Using Agent-Based Modelling (ABM) to Understand Habitat Connectivity in Decision Making

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Track 3: Session 1
Healthy Coasts and Healthy ASEAN: Saving the ASEAN through Effective Collaboration

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Challenges in coastal & marine environment management

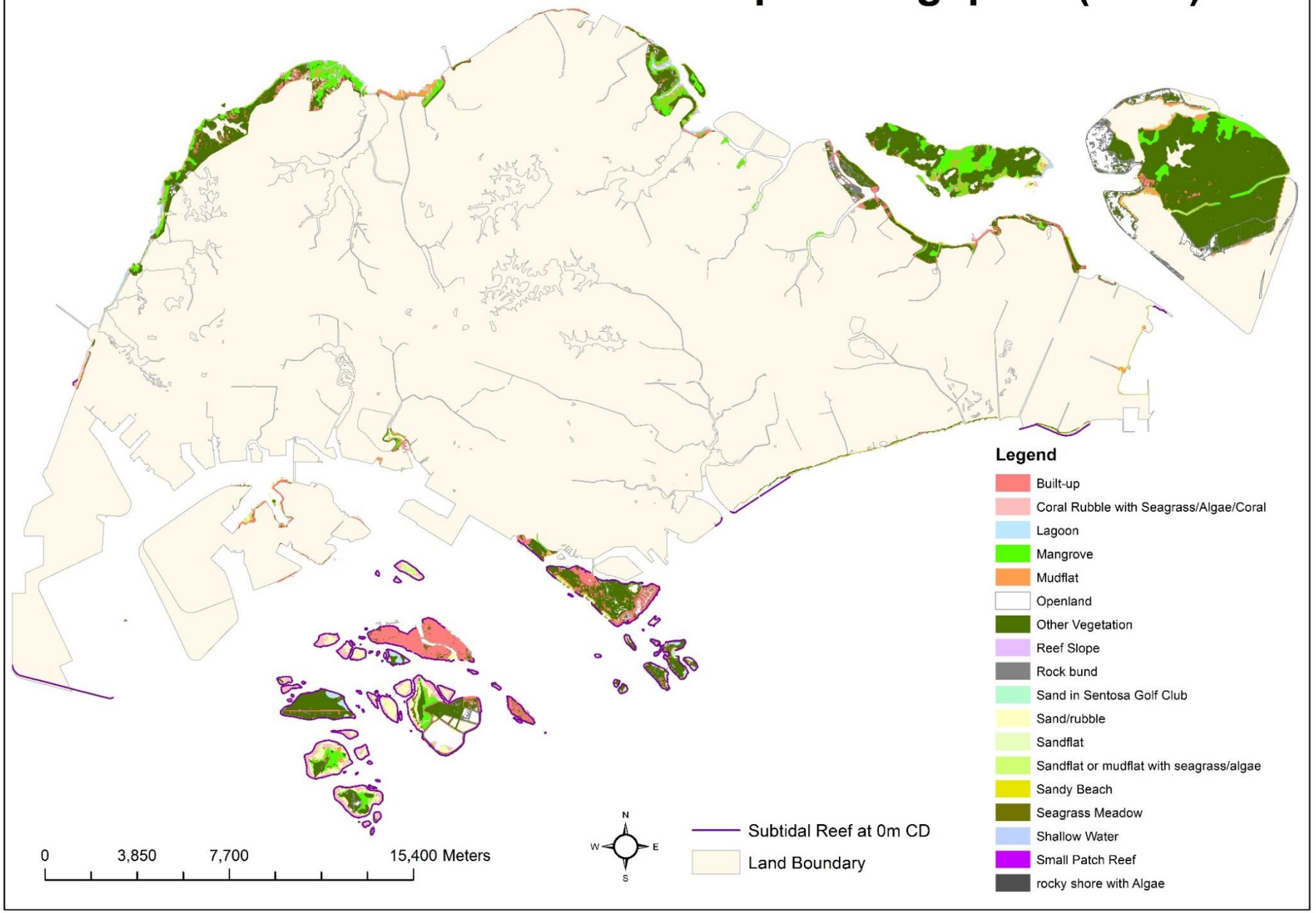
- Heavy demands from multiple users/ stakeholders
- Often limited *"suitable"* land and sea space
- Increasing coastal (urban) populations
- Constantly changing environmental baselines
- Increasing climate change pressures
- Realizing healthy coasts and healthy ASEAN

  ⇒ ***Balancing competing land-use, development and societal needs within the limited "suitable" land and sea resources***

  ⇒ ***Tools and strategies to help us make effective management decisions***

C&M ENVIRONMENTAL MANAGEMENT IN SINGAPORE

Coastal and Marine Habitat Map of Singapore (2012)



Key management questions

- Document biodiversity baselines
- Understand ecosystem processes and socio-economic drivers
- Expand habitat enhancement and restoration efforts
- Understand habitat connectivity patterns

Understanding habitat connectivity

- Research on habitat connectivity initiated in 2013 to aid conservation and development planning
- Using numerical agent-based modelling, and incorporating molecular techniques to validate the numerical models
- Using representative “agents” to elucidate patterns:
  - Coral reef connectivity using coral larval settlement based on broadcast spawning of a dominant hard coral species
  - Intertidal connectivity using larval settlement of the broadcast spawning knobbly seastar
  - Mangrove habitat connectivity using successful settlement of mangrove propagules of 3 mangrove species
  - Seagrass habitat connectivity using dispersal and recruitment of a common seagrass species

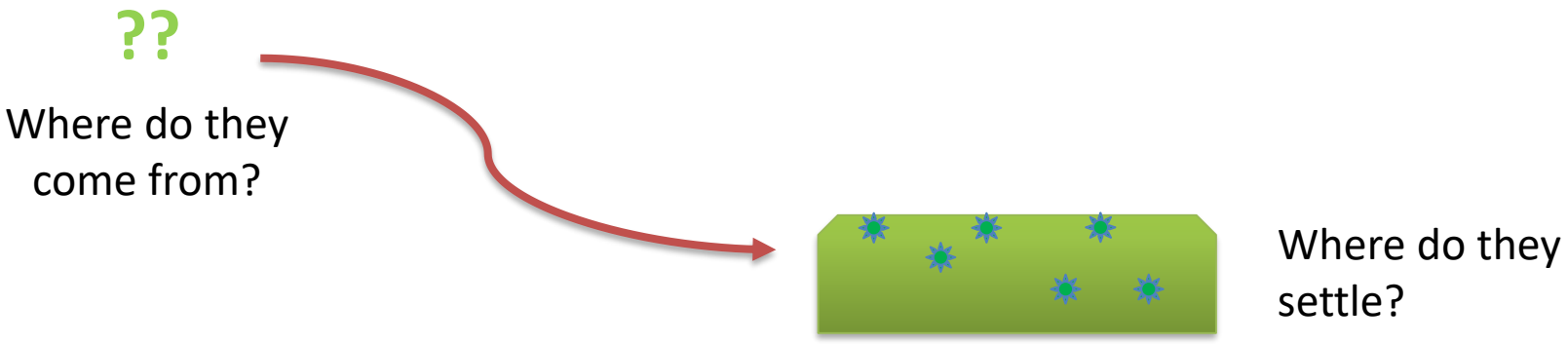
Example: Coral reef connectivity

- Research questions:
  - How connected are Singapore coral reefs?
  - How has Singapore's coastline development changed connectivity patterns?
  - Are Singaporean and Indonesian reefs in northern Riau connected?

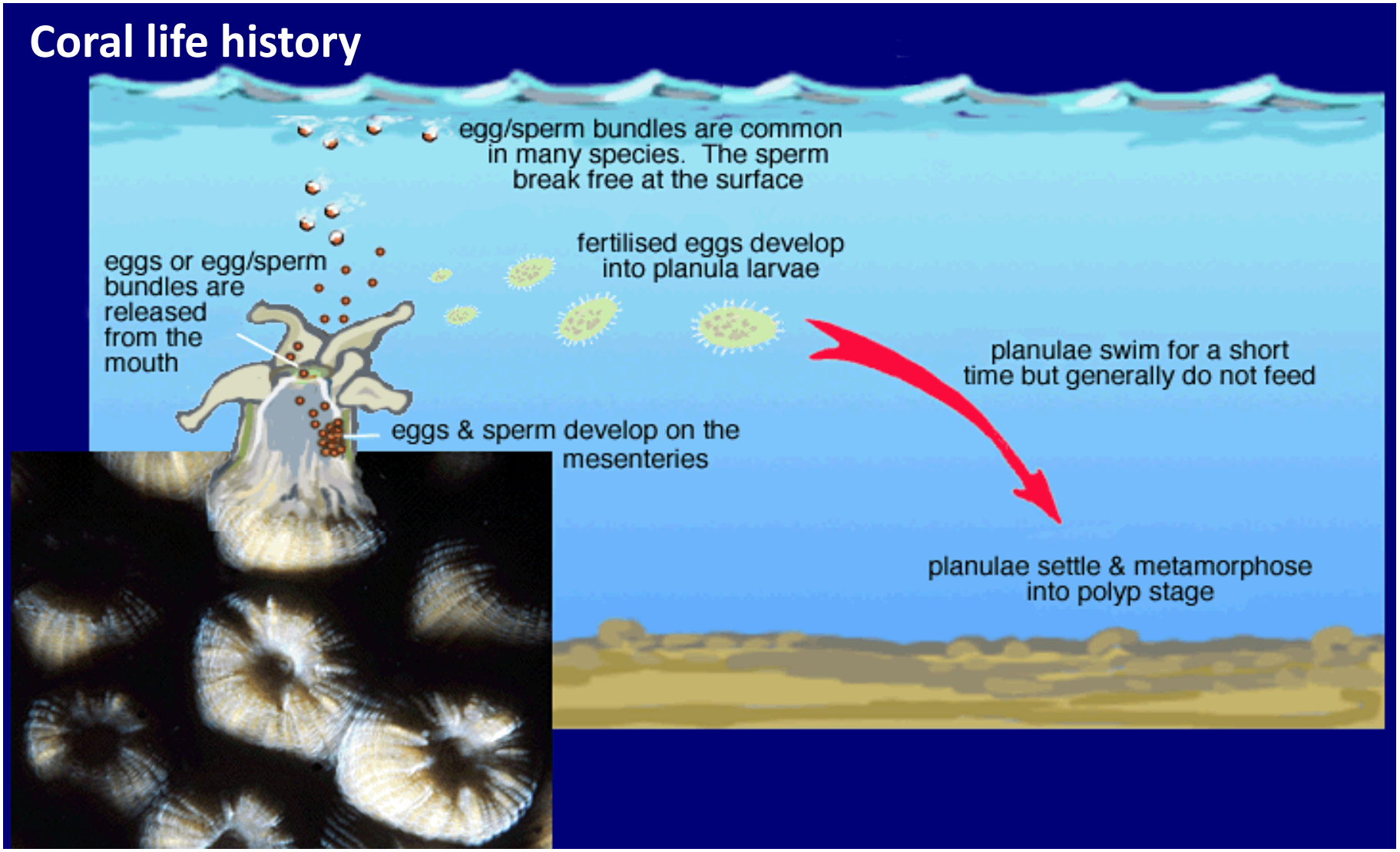
Example: Coral reef connectivity

- Downstream Connectivity

- Upstream Connectivity



Example: Coral reef connectivity

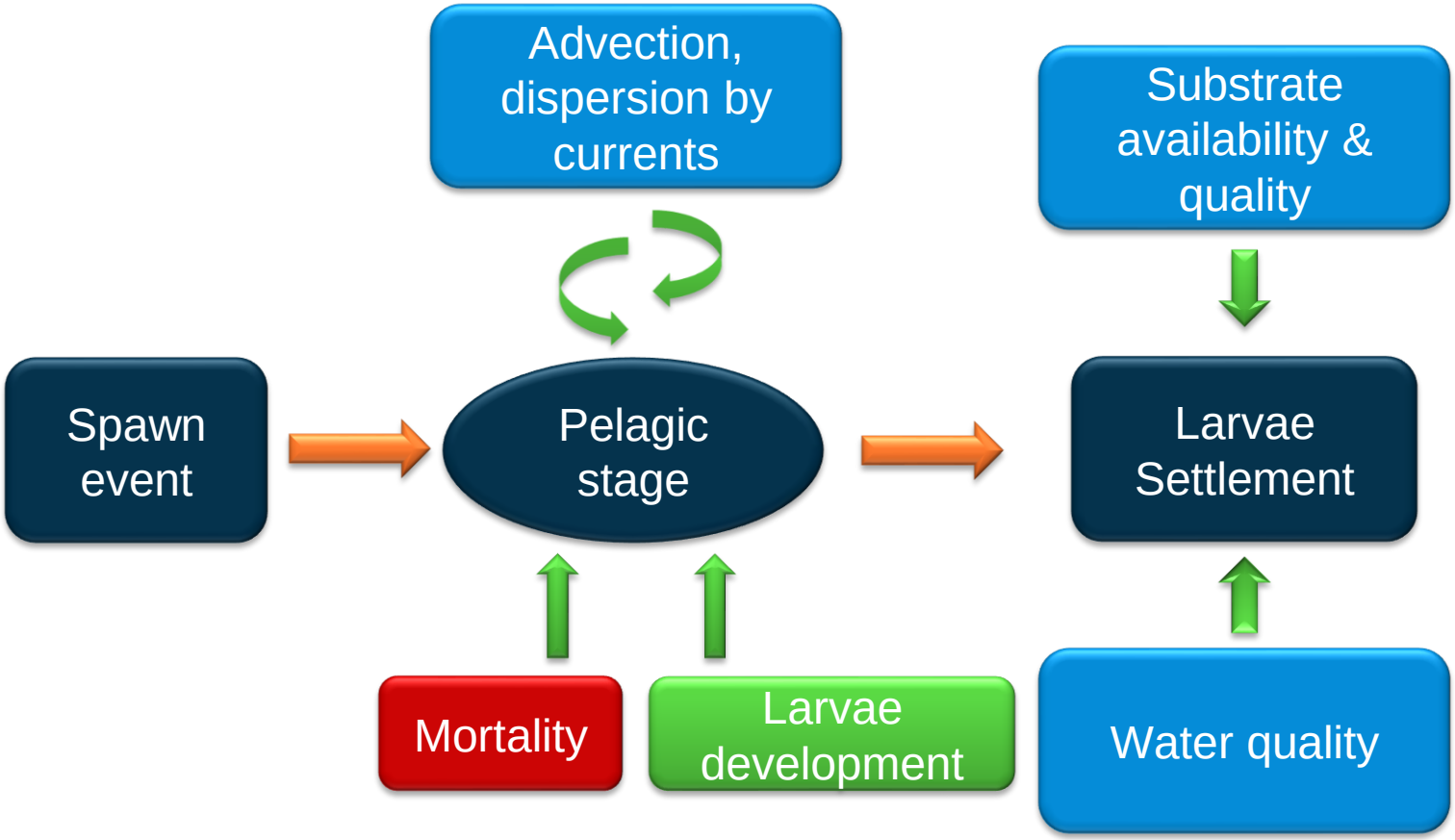


Example: Coral reef connectivity

- **Water quality**
  - *Physico-chemical parameters*
  - *Sediments*
- **Substrate availability & quality**
  - *Consolidation*
  - *Complexity & rugosity*
  - *Surface features*
- **Hydrodynamics**
  - *Sources & sinks*
  - *Larval transport*

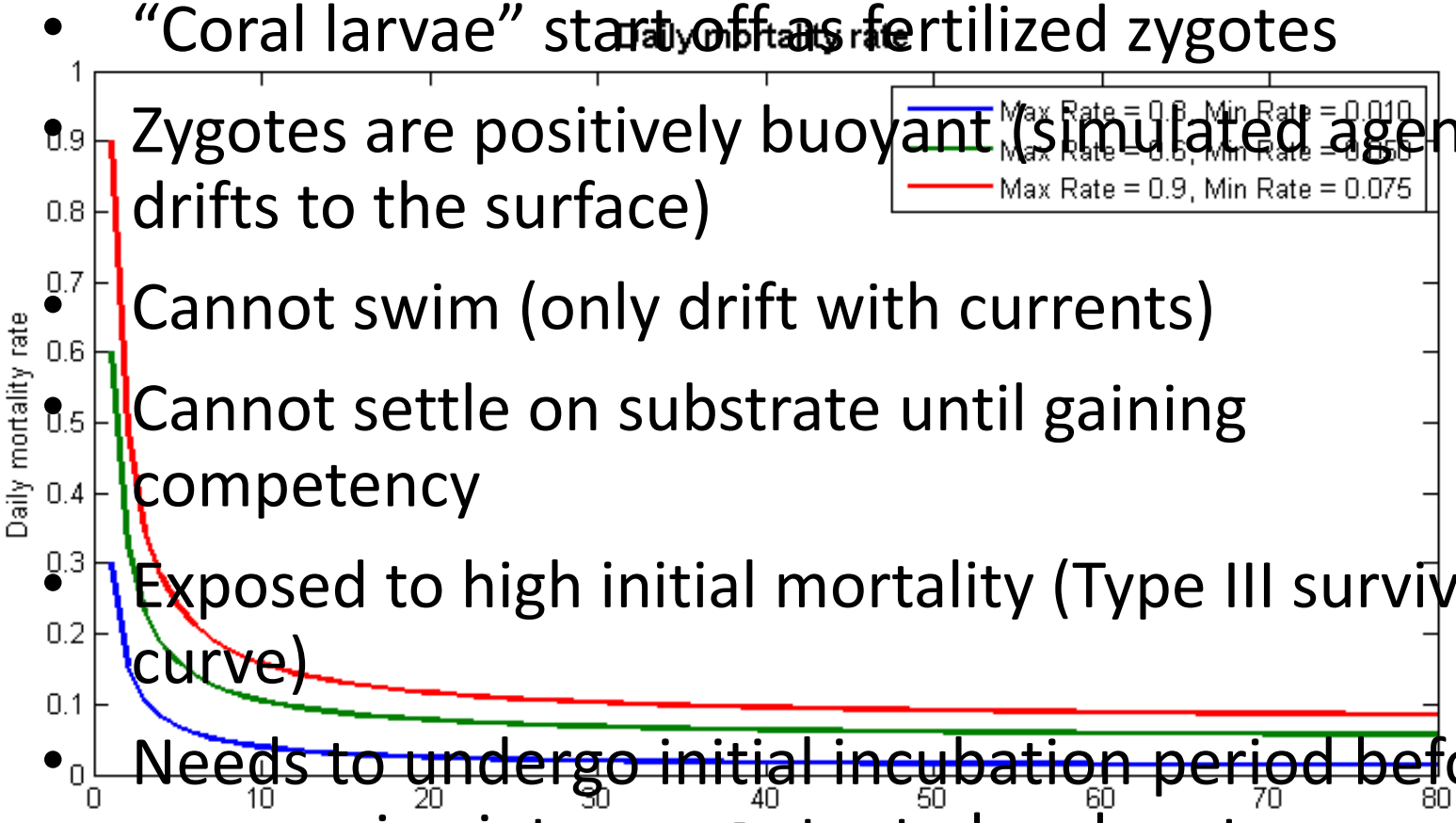
Example: Coral reef connectivity

Translating variables into a conceptual model



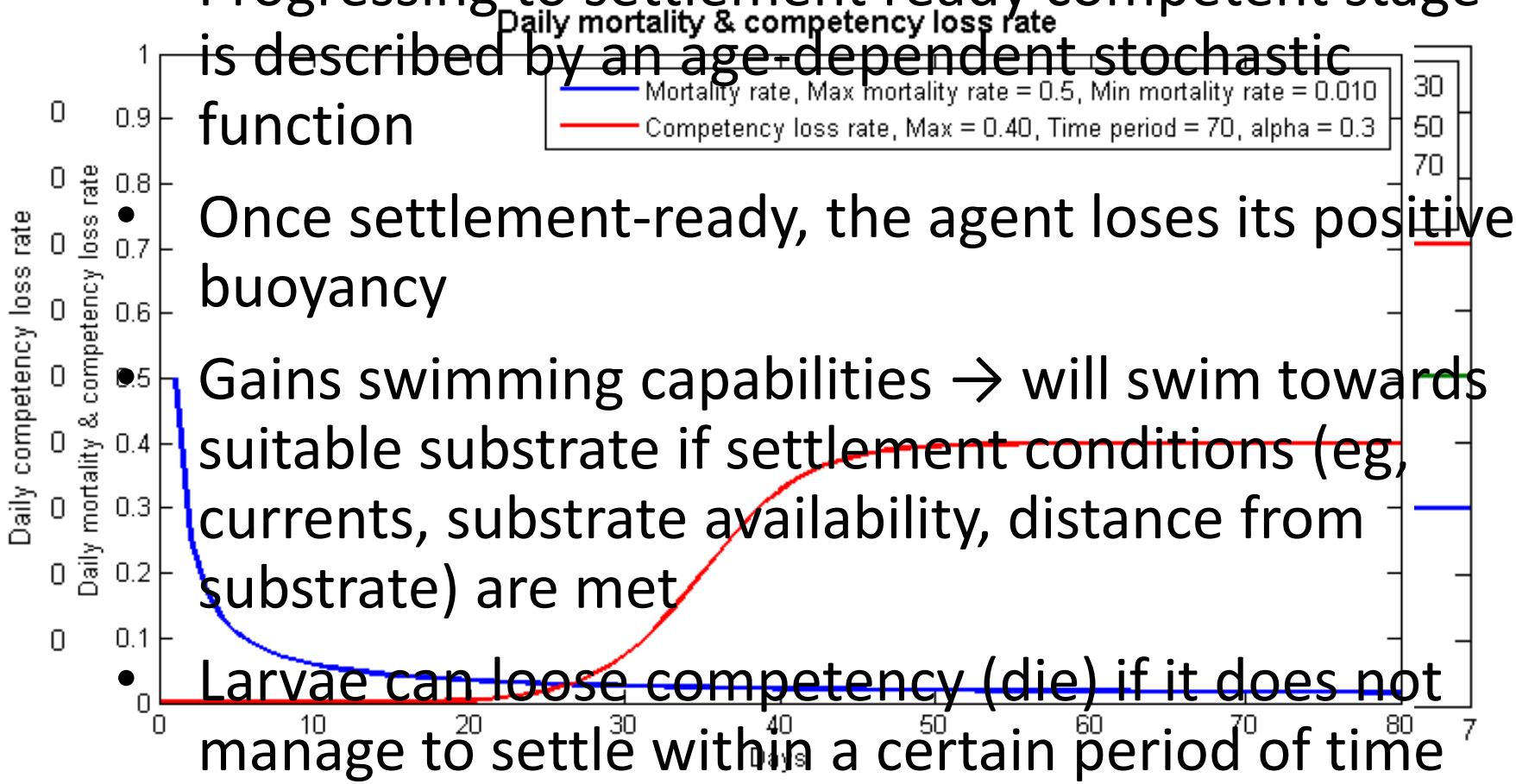
Example: Coral reef connectivity

- Model features – ***zygote stage***:
  - "Coral larvae" start off as fertilized zygotes
  - Zygotes are positively buoyant (simulated agents drifts to the surface)
  - Cannot swim (only drift with currents)
  - Cannot settle on substrate until gaining competency
  - Exposed to high initial mortality (Type III survival curve)
  - Needs to undergo initial incubation period before progressing into competent planulae stage

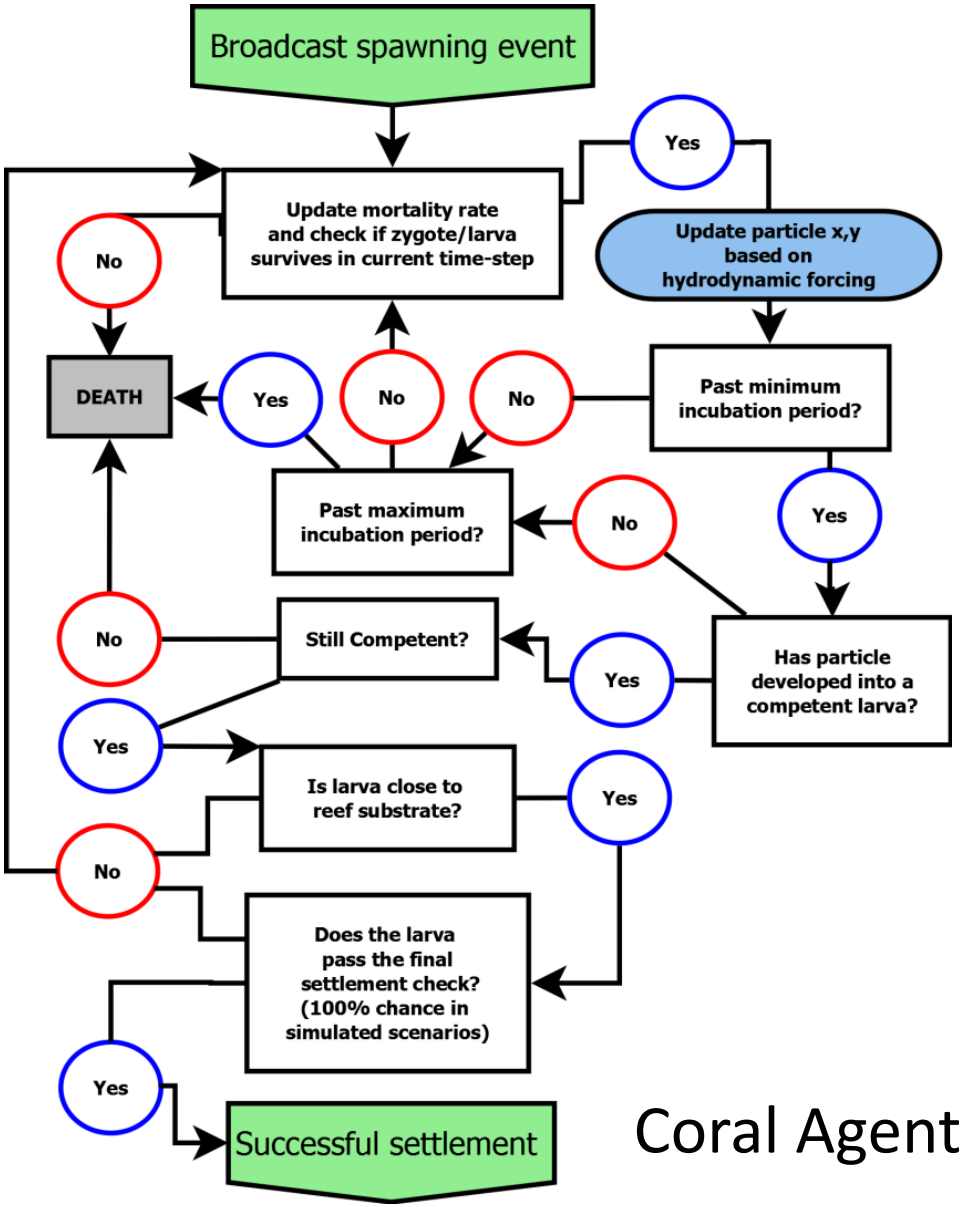


Example: Coral reef connectivity

- Model features – ***planulae stage***:
  - Progressing to settlement ready competent stage is described by an age-dependent stochastic function
  - Once settlement-ready, the agent loses its positive buoyancy
  - Gains swimming capabilities → will swim towards suitable substrate if settlement conditions (eg, currents, substrate availability, distance from substrate) are met
  - Larvae can loose competency (die) if it does not manage to settle within a certain period of time



Example: Coral reef connectivity



Coral Agent-Based Model

Example: Coral reef connectivity

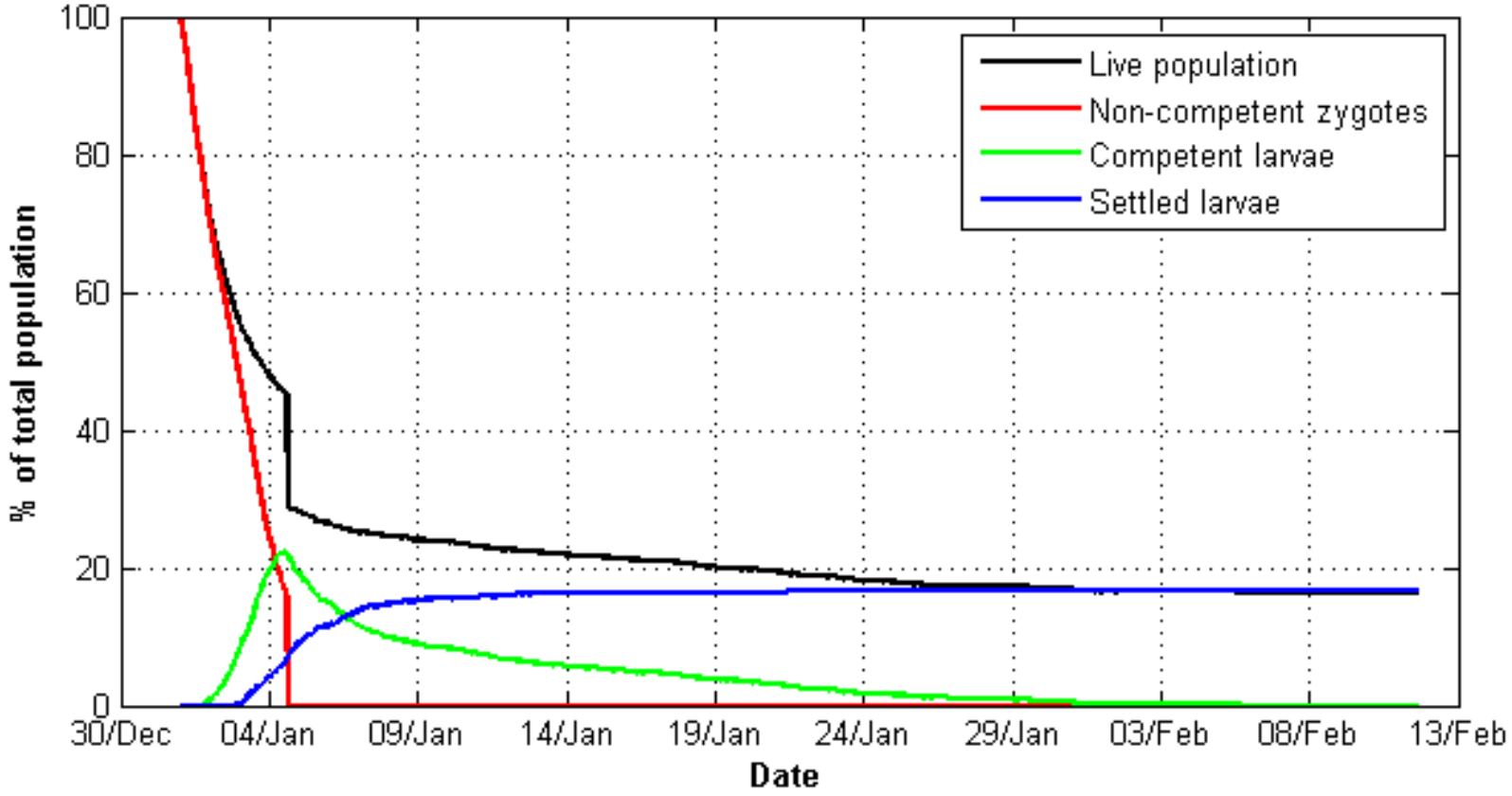
Single-source reef

Example: Coral reef connectivity

Multiple-source reefs

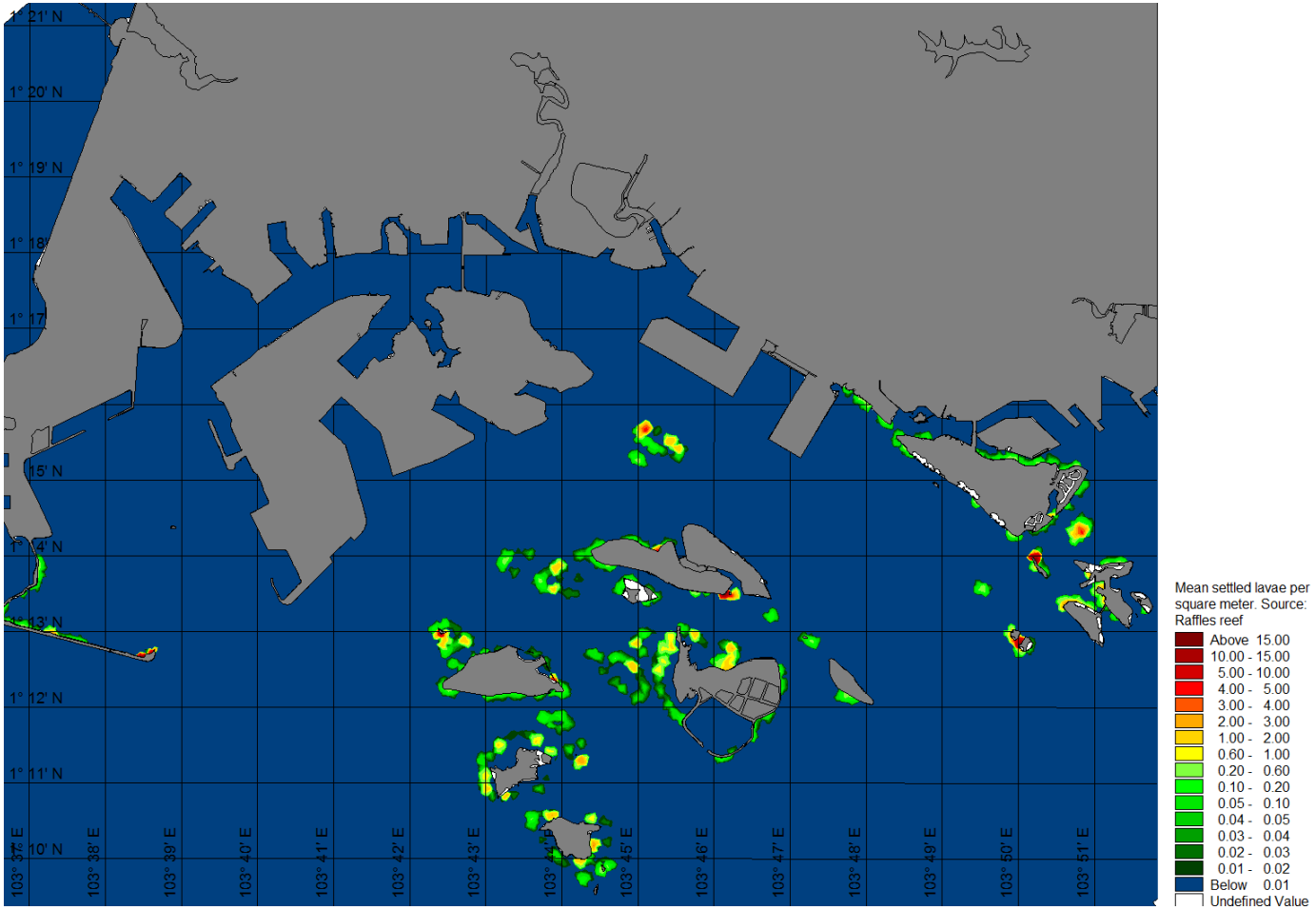
Example: Coral reef connectivity

Model predicted life-history of coral larvae



Example: Coral reef connectivity

Model-predicted settlement success



Example: Coral reef connectivity

Cumulative densities of coral larvae reveal connectivity corridors

Example: Coral reef connectivity

- From model to understanding connectivity patterns:
  - Larvae populations highly inter-connected due to high mixing environment ***=> limited connectivity barriers within coastal waters***
  - Overall settlement has reduced with a factor 2 (proportional to coral cover lost) since pre-industrial era ***=> if coral cover can be maintained, continued recruitment can be sustained***
  - High current speeds act as invisible barrier for connectivity between Singapore and Indonesia ***=> reefs are largely self-seeding, thus maintaining cover and diversity crucial to coral reef survival in Singapore***

Example: Coral reef connectivity

- From understanding connectivity patterns to management:
  - Useful tool for establishing baseline connectivity between important habitats ***=> allows prioritization of habitats for conservation and management***
  - Useful tool for identifying best suited areas for habitat enhancement/restoration efforts ***=> e.g., allows optimal site selection for artificial reef development***

Scaling up

- Locally:
  - Using various ABM models individually or in combination in spatial planning, optimizing coastal development, etc.
- Regionally:
  - Determining regional habitat connectivity for development of Same Risk Areas (IMO BWMC G7 Risk Assessment Guidelines (2017))

So what's next?

- Field validation
- Model optimisation
- Expand to include more taxa groups and species
- Test-bedding – locally, regionally

Thank you!

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THANK YOU!