

Techniques for incorporating trait and mixing heterogeneity in population models

- ▶ Biology pitch session

Techniques for incorporating trait and mixing heterogeneity in population models

- ▶ Biology pitch session

- ▶ August 2025

Techniques for incorporating trait and mixing heterogeneity in population models

- ▶ Biology pitch session
- ▶ August 2025

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me
- ▶ Investigate sources and effects of heterogeneity in a dynamical context

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me
- ▶ Investigate sources and effects of heterogeneity in a dynamical context
 - ▶ What are the assumptions of classical models?

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me
- ▶ Investigate sources and effects of heterogeneity in a dynamical context
 - ▶ What are the assumptions of classical models?
 - ▶ How does emergent heterogeneity interact with explicit heterogeneity?

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me
- ▶ Investigate sources and effects of heterogeneity in a dynamical context
 - ▶ What are the assumptions of classical models?
 - ▶ How does emergent heterogeneity interact with explicit heterogeneity?
- ▶ Practical approaches for modeling heterogeneity

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me
- ▶ Investigate sources and effects of heterogeneity in a dynamical context
 - ▶ What are the assumptions of classical models?
 - ▶ How does emergent heterogeneity interact with explicit heterogeneity?
- ▶ Practical approaches for modeling heterogeneity
 - ▶ Includes both algorithms and mathematical analysis

Aims

- ▶ Develop statistical methods for analyzing and building on mixing data
 - ▶ Exciting, but I'm not necessarily up to date
 - ▶ A lot of ad hoc COVID stuff, including by me
- ▶ Investigate sources and effects of heterogeneity in a dynamical context
 - ▶ What are the assumptions of classical models?
 - ▶ How does emergent heterogeneity interact with explicit heterogeneity?
- ▶ Practical approaches for modeling heterogeneity
 - ▶ Includes both algorithms and mathematical analysis

Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographical

Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones

Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones
- ▶ Matrices often don't balance

Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones
- ▶ Matrices often don't balance
 - ▶ Old people know more young people

Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones
- ▶ Matrices often don't balance
 - ▶ Old people know more young people
 - ▶ Men have more sex than women

Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones
- ▶ Matrices often don't balance
 - ▶ Old people know more young people
 - ▶ Men have more sex than women
- ▶ What are methods for incorporating these data?

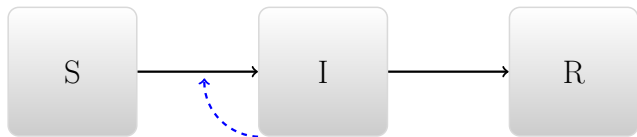
Aim 1: Mixing matrices

- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones
- ▶ Matrices often don't balance
 - ▶ Old people know more young people
 - ▶ Men have more sex than women
- ▶ What are methods for incorporating these data?
- ▶ How do assumptions propagate to outcomes?

Aim 1: Mixing matrices

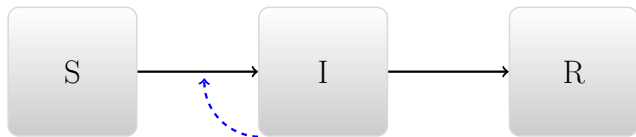
- ▶ E.g., ages, risk groups, geographica
- ▶ Data from surveys, cell phones
- ▶ Matrices often don't balance
 - ▶ Old people know more young people
 - ▶ Men have more sex than women
- ▶ What are methods for incorporating these data?
- ▶ How do assumptions propagate to outcomes?

Aim 2: Dynamical heterogeneity



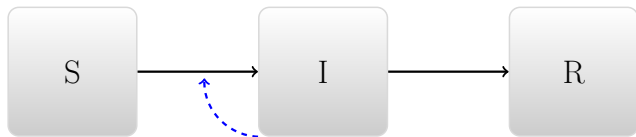
- People are in different “groups”

Aim 2: Dynamical heterogeneity



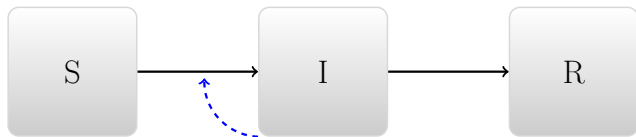
- ▶ People are in different “groups”
 - ▶ sex, age, behaviour

Aim 2: Dynamical heterogeneity



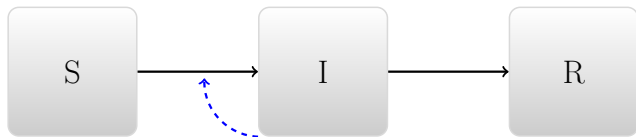
- ▶ People are in different “groups”
 - ▶ sex, age, behaviour
- ▶ People get infected at different times, recover at different times

Aim 2: Dynamical heterogeneity



- ▶ People are in different “groups”
 - ▶ sex, age, behaviour
- ▶ People get infected at different times, recover at different times
 - ▶ effectively modeled as random

Aim 2: Dynamical heterogeneity



- ▶ People are in different “groups”
 - ▶ sex, age, behaviour
- ▶ People get infected at different times, recover at different times
 - ▶ effectively modeled as random

Aim 3: Practical approaches

- ▶ This is kind of a hodge-podge

Aim 3: Practical approaches

- ▶ This is kind of a hodge-podge
- ▶ Making multi-group models

Aim 3: Practical approaches

- ▶ This is kind of a hodge-podge
- ▶ Making multi-group models
- ▶ Making network models

Aim 3: Practical approaches

- ▶ This is kind of a hodge-podge
- ▶ Making multi-group models
- ▶ Making network models
- ▶ Making models with simple approximations

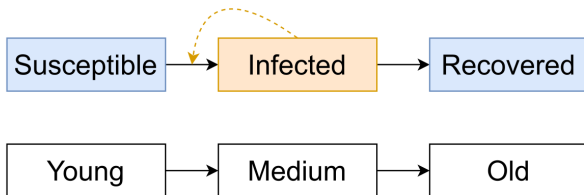
Aim 3: Practical approaches

- ▶ This is kind of a hodge-podge
- ▶ Making multi-group models
- ▶ Making network models
- ▶ Making models with simple approximations
 - ▶ ... and testing them

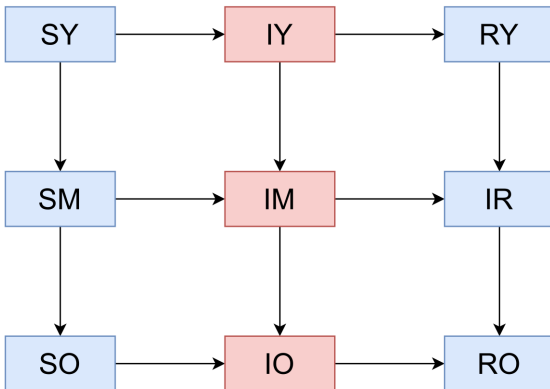
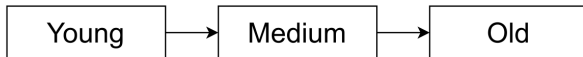
Aim 3: Practical approaches

- ▶ This is kind of a hodge-podge
- ▶ Making multi-group models
- ▶ Making network models
- ▶ Making models with simple approximations
 - ▶ ... and testing them

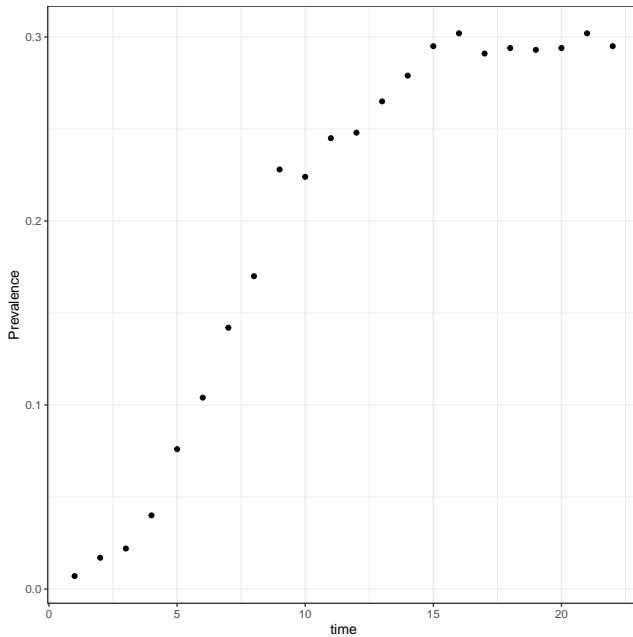
Structured models



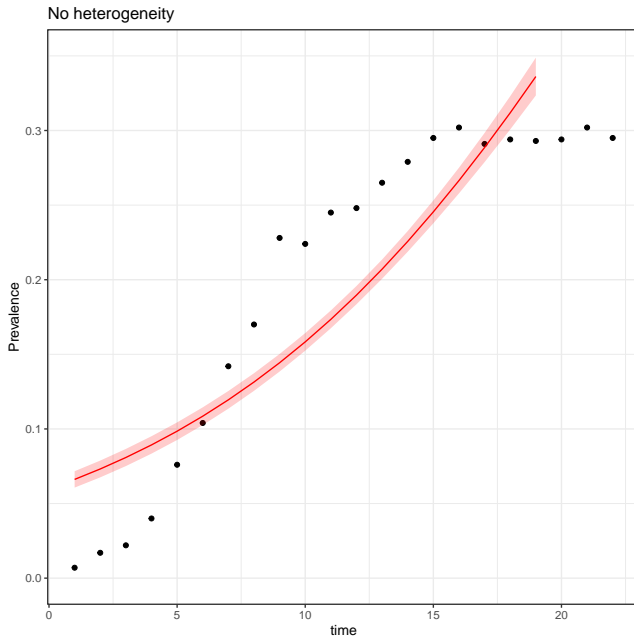
Structured models



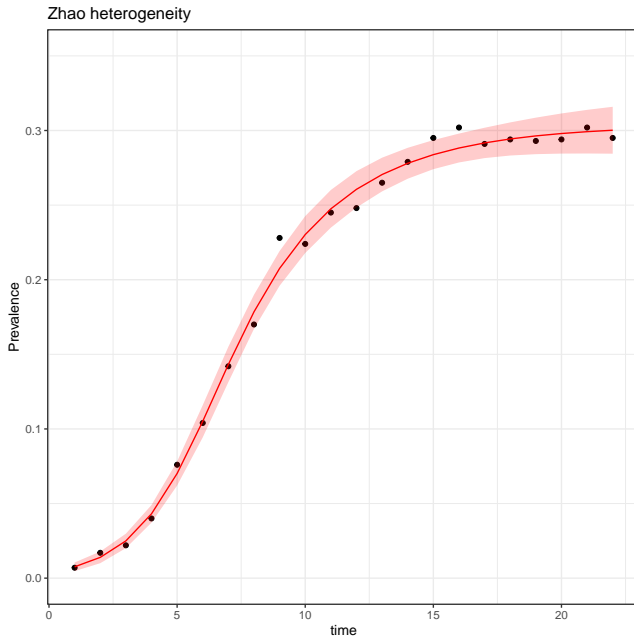
Approximations



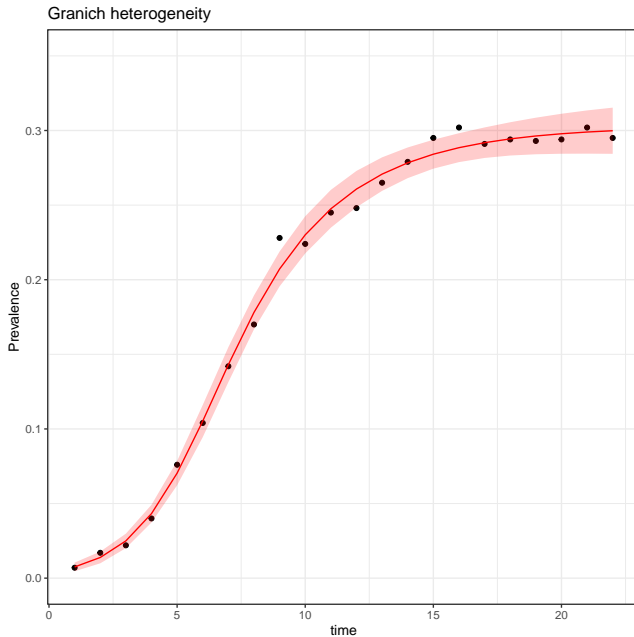
Approximations



Approximations



Approximations



Methodology

- ▶ Lots of validation in simulated worlds

Methodology

- ▶ Lots of validation in simulated worlds
 - ▶ Simulate survey answers and movement data with biases

Methodology

- ▶ Lots of validation in simulated worlds
 - ▶ Simulate survey answers and movement data with biases
 - ▶ Simulate how disease would spread in these populations

Methodology

- ▶ Lots of validation in simulated worlds
 - ▶ Simulate survey answers and movement data with biases
 - ▶ Simulate how disease would spread in these populations
 - ▶ And what inferences would be made with various methodologies

Methodology

- ▶ Lots of validation in simulated worlds
 - ▶ Simulate survey answers and movement data with biases
 - ▶ Simulate how disease would spread in these populations
 - ▶ And what inferences would be made with various methodologies
- ▶ Simulate outbreaks with lots of unknowns

Methodology

- ▶ Lots of validation in simulated worlds
 - ▶ Simulate survey answers and movement data with biases
 - ▶ Simulate how disease would spread in these populations
 - ▶ And what inferences would be made with various methodologies
 - ▶ Simulate outbreaks with lots of unknowns

Math vs. ecology

- ▶ This looks like biology to math people and like math to ecologists

Math vs. ecology

- ▶ This looks like biology to math people and like math to ecologists
- ▶ I suggested Evolution and ecology group

Math vs. ecology

- ▶ This looks like biology to math people and like math to ecologists
- ▶ I suggested Evolution and ecology group
 - ▶ It does have people that will understand

Math vs. ecology

- ▶ This looks like biology to math people and like math to ecologists
- ▶ I suggested Evolution and ecology group
 - ▶ It does have people that will understand
- ▶ Could be passed a math/stats group

Math vs. ecology

- ▶ This looks like biology to math people and like math to ecologists
- ▶ I suggested Evolution and ecology group
 - ▶ It does have people that will understand
- ▶ Could be passed a math/stats group
 - ▶ Most of my reviewers are in math departments, although they all do stuff that could be seen as evolution and ecology

Math vs. ecology

- ▶ This looks like biology to math people and like math to ecologists
- ▶ I suggested Evolution and ecology group
 - ▶ It does have people that will understand
- ▶ Could be passed a math/stats group
 - ▶ Most of my reviewers are in math departments, although they all do stuff that could be seen as evolution and ecology

Scoping

- ▶ These phenomena are very important for the spread of infectious disease, and I know a lot about this.

Scoping

- ▶ These phenomena are very important for the spread of infectious disease, and I know a lot about this.
- ▶ I will also talk about other examples, but I really don't know strategically how broad or focused to be

Scoping

- ▶ These phenomena are very important for the spread of infectious disease, and I know a lot about this.
- ▶ I will also talk about other examples, but I really don't know strategically how broad or focused to be

NSERC vs. CIHR

- ▶ NSERC supports foundational work, new models, etc.

NSERC vs. CIHR

- ▶ NSERC supports foundational work, new models, etc.
- ▶ Be specific about scoping

NSERC vs. CIHR

- ▶ NSERC supports foundational work, new models, etc.
- ▶ Be specific about scoping
- ▶ Apply for a CIHR grant and try to draw clear lines

NSERC vs. CIHR

- ▶ NSERC supports foundational work, new models, etc.
- ▶ Be specific about scoping
- ▶ Apply for a CIHR grant and try to draw clear lines
 - ▶ make it clear that work will still be useful without the CIHR grant

NSERC vs. CIHR

- ▶ NSERC supports foundational work, new models, etc.
- ▶ Be specific about scoping
- ▶ Apply for a CIHR grant and try to draw clear lines
 - ▶ make it clear that work will still be useful without the CIHR grant

Other applications

- ▶ Maybe easiest to stick with things that are infectious

Other applications

- ▶ Maybe easiest to stick with things that are infectious
 - ▶ Definitely include non-human disease systems

Other applications

- ▶ Maybe easiest to stick with things that are infectious
 - ▶ Definitely include non-human disease systems
 - ▶ Bats, bacteria

Other applications

- ▶ Maybe easiest to stick with things that are infectious
 - ▶ Definitely include non-human disease systems
 - ▶ Bats, bacteria
 - ▶ Could include spread of information, ideas, behaviours

Other applications

- ▶ Maybe easiest to stick with things that are infectious
 - ▶ Definitely include non-human disease systems
 - ▶ Bats, bacteria
 - ▶ Could include spread of information, ideas, behaviours
 - ▶ Bacterial signaling?

Other applications

- ▶ Maybe easiest to stick with things that are infectious
 - ▶ Definitely include non-human disease systems
 - ▶ Bats, bacteria
 - ▶ Could include spread of information, ideas, behaviours
 - ▶ Bacterial signaling?
- ▶ Are there other contexts where it makes sense?

Other applications

- ▶ Maybe easiest to stick with things that are infectious
 - ▶ Definitely include non-human disease systems
 - ▶ Bats, bacteria
 - ▶ Could include spread of information, ideas, behaviours
 - ▶ Bacterial signaling?
 - ▶ Are there other contexts where it makes sense?

Metapopulation models

Bacterial co-operation and quorum sensing

Viral “behaviour”; can also talk about viral dynamics as another scale for disease modeling