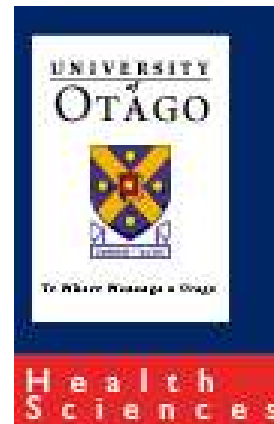


# Does Mortality Vary Between Pacific Groups?

Estimating Samoan, Cook Island Maori, Tongan and Niuean mortality rates using hierarchical Bayesian modelling

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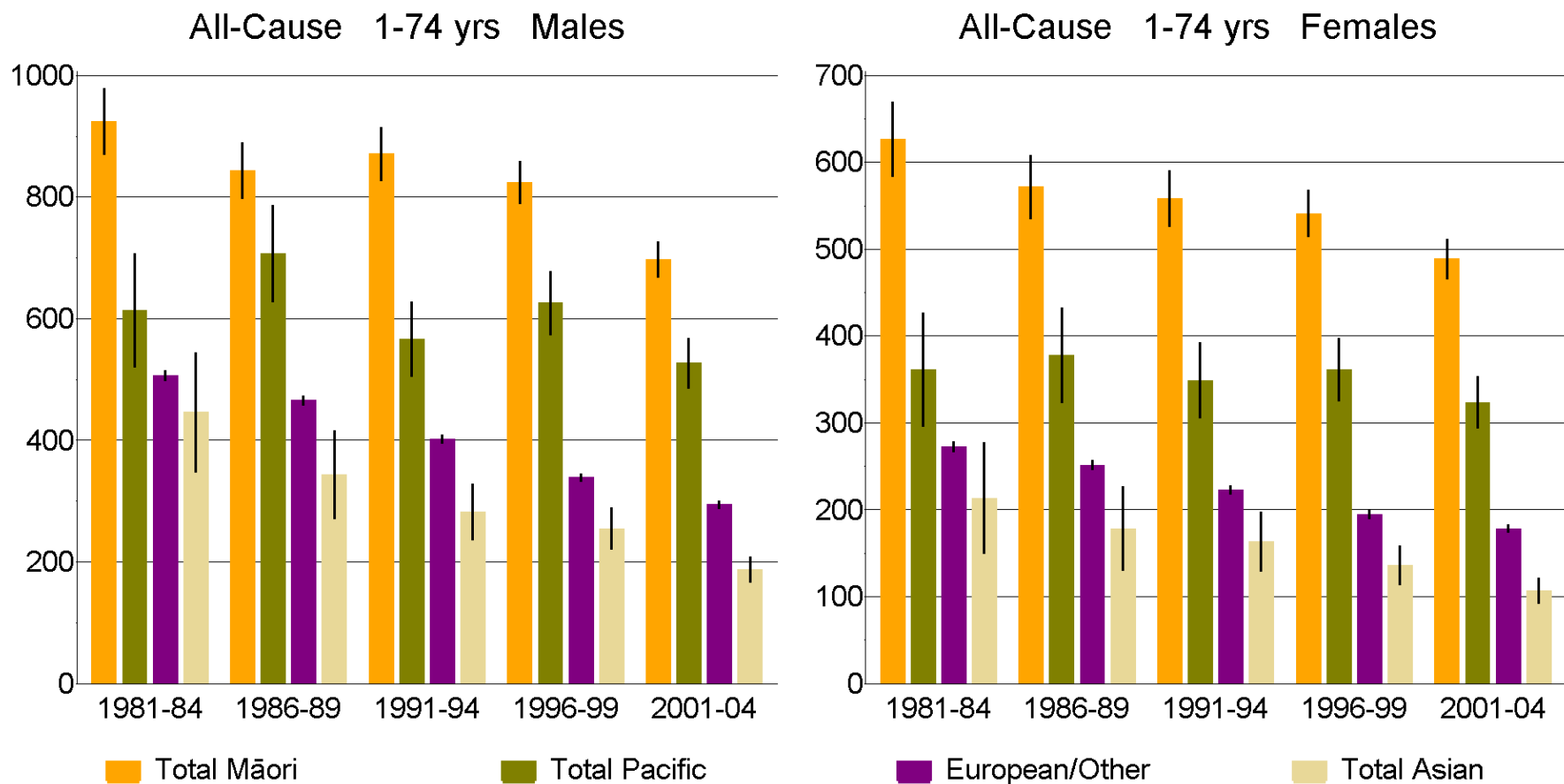
# Overview

- Background – Pacific mortality
- Objectives of project
- Method:
  - Data
  - Hierarchical Bayesian (HB) modeling
- Results:
  - HB results
  - HB versus direct standardisation results
  - Sensitivity analyses
- Conclusions

# Background

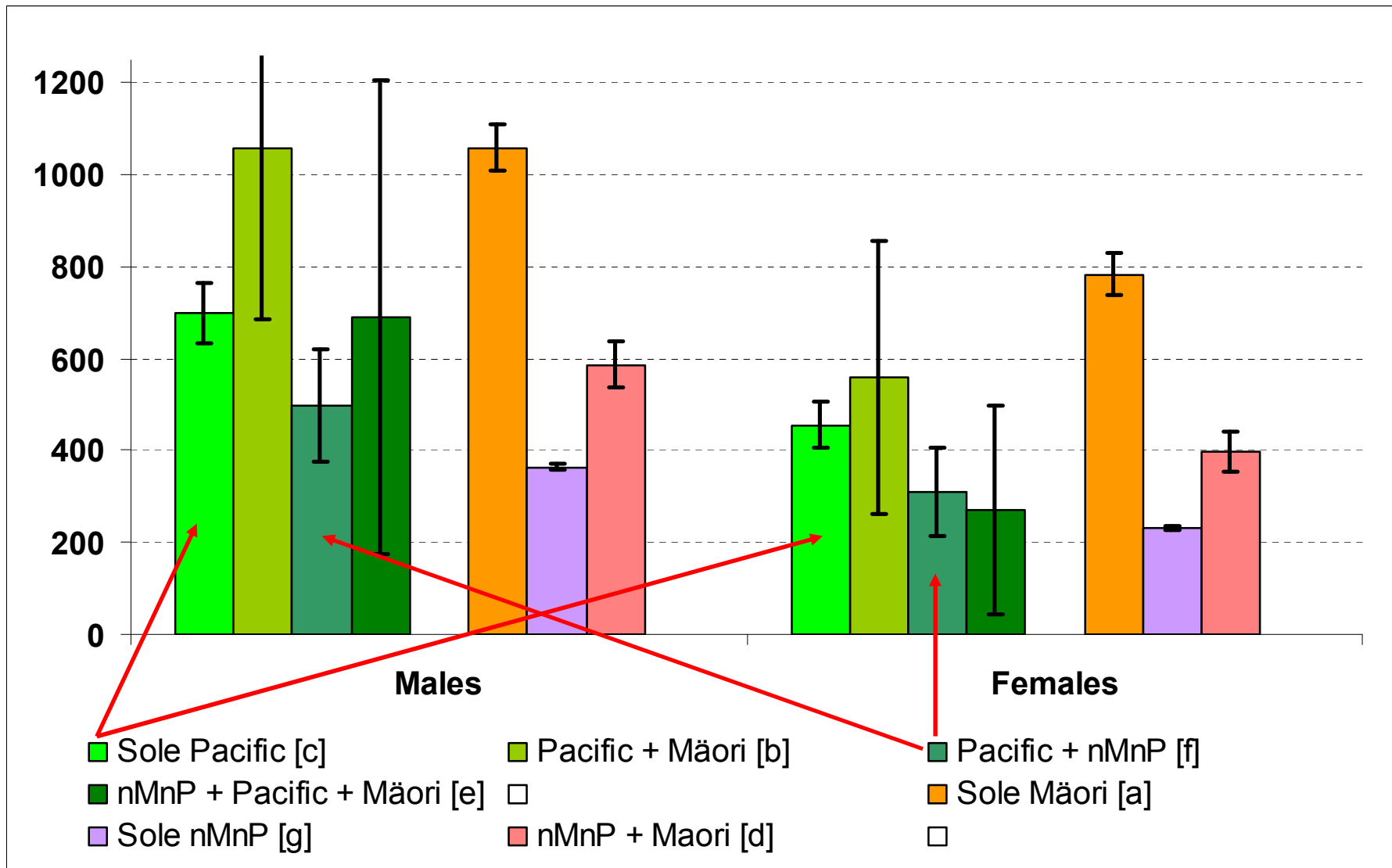
- Pacific mortality rates are traditionally presented for all Pacific people combined...
- ...yet there is likely heterogeneity between separate Pacific groups.

# All-cause mortality rates by ethnicity, 1-74 yrs



Percentage decline 1981-84 to 2001-04				
	Māori	Pacific	Asian	European/Other
Males	25%	14%	58%	42%
Females	22%	10%	50%	35%

# Mortality rates for various groupings of Pacific ethnicity: 1996-99 NZCMS results



# Socio-demographic data

<b>Variable</b>	<b>Census year</b>	<b>Samoan</b>	<b>Cook Island Maori</b>	<b>Tongan</b>	<b>Niuean</b>
<b>Number</b>	2001	115,000	52,600	40,700	20,100
<b>Median age (years) #</b>	2006	20.9	18.9	18.6	19.6
<b>Current smokers #</b>	2006	28%	38%	29%	33%
<b>% adults with formal qualification #</b>	2006	69%	55%	64%	60%
<b>Born in NZ</b>	2001	58%	70%	53%	70%
<b>Median personal income for adults</b>	2006	\$21,400	\$19,800	\$17,500	\$21,500

# Objectives

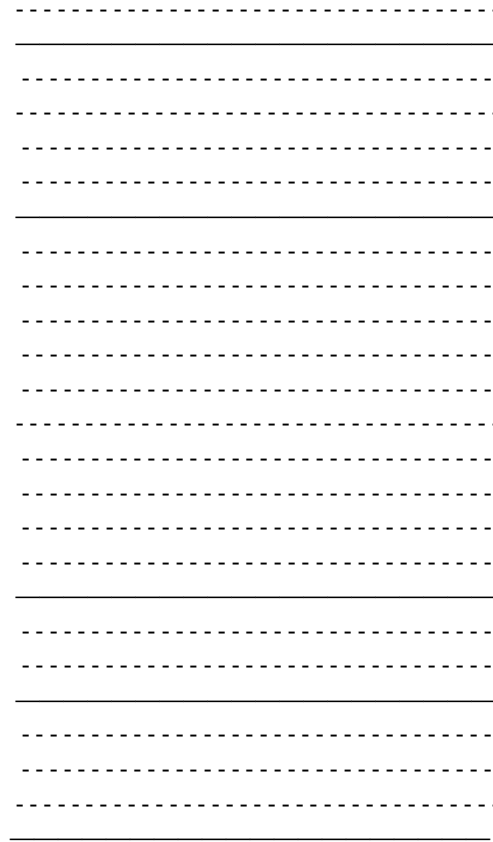
- We aimed to determine mortality rates for Samoan, Cook Island Maori, Tongan and Niuean people.
- We also aimed to test and demonstrate the application of hierarchical Bayesian methods to sparse data.

# NZCMS: method in one slide

1991 census cohort  
(0-74 yr olds)



Anonymous and probabilistic  
record linkage



Deaths

+

+

+

+

+

# Data definitions

- Linked census-mortality (NZCMS) data
- Cohort: 01/04
- Ages: 0-74
- What: Aggregated deaths (counts) and person-time-at-risk (years) in 240 ethnicity-sex-age-income-natality strata
- CoD: Allcause, CVD, cancer, injury-suicide

# Stratum definitions

- Ethnicity: “Total” counts  
(Samoan, Cook Island Maori, Tongan, Niuean)
- Ages: 0-14, 15-34, 35-44<sup>k1</sup>, 45-64<sup>k2</sup>, 65-74  
(centred & scaled)
- Income: Equivalised household (tertiles, centred & scaled)
- Natality: NZ or overseas born

# Hierarchical Bayesian model

At the ‘data level’, for stratum  $i$ , ethnicity  $j$ , death is a Poisson process with a cell-specific mortality rate:

$$d_{ij} \mid P_{ij}, \lambda_{ij} \sim \text{Poisson}[P_{ij} \lambda_{ij}, P_{ij} \lambda_{ij}]$$

with mortality rates and prior model (at level 2):

$$\lambda_{ij} \mid X_i, \boldsymbol{\beta}_j, \zeta \sim \text{gamma}[\mu_{ij}, \mu_{ij}^2 / \zeta],$$

$$\log(\mu_{ij}) = X_i \boldsymbol{\beta}_j$$

- and ‘hyperpriors’ (level 3)

$$(\boldsymbol{\beta}_j, \zeta) \sim \pi \text{ (vague)}$$

- Prior model coefficients (level 2)

$$\boldsymbol{\beta}_j = (\beta_{0j}, \beta_{sex}, \beta_{age}, \beta_{nat}, \beta_{inc}, \dots)$$

can include an (ethnicity-dependent) intercept, sex, age, natality, income, age x income, and sex x income

Level 1	$d_{ij} \mid P_{ij}, \lambda_{ij} \sim \text{Poisson}[P_{ij} \lambda_{ij}, P_{ij} \lambda_{ij}]$
Level 2	$\lambda_{ij} \mid X_i, \boldsymbol{\beta}_j, \zeta \sim \text{gamma}[\mu_{ij}, \mu_{ij}^2 / \zeta]$ $\log(\mu_{ij}) = X_i \boldsymbol{\beta}_j$
Level 3	$(\boldsymbol{\beta}, \zeta) \sim \pi$

# HB model implications: Shrinkage

- The conditional mean posterior mortality rate  $E(\lambda_{ij} | y, \beta_j, \zeta)$  is a weighted mean of the prior mean  $\mu_{ij}$  and the empirical rate  $d_{ij}/P_{ij}$
- The weights depend on the mortality rate variance parameter  $\zeta$ , and  $P_{ij}$
- As  $P_{ij} \rightarrow \infty$ ,  $E(\lambda_{ij} | \dots) \rightarrow d_{ij}/P_{ij}$
- As  $P_{ij} \rightarrow 0$ ,  $E(\lambda_{ij} | \dots) \rightarrow \mu_{ij}$

## HB model implications:

- Estimation of prior model parameters tends to smooth out instabilities in empirical rates arising from low person-time-at risk ...
- but without forcing posterior rates to conform exactly to the prior model
- Removing a variable from the prior model doesn't remove its influence on posterior rates

# HB model output

- For each ethnic group and CoD, posterior stratum mortality rates and rate ratios standardised to the person-time of the Pacific population across strata of sex, age, income, and natality (and subsets thereof)
- Means and credibility intervals (CIs) for the standardised Pacific-specific rates
- Means and CIs for rate ratios between Pacific groups

# HB model pros:

- Pools information across “small” cells/domains
- Accommodates heteroskedasticity across clusters
- Some protection against model miss-specification
- Good out-of-sample predictive properties
- Realistic estimates of uncertainty without further assumptions (e.g., asymptotic normality)
- A consistent framework for realistically complex models. Thus comparisons possible at lower levels of aggregation e.g., NZ vs overseas born

## HB model cons:

- Bayesian approaches not (yet) common in epidemiology
- Plenty of tools to help (R, WinBugs) but a “black box” approach is not feasible e.g., sensitivity to priors, ...
- Model convergence/selection/etc methods available (e.g., Gelman-Rubin statistic, deviance information criterion) but less automated than in likelihood approaches
- Complex models (can be) demanding of staff/computational resources and time

Posterior all-cause mortality rates (per 100 000) and rate ratios (95% credibility intervals) by Pacific groups from models extended to include natality and household income

Group	Rates			Rate ratios c.f. Samoan		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Cook Island	288 (255, 325)			1.18 (1.02,1.37)		
Niue	252 (208, 297)			1.03 (0.84, 1.24)		
Samoa	244 (224, 266)			1		
Tonga	234 (197, 269)			0.96 (0.80, 1.12)		

Model 1 = data stratified by ethnic group, sex and age only; sex and age included as independent variables in prior model; posterior rates directly standardised to the NZ Pacific population using a total definition of ethnicity.

Posterior all-cause mortality rates (per 100 000) and rate ratios (95% credibility intervals) by Pacific groups from models extended to include natality and household income

Group	Rates			Rate ratios c.f. Samoan		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Cook Island	288 (255, 325)	295 (260, 333)		1.18 (1.02,1.37)	1.22 (1.05, 1.41)	
Niue	252 (208, 297)	257 (211, 306)		1.03 (0.84, 1.24)	1.06 (0.86, 1.28)	
Samoa	244 (224, 266)	243 (222, 264)		1	1	
Tonga	234 (197, 269)	228 (193, 264)		0.96 (0.80, 1.12)	0.94 (0.79, 1.11)	

Model 1 = data stratified by ethnic group, sex and age only; sex and age included as independent variables in prior model; posterior rates directly standardised to the NZ Pacific population using a total definition of ethnicity.

Model 2 = model 1, additionally including natality as independent variable; posterior rates standardised as for model 1

Posterior all-cause mortality rates (per 100 000) and rate ratios (95% credibility intervals) by Pacific groups from models extended to include natality and household income

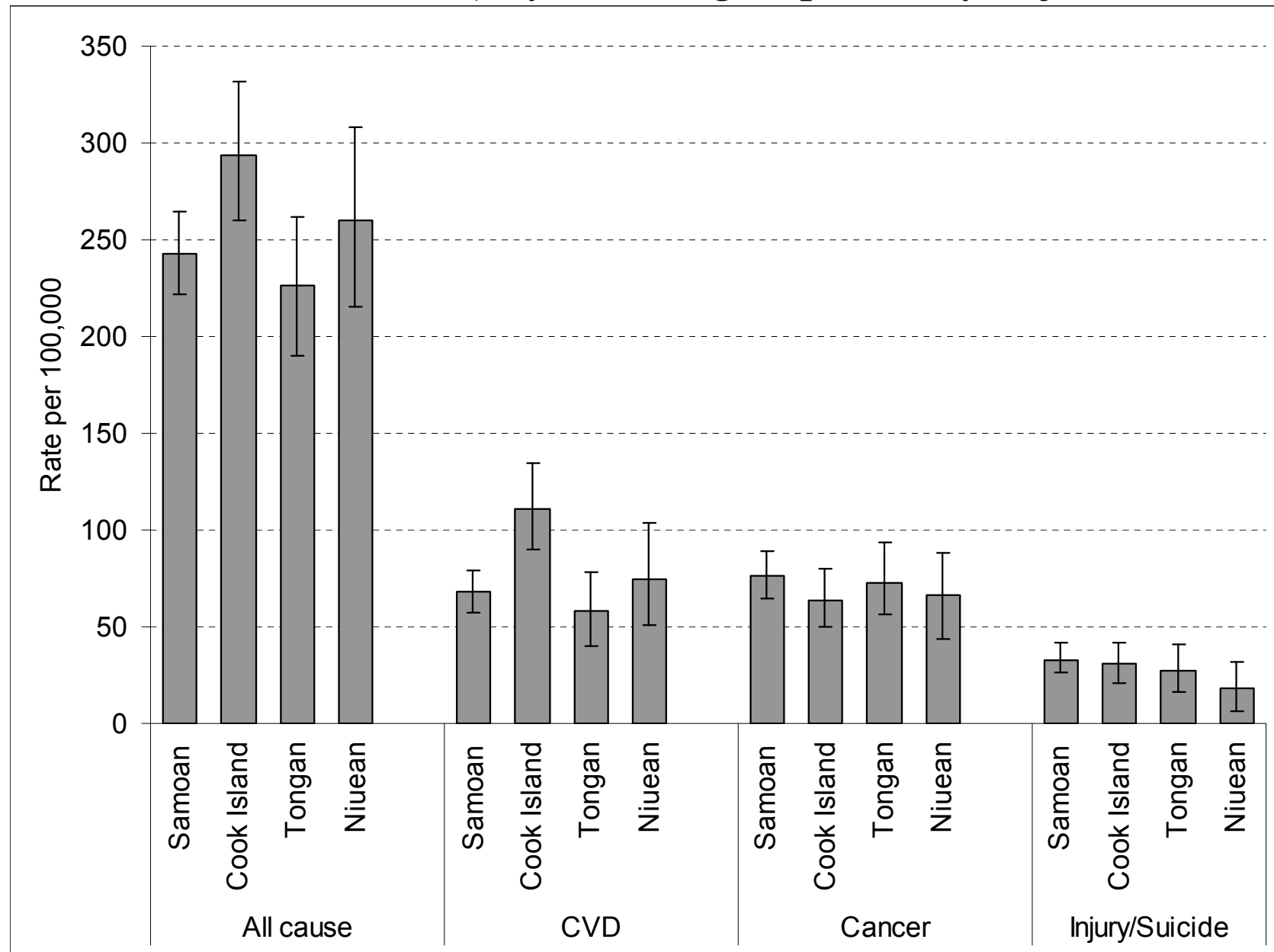
Group	Rates			Rate ratios c.f. Samoan		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Cook Island	288 (255, 325)	295 (260, 333)	294 (260, 332)	1.18 (1.02,1.37)	1.22 (1.05, 1.41)	1.21 (1.05, 1.42)
Niue	252 (208, 297)	257 (211, 306)	260 (215, 308)	1.03 (0.84, 1.24)	1.06 (0.86, 1.28)	1.07 (0.88, 1.29)
Samoa	244 (224, 266)	243 (222, 264)	243 (222, 265)	1	1	1
Tonga	234 (197, 269)	228 (193, 264)	226 (190, 262)	0.96 (0.80, 1.12)	0.94 (0.79, 1.11)	0.93 (0.77, 1.10)

Model 1 = data stratified by ethnic group, sex and age only; sex and age included as independent variables in prior model; posterior rates directly standardised to the NZ Pacific population using a total definition of ethnicity.

Model 2 = model 1, additionally including natality as independent variable; posterior rates standardised as for model 1

Model 3 = model 2, but extended similarly for household income.

Posterior all-cause and cause-specific mortality rates (per 100 000; 95% credible intervals) by Pacific groups – fully adjusted model



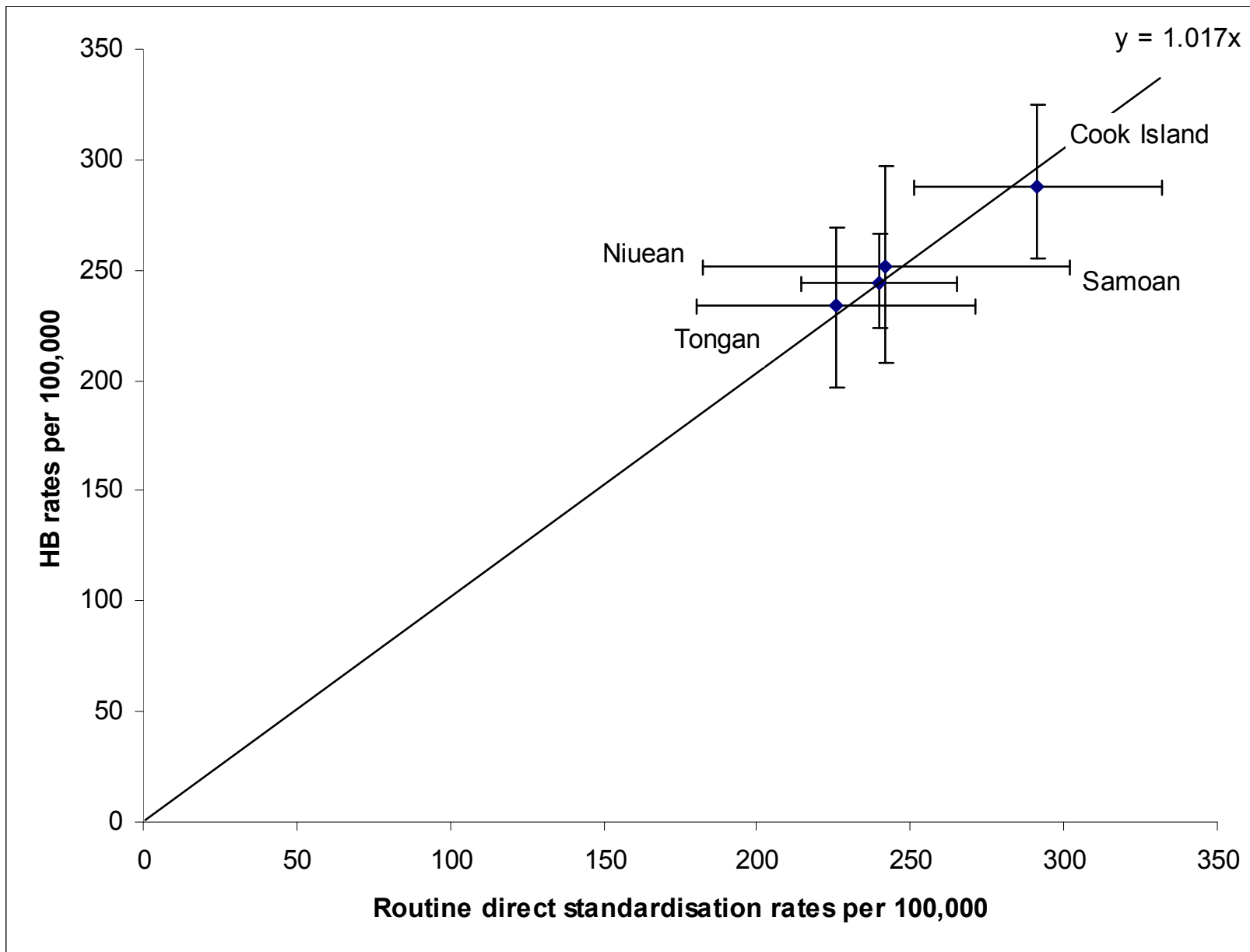
Posterior all-cause and cause-specific mortality rates (per 100 000) and rate ratios (95% credibility intervals) by Pacific groups

<b>Rates per 100,000</b>				
	<b>All-cause</b>	<b>CVD</b>	<b>Cancer</b>	<b>Inj/ Suicide</b>
Cook Island	294 (260, 332)	111 (90, 135)	64 (50, 80)	31 (21, 42)
Niue	260 (215, 308)	75 (51, 104)	66 (44, 88)	18 (6.0, 32)
Samoa	243 (222, 265)	68 (57, 79)	76 (65, 89)	33 (26, 42)
Tonga	226 (190, 262)	58 (40, 78)	73 (56, 94)	27 (16, 41)

<b>Rate ratios c.f. Samoan</b>				
<b>Group</b>	<b>All-cause</b>	<b>CVD</b>	<b>Cancer</b>	<b>Inj/ Suicide</b>
Cook Island	1.21 (1.05, 1.42)	1.66 (1.26, 2.13)	0.85 (0.56, 1.09)	0.93 (0.60, 1.34)
Niue	1.07 (0.88, 1.29)	1.11 (0.72, 1.58)	0.87 (0.54, 1.19)	0.53 (0.17, 0.99)
Samoa	1	1	1	1
Tonga	0.93 (0.77, 1.10)	0.86 (0.58, 1.20)	0.96 (0.71, 1.26)	0.82 (0.46, 1.28)

Scatter plot of HB versus direct standardisation all-cause mortality rates, sexes combined, for 0-74 year olds adjusted for sex and age



Sensitivity analyses about HB all-cause and CVD mortality rates for Cook Island Maori c.f. Samoan, for scenarios of: return migration when terminally ill; census undercounting

		All-cause	CVD
<b>HB rate ratio</b>		<b>1.21</b>	<b>1.63</b>
<i><u>Amount of return migration for terminally ill</u></i>			
<b>Non-differential</b>	<b>8%, 4%, 12% ...</b>	<b>1.21</b>	<b>1.63</b>
<i><u>Amount of census undercount</u></i>			

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<i><u>Amount of return migration for terminally ill</u></i>			
<b>Non-differential</b>	<b>8%, 4%, 12% ...</b>	<b>1.21</b>	<b>1.63</b>
<b>Differential, about best estimate of 8% as average</b>	<b>A. 10% Samoan; 5% Cook</b>	<b>1.15</b>	<b>1.55</b>
	<b>B. 12% Samoan; 3% Cook</b>	<b>1.10</b>	<b>1.48</b>
	<b>C. 25% Samoan; 0% Cook</b>	<b>0.91</b>	<b>1.22</b>
<i><u>Amount of census undercount</u></i>			

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	<b>C. 25% Samoan; 0% Cook</b>	<b>0.91</b>	<b>1.22</b>
<i><u>Amount of census undercount</u></i>			
<b>Non-differential</b>	<b>4%, 2%, 6%</b>	<b>1.21</b>	<b>1.63</b>
<b>Differential, about best estimate of 4% as average</b>	<b>6% Samoan; 2% Cook</b>	<b>1.26</b>	<b>1.70</b>

# Conclusion – substantive results

- Standardising for sex, age, income and natality, all-cause mortality rate ratios compared to Samoan were:
  - 1.21 (95% credibility interval 1.05 to 1.42) for Cook Island Maori;
  - 0.93 (0.77 to 1.10) for Tongan;
  - and 1.07 (0.88 to 1.29) for Niuean.
- CVD mortality rate ratios were:
  - 1.66 (1.26 to 2.13) for Cook Island Maori;
  - 1.11 (0.72 to 1.58) for Niuean;
  - 0.86 (0.58 to 1.20) for Tongan.
- Results little different standardising for just sex and age.
- Sensitivity analyses found the results to be robust.

# Conclusions - policy

- “Policy makers and their advisors need to be aware of differences in health status and risks between Pacific ethnic groups, and consider Pacific ethnic group-specific policies and programmes where relevant, alongside pan-Pacific approaches.”

# Conclusions - methodological

- We successfully implemented HB modelling – but it was time consuming and therefore costly
- Significant researcher up-skilling – but this barrier is overcome for future projects.
- Results in this project for HB little different than routine analyses. But in future we should be able to extend method to even more sparse data problems:
  - mortality rates across strata of age, sex, and natality
  - what is driving the high rates for Cook Island Māori?
  - Plus: longitudinal data, missing and misclassified data, imputation, complex survey design, and the generation of synthetic datasets.
- We anticipate that HB use will increase.