing monitoring systems
  - Lack of integration of natural system risk with impact of human and social factors on transmission

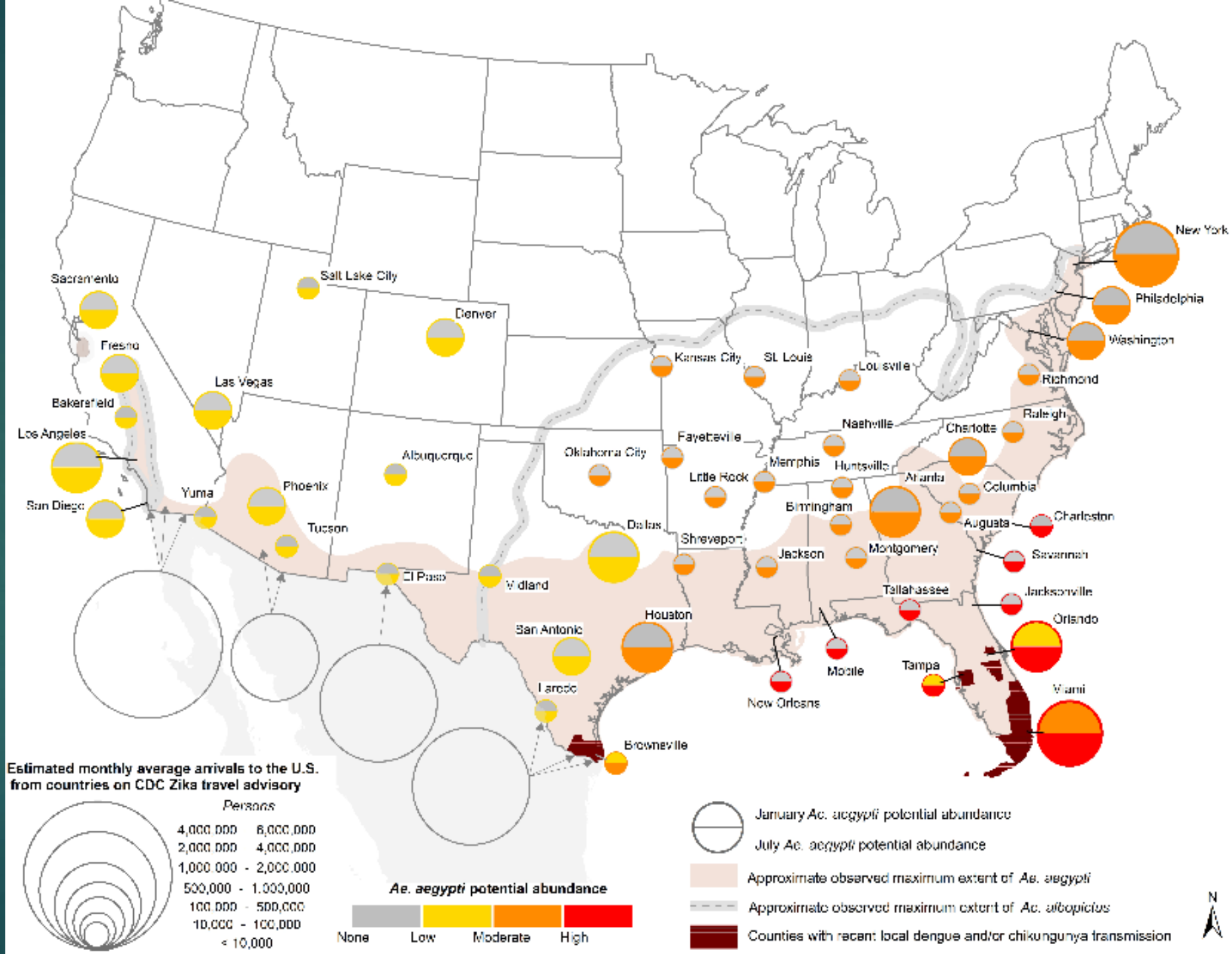
Some concepts adapted from BA Han and JM Drake EMBO Reports 2016

Early Warning Example

Zika Risk in CONUS

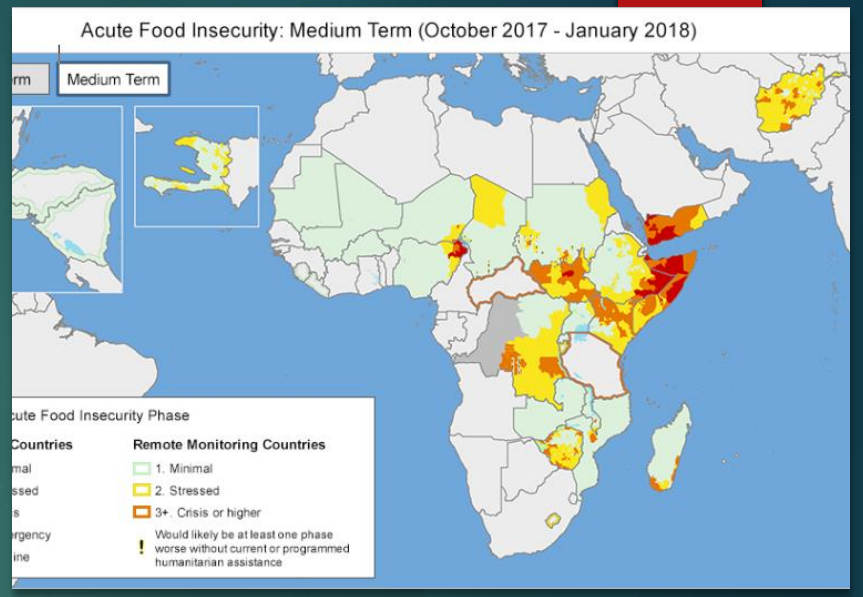
- Weather-driven mosquito models with
  - travel,
  - socioeconomic conditions
  - virus history
- Required rapid analysis
- Designed for widespread dissemination to stakeholders and the public.
- One time assessment
- Used climate not current weather

Monaghan AJ, Morin CW,….Ernst K. PLOS Currents (March 2016)

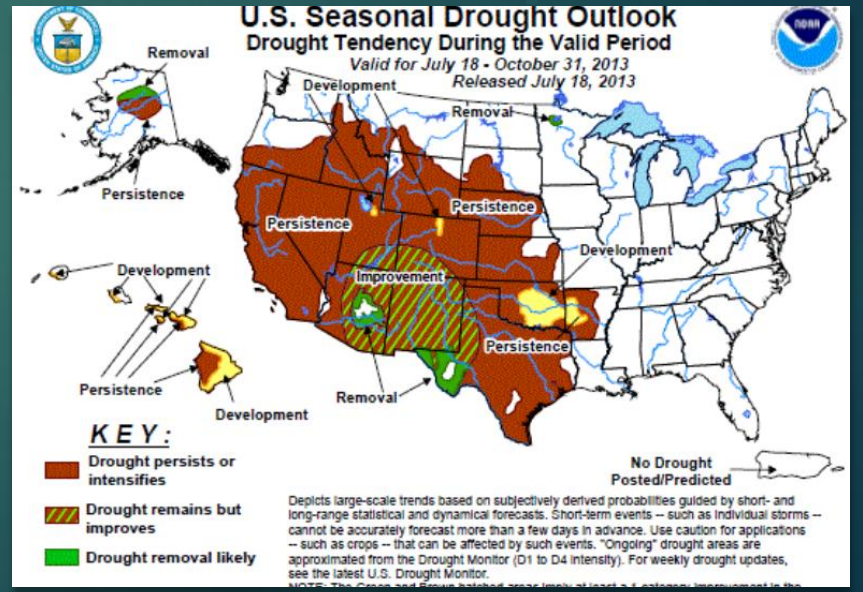


Examples from other fields

- Sustainable forecasting has been actualized in other disciplines
  - Drought monitoring
  - Food security
- Typically more directly related to environmental measurements readily available
  - Temperature
  - Rainfall
- Do not include projects of health, economic or other downstream impacts in which social science has a stronger role



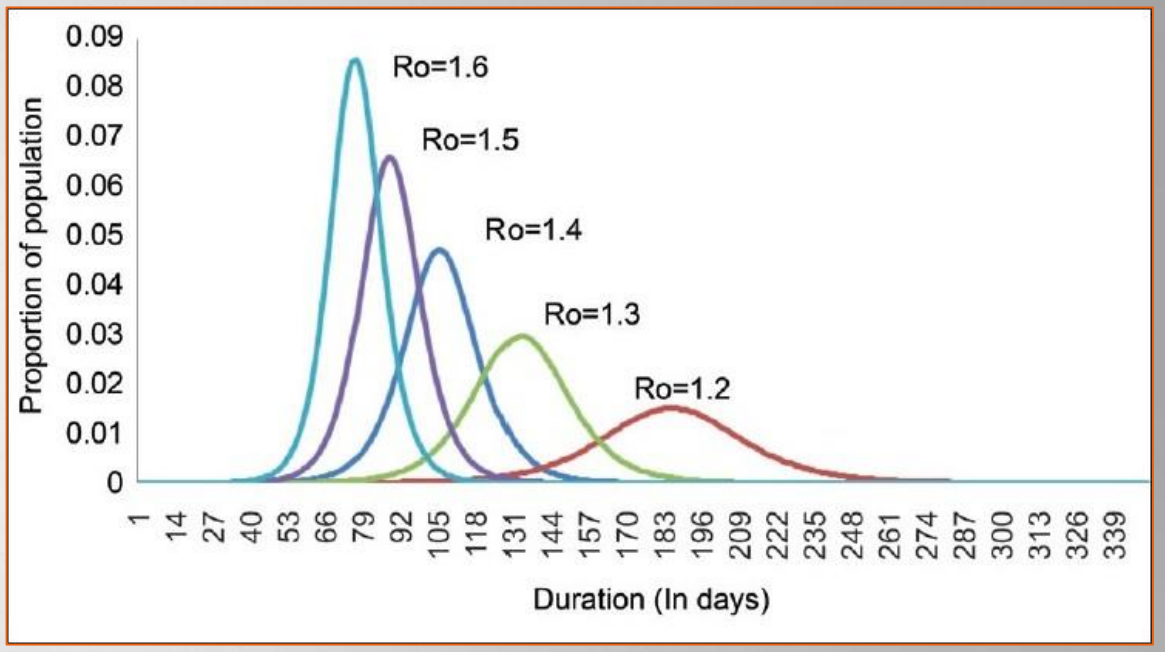
http://www.fews.net/



https://www.drought.gov/drought/

Early detection

- Goal of early detection
  - Reduce the reproductive number to minimize transmission
- Methods:
  - Reduce contacts
  - Reduce duration of infectiousness
  - Target interventions
  - Maximize uptake



Components of Basic R_o:

B = Probability of transmission given contact
c = Number of contacts per given time period
D = Duration of infectiousness

Can modify by: x – proportion susceptible

- Targeted vaccination (measles OB)
- Distribution of control measures (bed net)

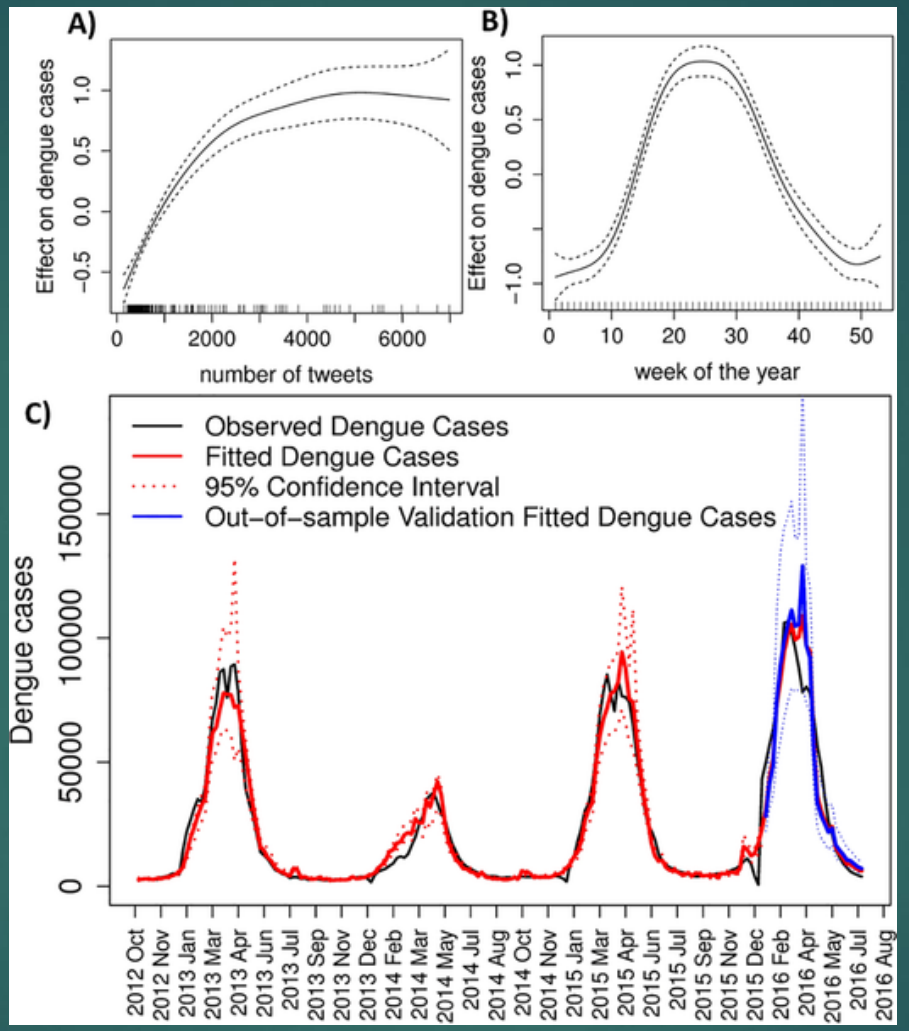
Non-traditional Early Detection sources

- Social listening: Using social media data to identify trends and respond (often used in marketing but can be used for infectious disease trends)
- Sources of data
  - Twitter (predomínate source)
  - Facebook
  - Internet searches
  - Instagram
- Key strategy
  - Develop algorithims for searching for key words/ phrases – machine learning (Kagashe I, Yan Z, Suheryani I J Med Internet Res 2017)
  - Monitor trends
- Key Challenges
  - Biases in data (age, geography)
  - Noisy data – best suited for trends in high transmission diseases (influenza (n=50), dengue (some regions) etc.)
  - Other factors may influence discussion of a topic

Fig 2. Tweets are a useful tool for estimating Dengue activity at country level.

Dengue in Brazil

- Tweets strongly correlated with case reports
  - County level
  - City level
- Nowcasting
- Forecasting up to 8 weeks



Marques-Toledo CdA, Degener CM, Vinhal L, Coelho G, Meira W, et al. (2017) Dengue prediction by the web: Tweets are a useful tool for estimating and forecasting Dengue at country and city level. PLOS Neglected Tropical Diseases 11(7): e0005729. https://doi.org/10.1371/journal.pntd.0005729
http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0005729

Non-traditional early detection sources cont.

- Community-based participatory surveillance
  - Recruited group of users report symptoms each week
- Examples
  - FluNearYou
    - successfully implemented (Pearson corr. >90% adjusted)
    - Biased population
      - More females
      - Higher human development index

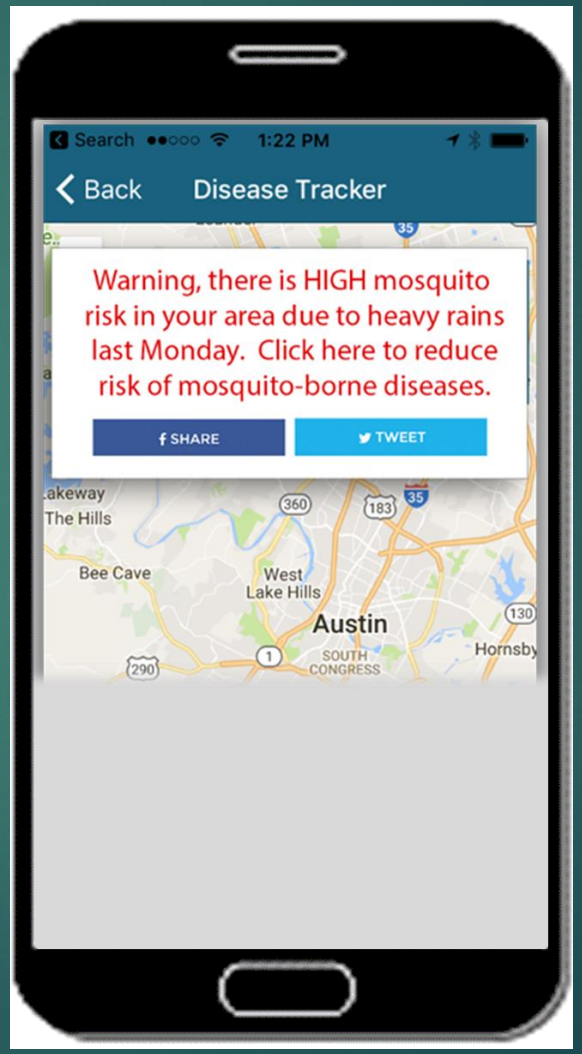
Smolinski, M. S., Crawley, A. W., Baltrusaitis, K., Chunara, R., Olsen, J. M., Wójcik, O., . . . Brownstein, J. S. (2015). 105(10), 2124-2130.

Baltrusaitis K, Santillana M, Crawley AW, Chunara R, Smolinski M, Brownstein JS. JMIR Public Health Surveill. 2017 Apr 7;3(2):

Kidenga – CBS for vector-borne

- System:
  - Similar to Flu Near You
    - Monitoring of syndromes and mosquito activity in US-Mexico border región
- Key lessons
  - Recruitment and retention of participants is challenging
  - Need to provide tailored messages to motivate action
  - Interest falls off after transmission wanes
  - Too high numbers required for identification of rare events
- Current utility
  - Platform for educational messaging and dissemination of EWS messages
  - Intention – get it on everyone's phone – periodic activitation

Kidenga 2.0: Iterate with alerts and cues to action



Summary

- Identify the complex processes behind disease transmission – integrate human and natural processes
- Parameterize models for predicting future risk – both long and short term
- Invest in sustainable infrastructure to support forecasting efforts
- Identify best practices to convey information to motivate action in stakeholders and public
- Operationalize messaging at an appropriate and actionable spatial and temporal scale

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