Driving-point admittance effects on the static playability of bowed strings

A case study using simulations from a bowed string physical model including finite-width thermal friction and hair dynamics

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What makes a good violin?

Tone

Spectral characteristics of the radiativity

Playability

Variety and feasibility of gestures that result in good sound

Violin gestures

Bow velocity: Controls **amplitude**

Bow force (or pressure)**:** Controls **high frequencies**

Bow-bridge distance: Controls **both**

Others: Position, tilt, skew, inclination

Vibration regimes

“Good sound” (Helmholtz)

“Aperiodic” sound

Anomalous Low Frequencies

Multiple Stick-Slip

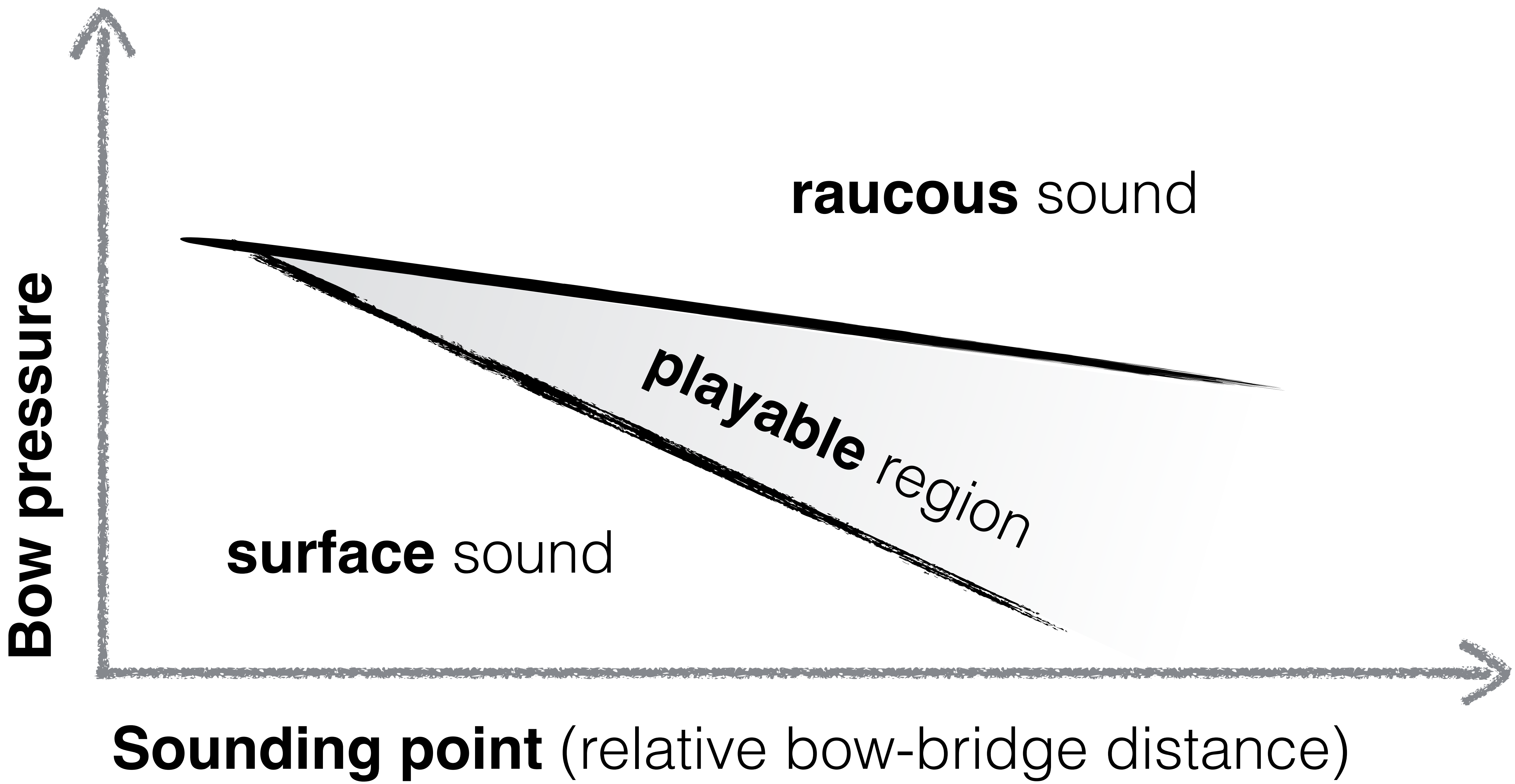
Playability

How do **gestures** map to **regimes**?

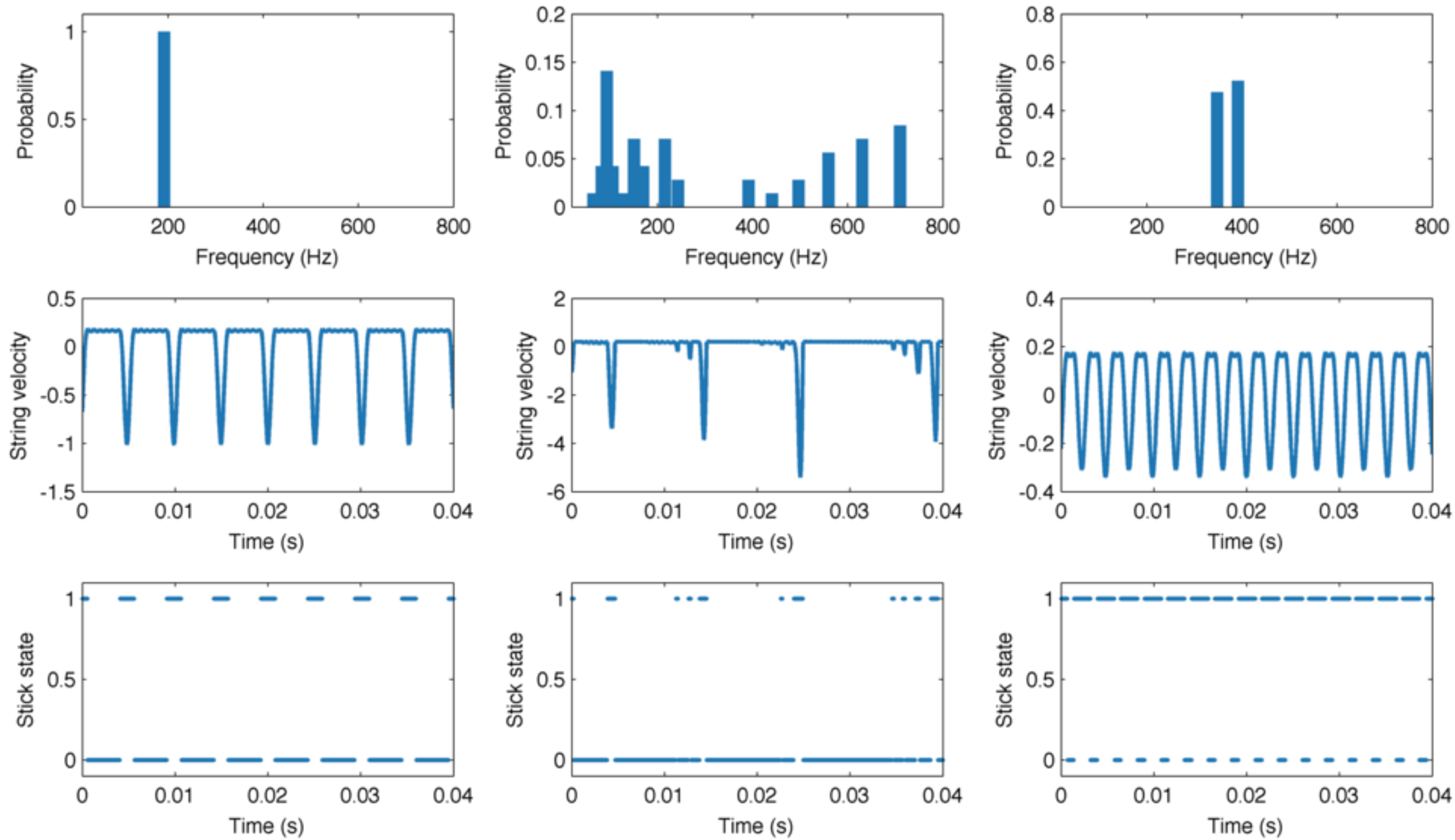
(volume and feasibility)

How do **model** parameters affect that?

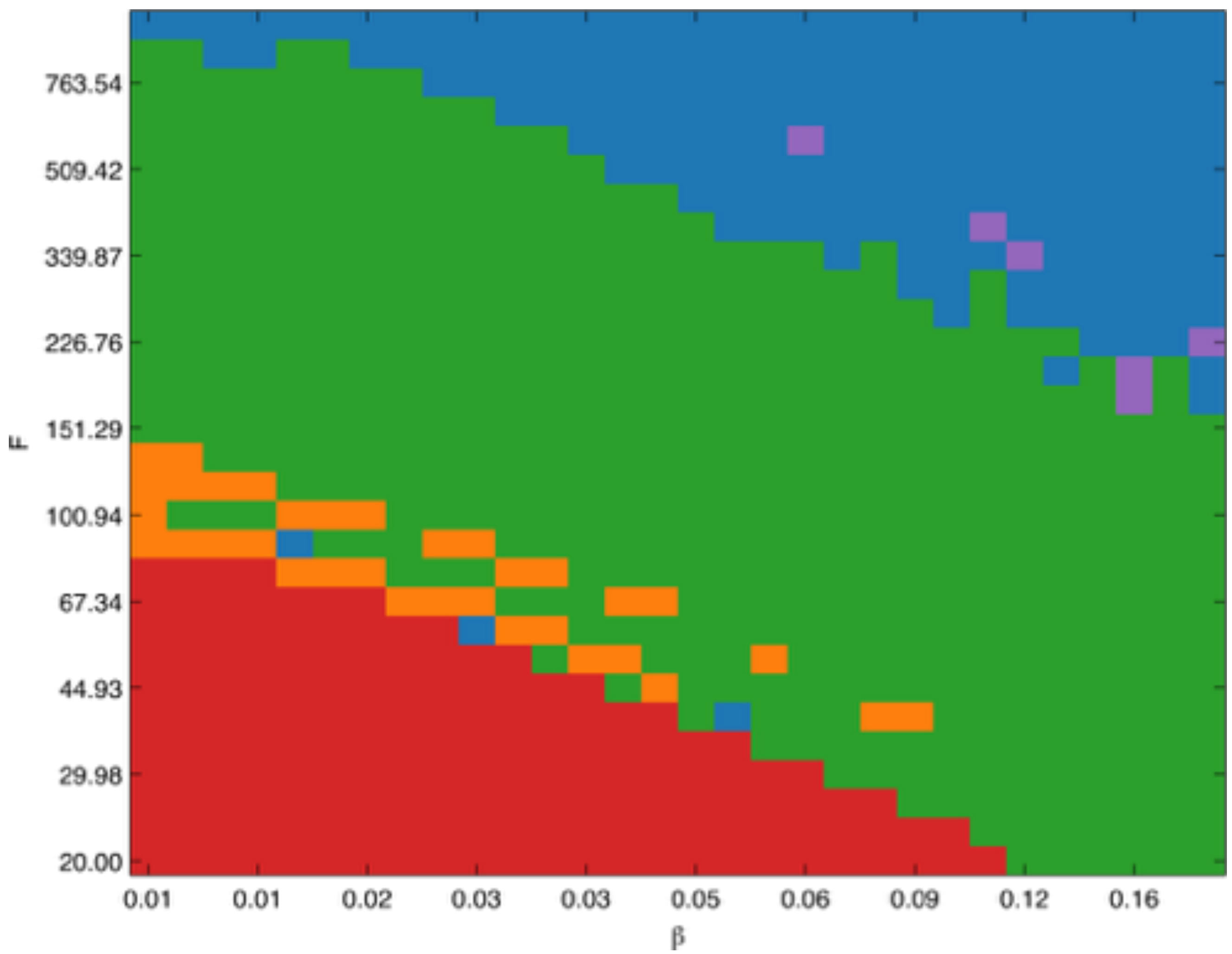
Schelleng Diagram

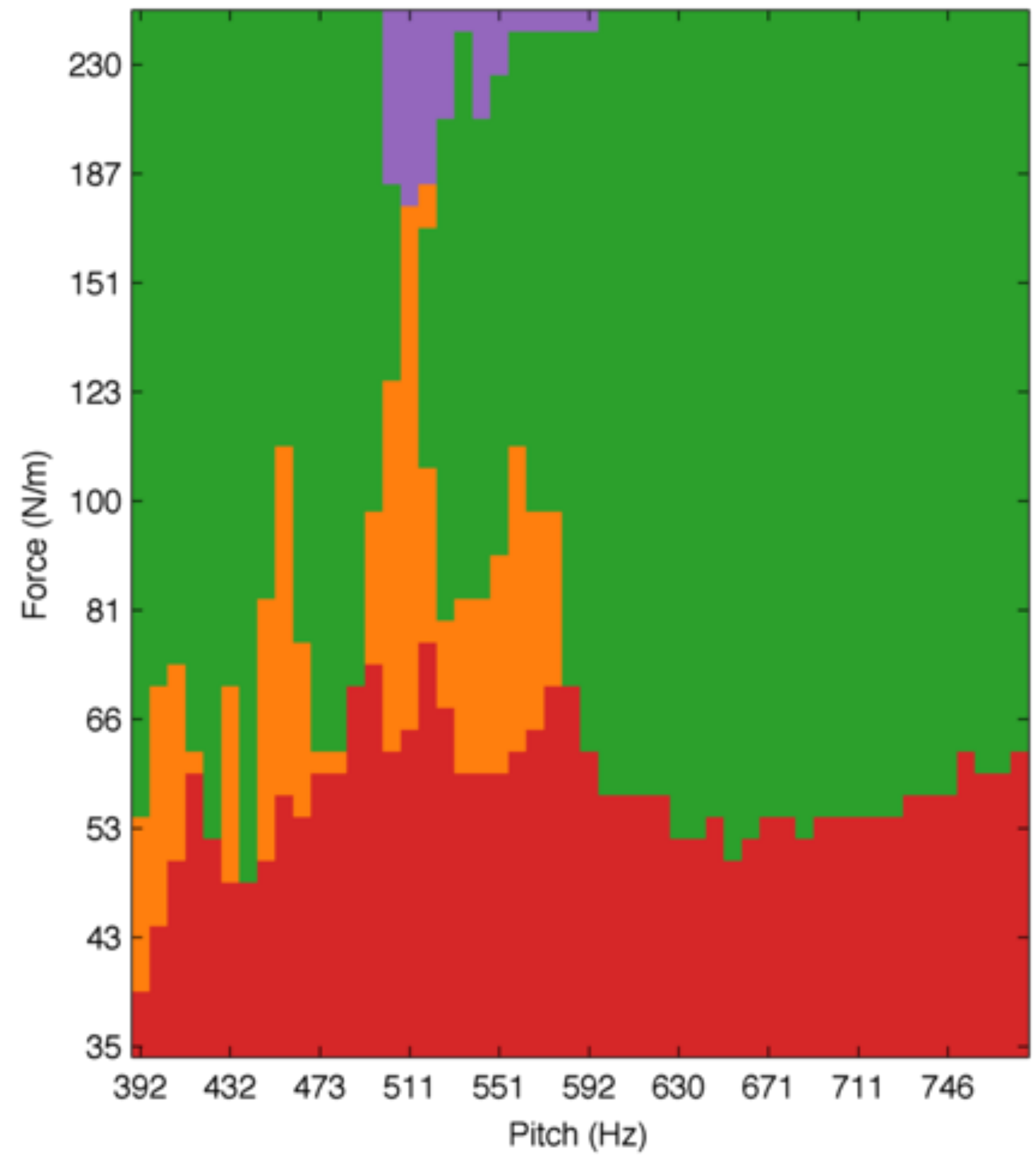


Regime estimation



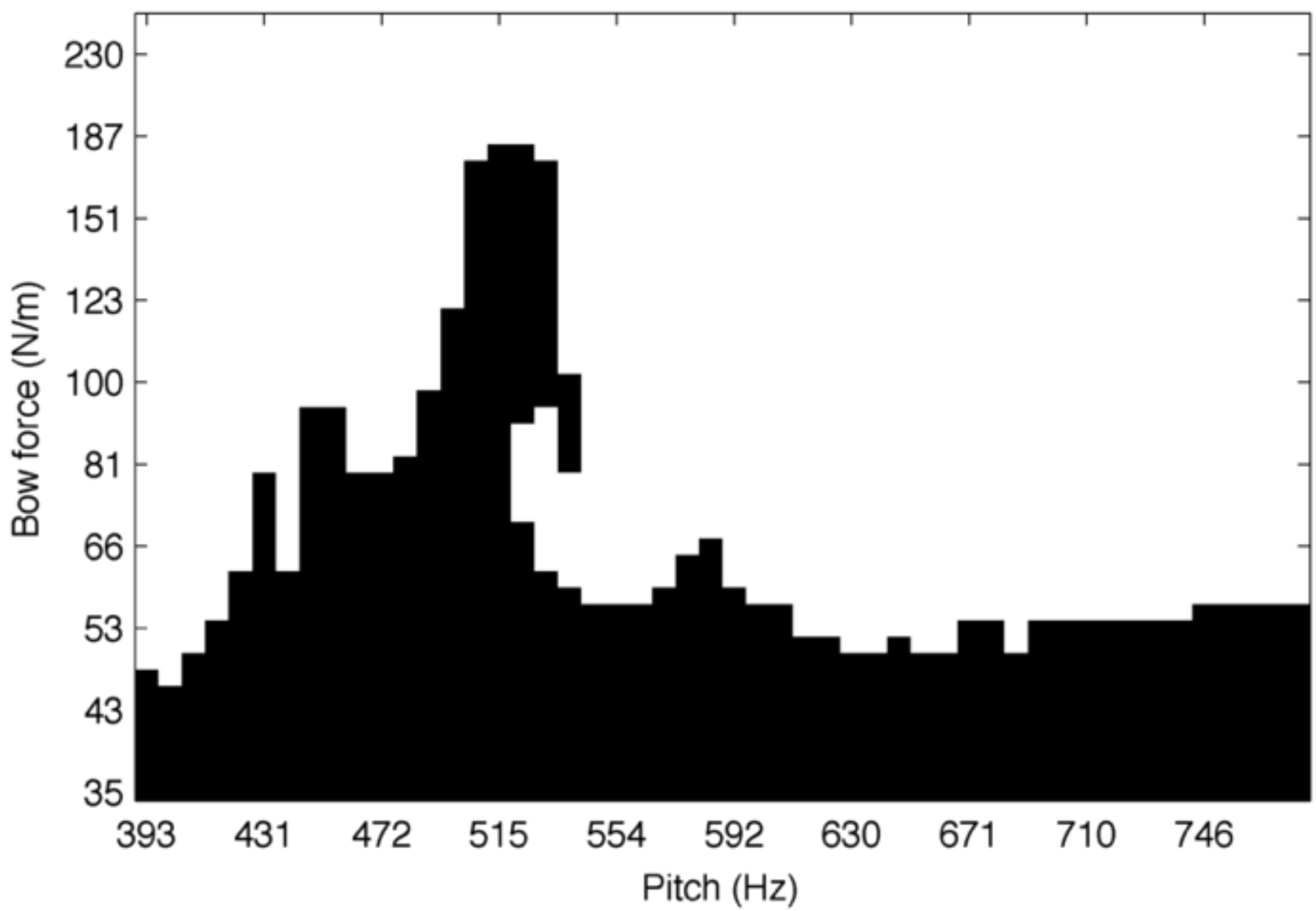
Regime maps


763.54
509.42
339.87
226.76
151.29
100.94
67.34
44.93
29.98
20.00
F
0.01
0.01
0.02
0.03
0.03
0.05
0.06
0.09
0.12
0.16
β


230
187
151
123
100
81
66
53
43
35
Force (N/m)
392
432
473
511
551
592
630
671
711
746
Pitch (Hz)

Minimum force estimation

Simplified regime estimator
that only looks around the expected pitch



Expected minimum force

(Woodhouse, 1993)

Instead of a dashpot (Schelleng), the body is a generic LTI

Schelleng's case: $Y_1(\omega) = 1/R$

$$f_{\min} = \frac{2 v_{\mathrm{b}}}{\pi^2 \beta^2 Y_0^2 (\mu_{\mathrm{s}} - \mu_{\mathrm{d}})} \cdot \left[\max_t \left\{ \mathrm{Re} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} Y_1(2n\pi f_0)\, \mathrm{e}^{2n\pi \mathrm{i} f_0 t} \right\} + \mathrm{Re} \sum_{n=1}^{\infty} \frac{Y_1(2n\pi f_0)}{n^2} \right],$$

Expected minimum force

(Woodhouse, 1993)

Instead of a dashpot (Schelleng), the body is a generic LTI

Schelleng's case: $Y_1(\omega) = 1/R$

$$f_{\min} = \frac{2 v_b}{\pi^2 \beta^2 Y_0^2 (\mu_s - \mu_d)} \cdot \left[\max_t \left\{ \mathrm{Re} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} Y_1(2n\pi f_0) \, e^{2n\pi i f_0 t} \right\} + \mathrm{Re} \sum_{n=1}^{\infty} \frac{Y_1(2n\pi f_0)}{n^2} \right],$$

Ideal sawtooth wave

Expected minimum force

(Woodhouse, 1993)

Instead of a dashpot (Schelleng), the body is a generic LTI

Schelleng's case: $Y_1(\omega) = 1/R$

$$f_{\min} = \frac{2 v_{\mathrm{b}}}{\pi^2 \beta^2 Y_0^2 (\mu_{\mathrm{s}} - \mu_{\mathrm{d}})} \cdot \left[\max_t \left\{ \mathrm{Re} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} \boxed{Y_1(2n\pi f_0)}\, e^{2n\pi \mathrm{i} f_0 t} \right\} + \mathrm{Re} \sum_{n=1}^{\infty} \frac{Y_1(2n\pi f_0)}{n^2} \right],$$

Admittance convolution

Expected minimum force

(Woodhouse, 1993)

Instead of a dashpot (Schelleng), the body is a generic LTI

Schelleng's case: $Y_1(\omega) = 1/R$

$$f_{\min} = \frac{2 v_b}{\pi^2 \beta^2 Y_0^2 (\mu_s - \mu_d)} \cdot \left[\boxed{\max_t} \left\{ \mathrm{Re} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} Y_1(2n\pi f_0) \, e^{2n\pi i f_0 t} \right\} + \mathrm{Re} \sum_{n=1}^{\infty} \frac{Y_1(2n\pi f_0)}{n^2} \right],$$

Select phase with largest force"kick"

Expected minimum force

(Woodhouse, 1993)

Instead of a dashpot (Schelleng), the body is a generic LTI

Schelleng's case: $Y_1(\omega) = 1/R$

$$f_{\min} = \frac{2 v_{\mathrm{b}}}{\pi^2 \beta^2 Y_0^2 (\mu_{\mathrm{s}} - \mu_{\mathrm{d}})} \cdot \left[\max_t \left\{ \mathrm{Re} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} Y_1(2n\pi f_0)\, \mathrm{e}^{2n\pi \mathrm{i} f_0 t} \right\} + \mathrm{Re} \sum_{n=1}^{\infty} \frac{Y_1(2n\pi f_0)}{n^2} \right],$$

Integration constant

Expected minimum force

(Woodhouse, 1993)

Instead of a dashpot (Schelleng), the body is a generic LTI

Schelleng's case: $Y_1(\omega) = 1/R$

$$f_{\min} = \frac{2 v_b}{\pi^2 \beta^2 Y_0^2 (\mu_s - \mu_d)} \cdot \left[\max_t \left\{ \operatorname{Re} \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{n^2} Y_1(2 n \pi f_0)\, e^{2 n \pi i f_0 t} \right\} + \operatorname{Re} \sum_{n=1}^{\infty} \frac{Y_1(2 n \pi f_0)}{n^2} \right],$$

Friction coefficients

Extensions to the Woodhouse model

Finite bow width

Minimum force is expressed in N/m (divide by hair width)

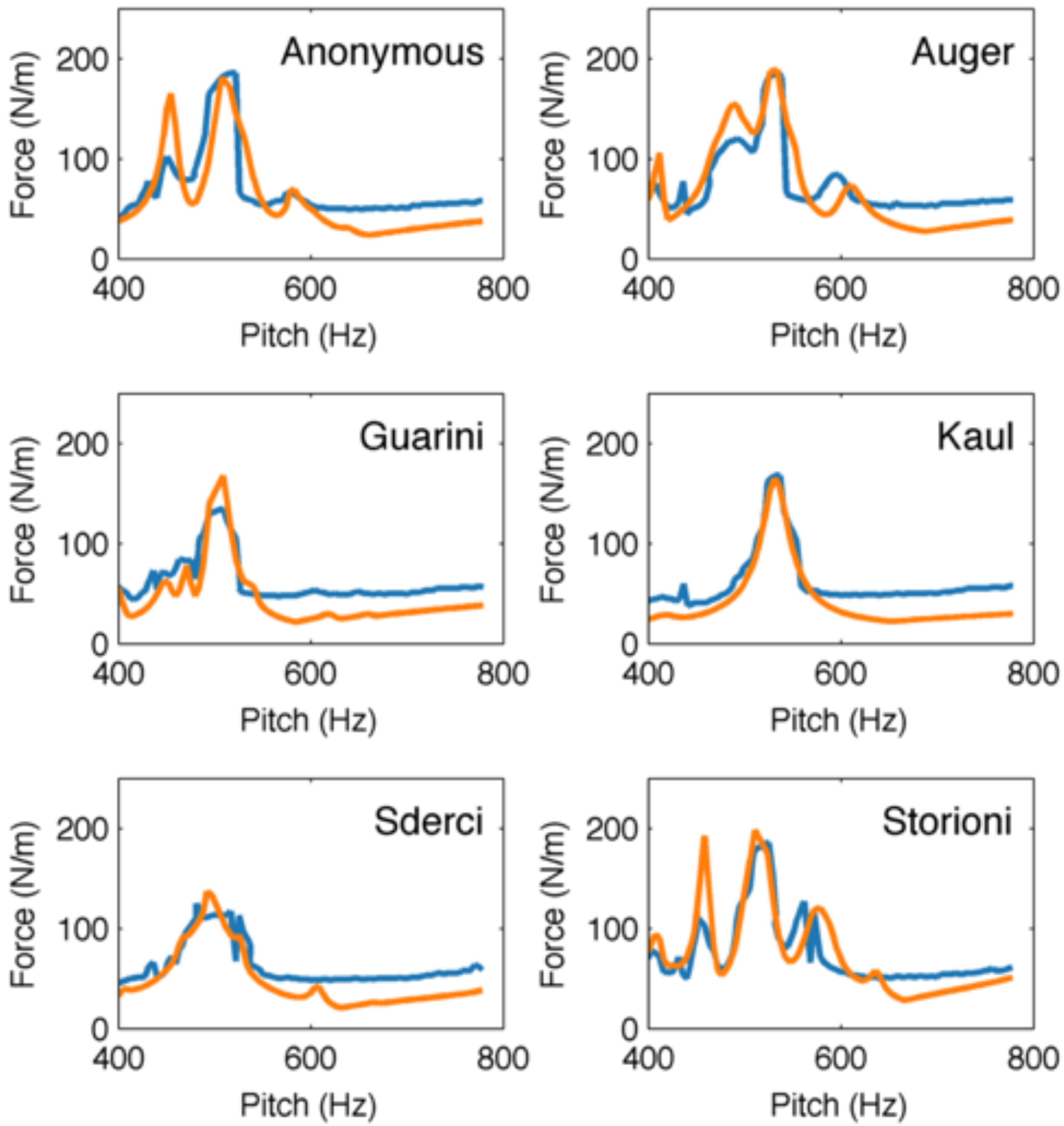
Numerical detuning and flattening

The f_0 is extracted with YIN rather than assumed from the score

Thermal friction

We assume a static value that makes sense

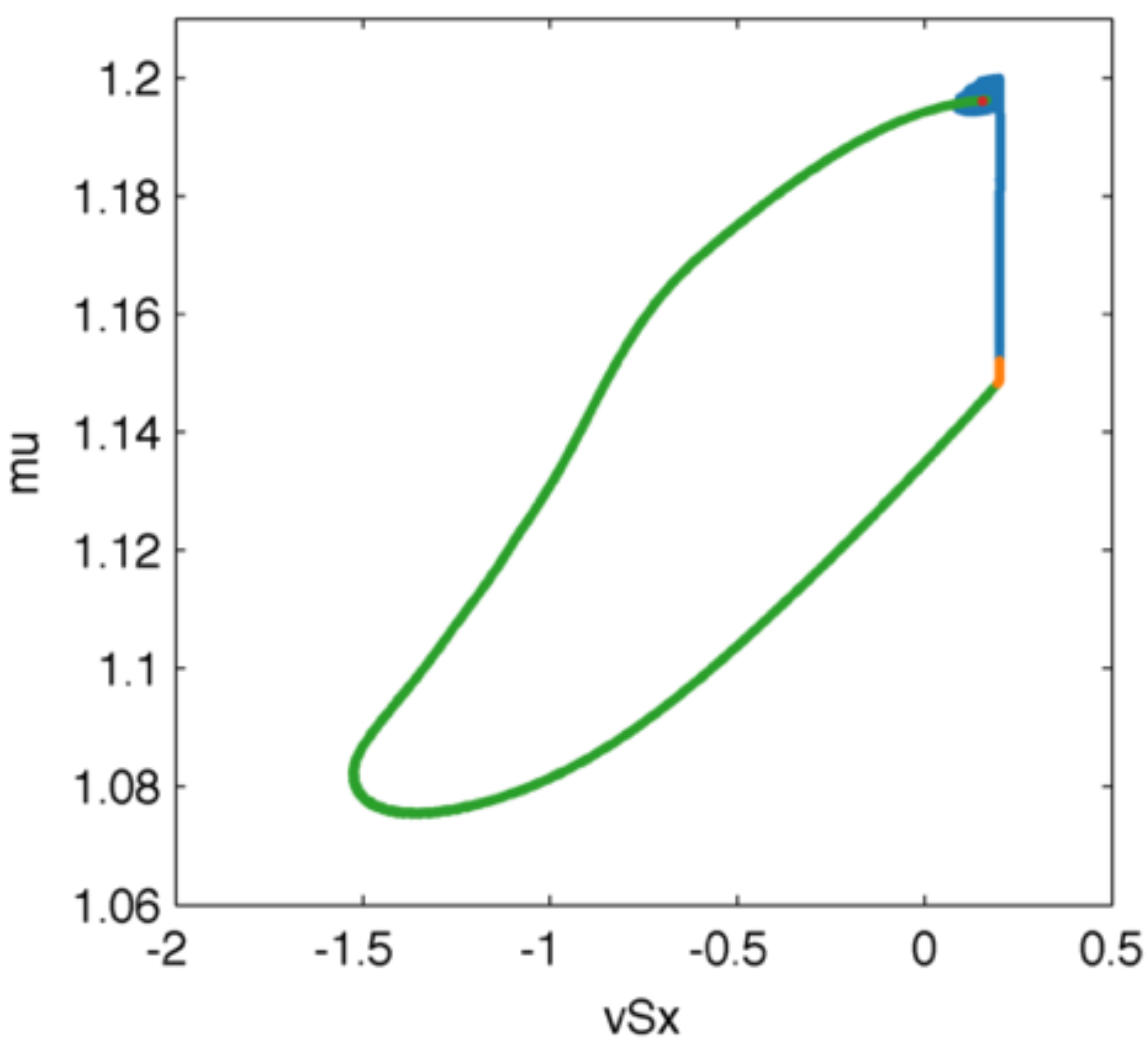
Prediction matching

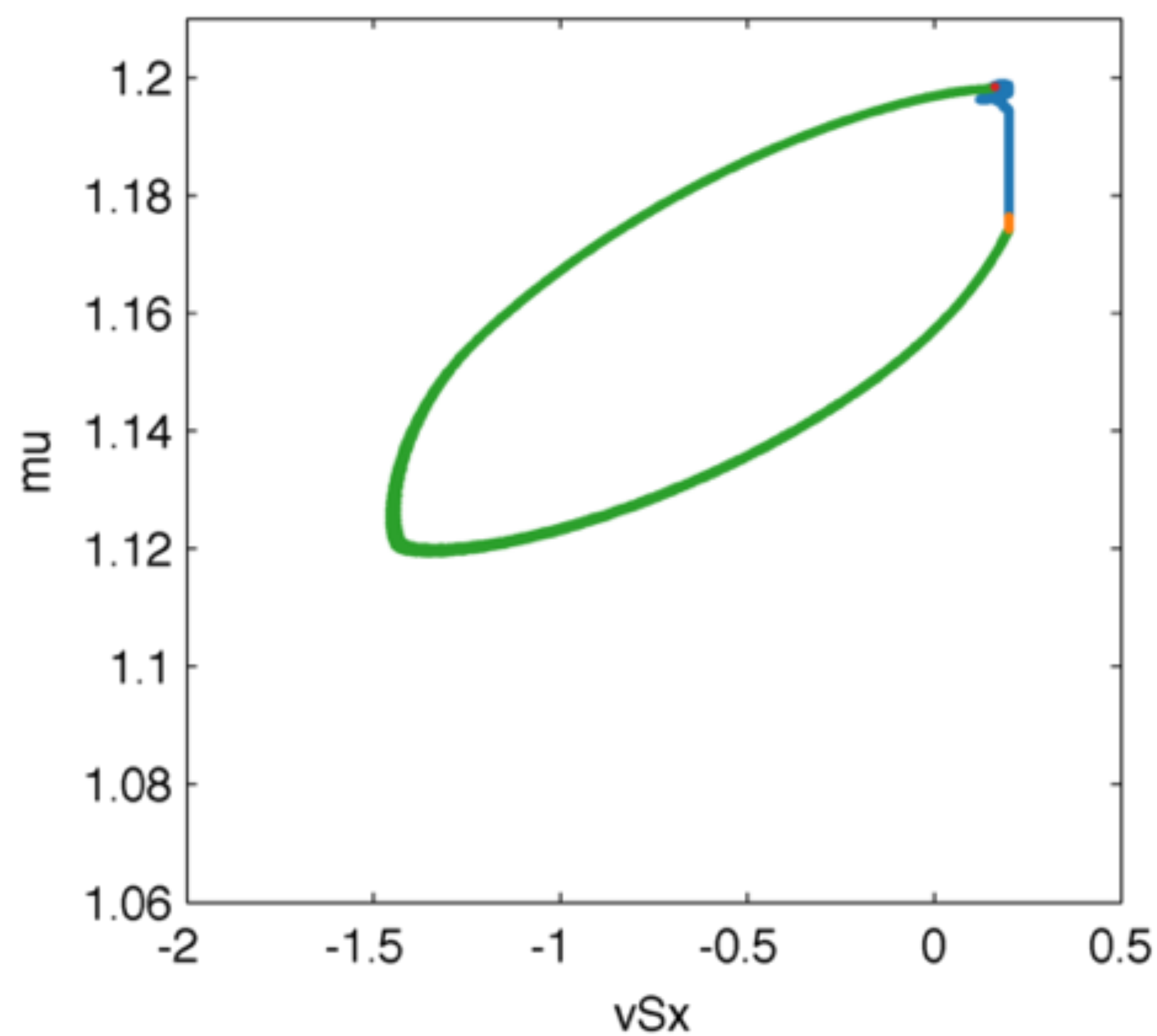


blue: measured
orange: expected

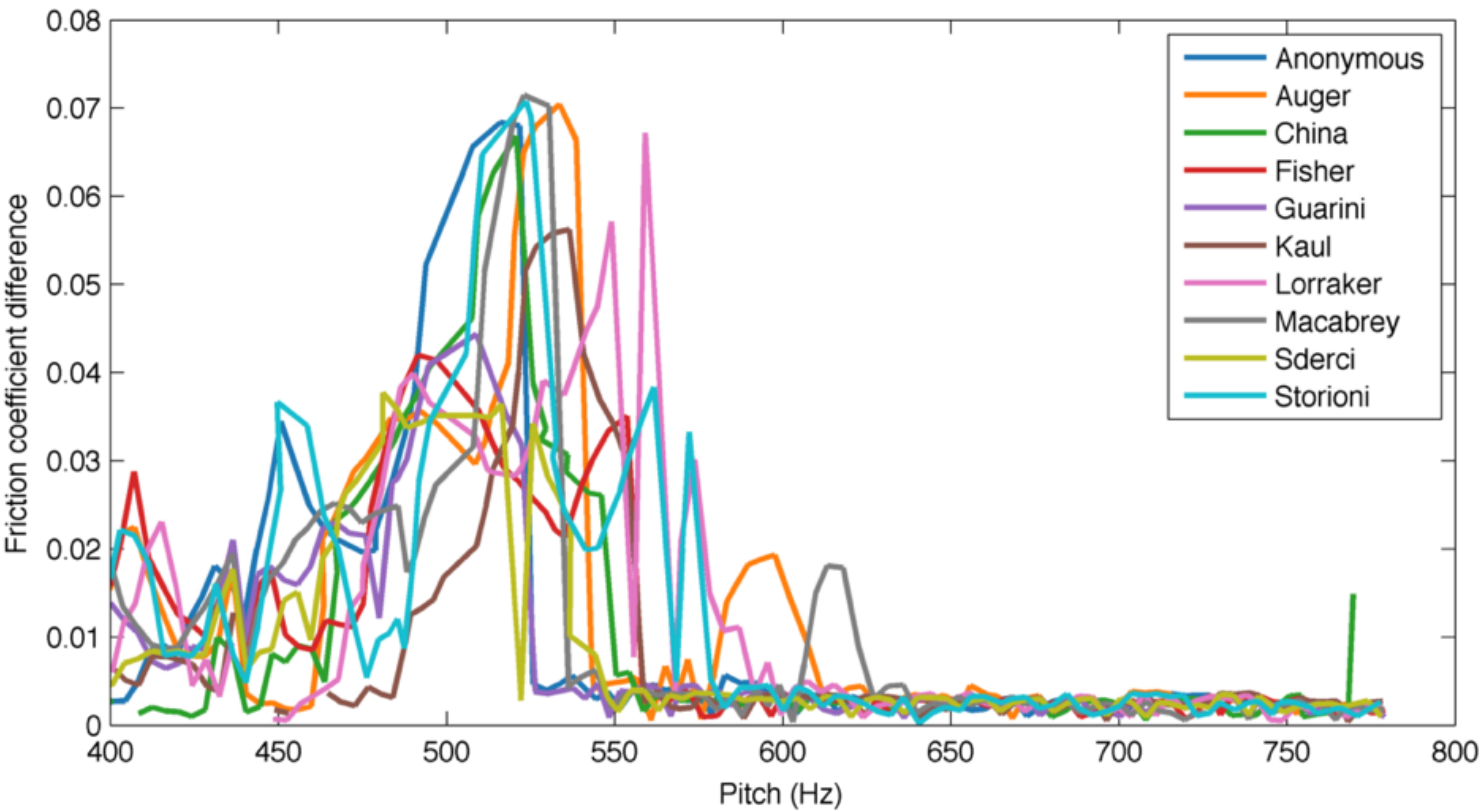
The tribology of rosin

The range of mu changes depending on temperature
Temperature increases during slip because of friction
Friction changes with (normal) bow force

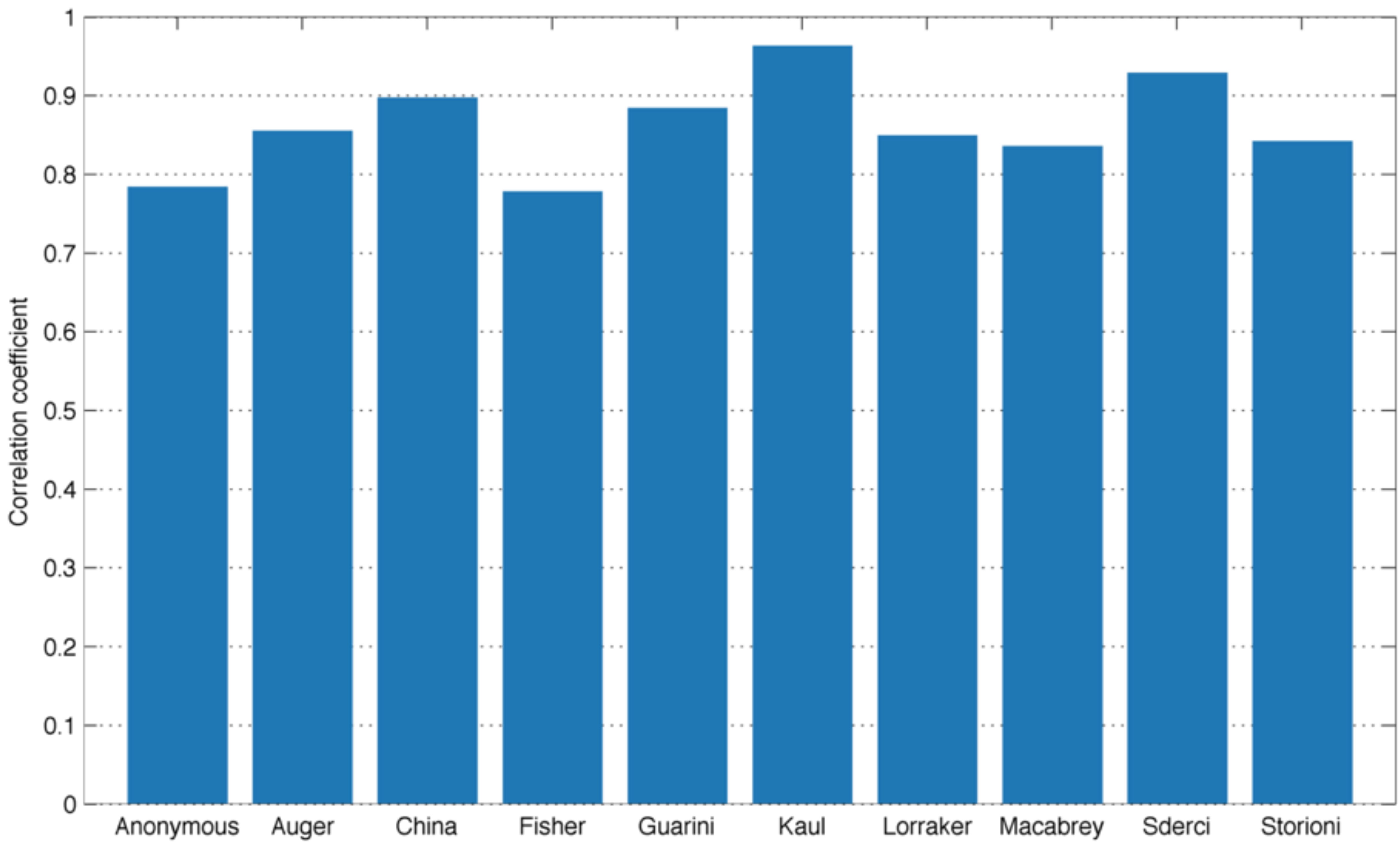


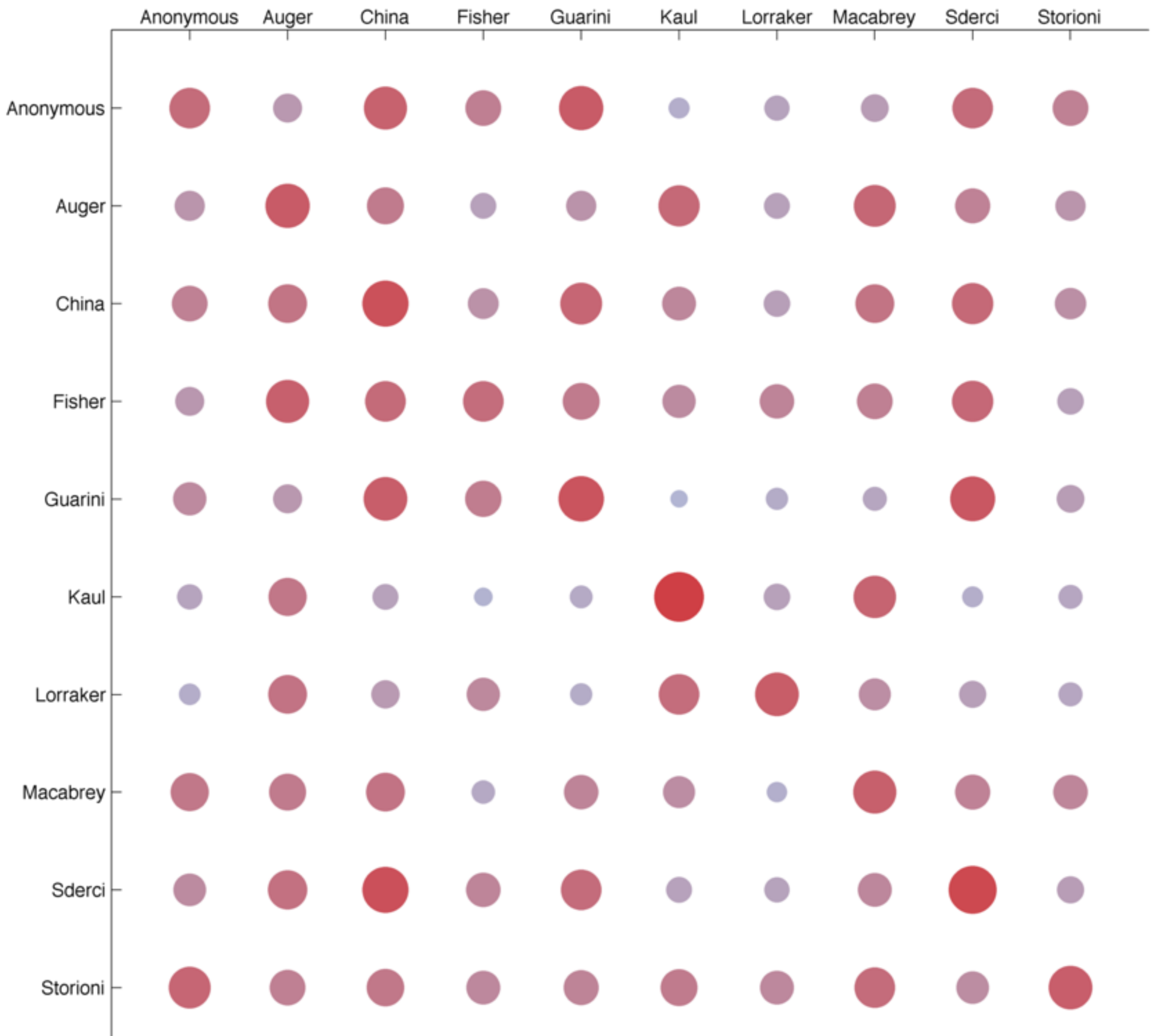


Post-computed friction coefficient difference during string capture and release at the minimum bow force



Correlation between expected and measured from the simulation




Anonymous
Auger
China
Fisher
Guarini
Kaul
Lorraker
Macabrey
Sderci
Storioni

Thanks!

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