DOG POPULATION CONTROL AS KEY INTERVENTION STRATEGY FOR ERADICATING RABIES IN DAVAO CITY, PHILIPPINES: A POLICY IMPLICATION VIA MECHANISTIC AND PHENOMENOLOGICAL MODELS

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DARE TO RESEARCH GRANT

BACKGROUND

- 55,000 estimated annual human rabies deaths in Africa and Asia are primarily due to dog bites.
- Fluctuating and expanding incidence of animal rabies cases around Davao City (Fig. 1) challenges the 2020 rabies-free goal of the Philippines.
- Objective: **Identify the factor/s that significantly contribute/s to transmission dynamics of rabies virus among dog populations in Davao City, Philippines using mechanistic and phenomenological modelling approaches.**

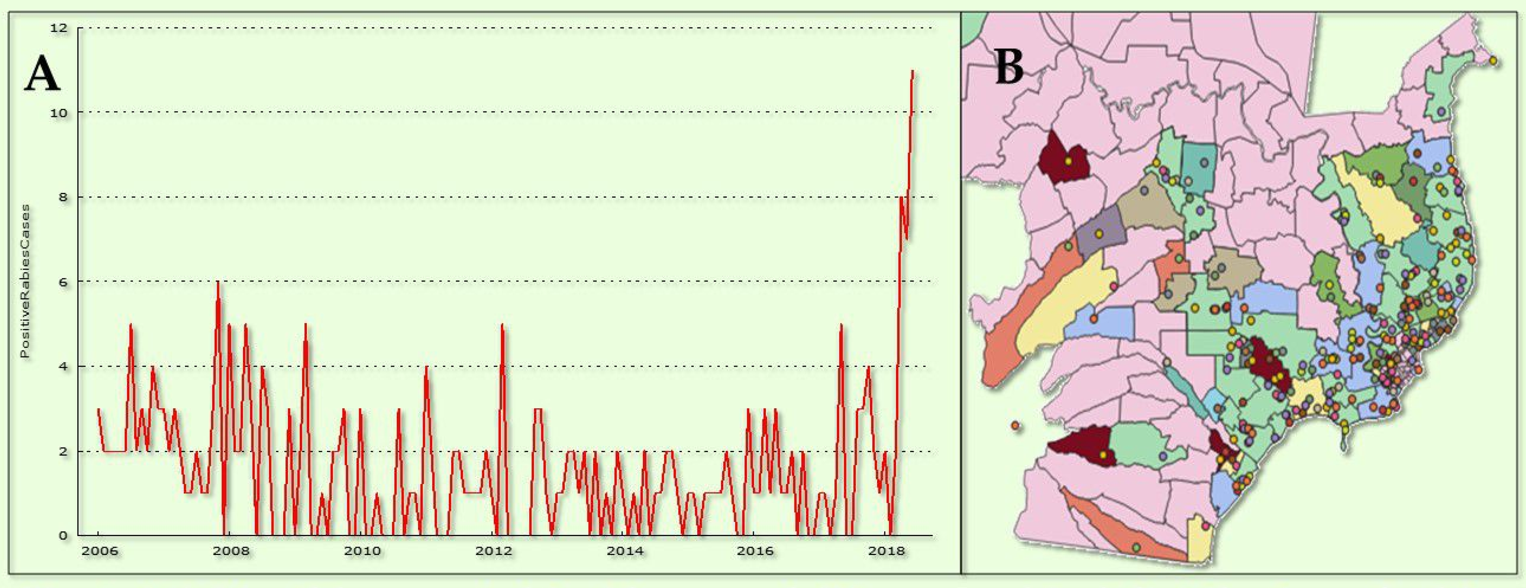

Fig. 1. (A) Monthly reported incidence and (B) geographical distribution of rabies cases in Davao City from January 2006 to June 2018.

MODELLING FRAMEWORKS

MECHANISTIC MODEL FOR RABIES TRANSMISSION

An SEIR (Susceptible-Exposed-Infectious-Recovered) epidemiological model was formulated based on the rabies model of Zhang et al. (2011) with slight modification on parameter definitions and basic assumptions. The interactions of the dynamic variables along with the parameters are described in the schematic diagram shown in Fig. 2.

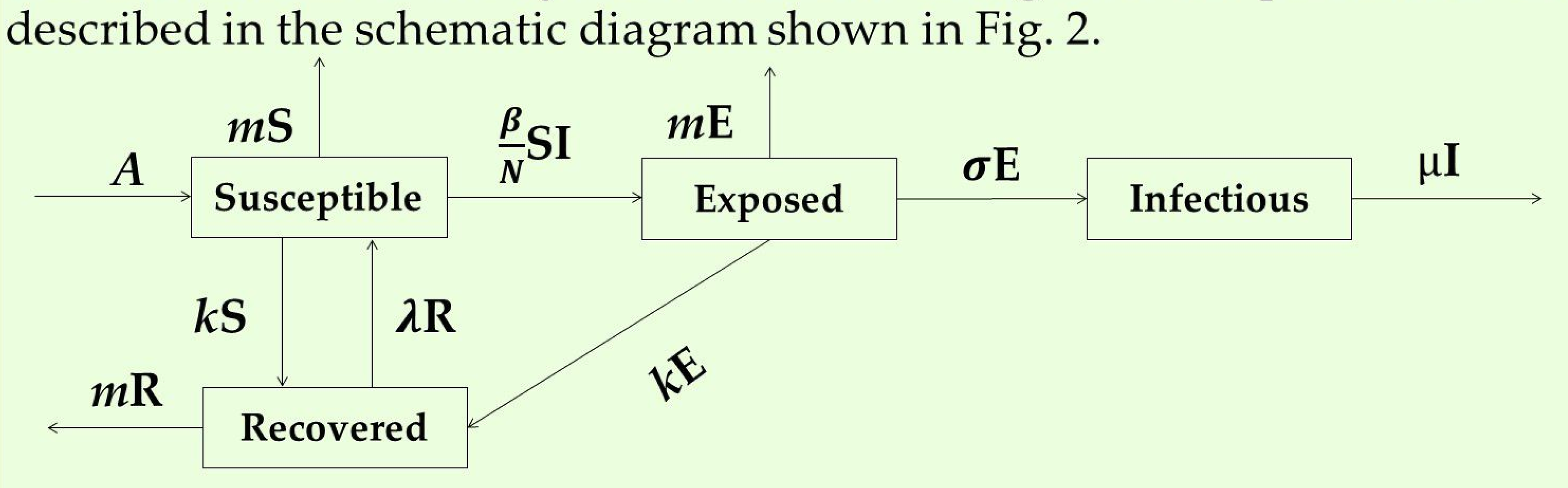

Fig. 2. SEIR model for rabies transmission.

Model Equations

$$\frac{dS}{dt} = A + \lambda R - S(k+m) - \beta SI \quad (1)$$

$$\frac{dE}{dt} = \frac{\beta}{N} SI - E(m+\sigma+k) \quad (2)$$

$$\frac{dI}{dt} = \sigma E - \mu I \quad (3)$$

$$\frac{dR}{dt} = k(E+S) - R(\lambda+m) \quad (4)$$

Model Parameters

β – direct transmission rate of rabies
μ – mortality rate of rabid dog
λ – rate of loss of vaccine immunity
$1/\sigma$ – incubation period
A – annual crop of dogs
k – vaccination rate for susceptible and exposed dogs
m – natural mortality rate of dogs
N – total dog population

PHENOMENOLOGICAL MODEL FOR IMPACT ASSESSMENT

The GLARMA (Generalized Linear Autoregressive Moving Average) framework was used to model the relationship of the monthly reported rabies cases (R) to their *previous observation/s* and its *potential drivers* shown in Fig. 3.

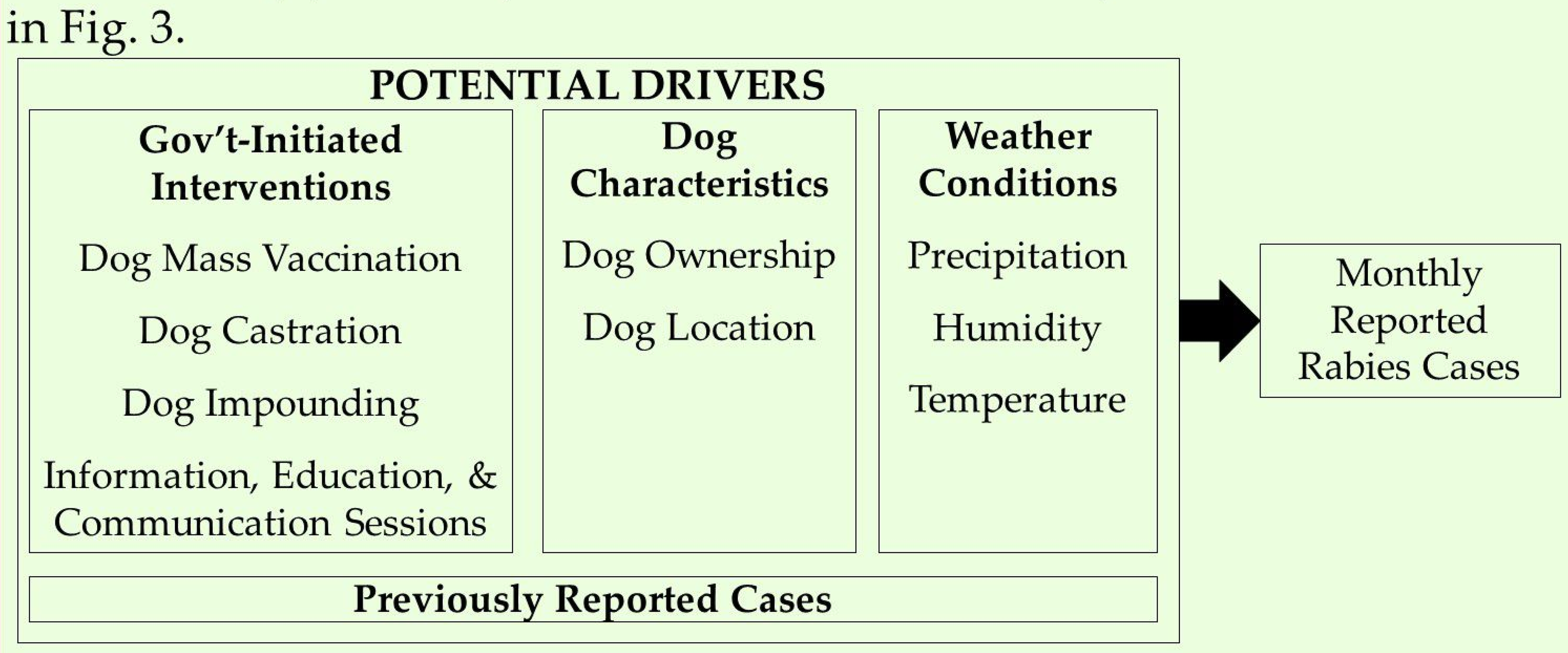

Fig. 3. Impact assessment modelling framework.

Model Equations

$$R = X_t^T \beta + \sum_{i=1}^{p} \phi_i \left(R_{t-i} + \varepsilon_{t-i} \right) + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \quad (5)$$

$$E(R \mid X) = \exp\left(X^T \beta \right) \quad (6)$$

Model Parameters

X_t^T – rabies incidence drivers with β coefficients at month t
$\boldsymbol{\phi}$ **(AR)** and $\boldsymbol{\theta}$ **(MA)** – time-series parameters with order p and q respectively
ε – random error

METHODOLOGY

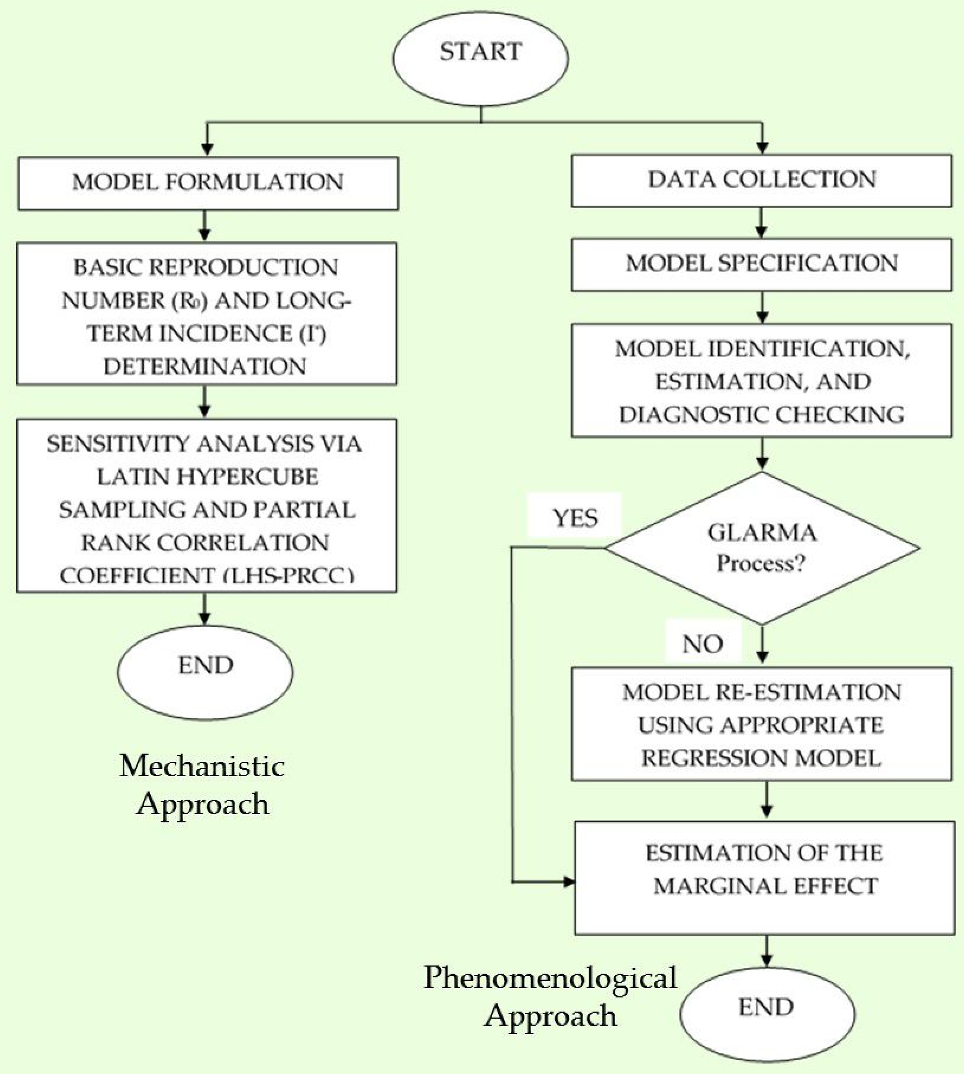

Fig. 4. Flowchart of two modelling approaches.

Key Terms:

- **R_0** – the average number of secondary infections by an infected dog.
- **I*** – stable steady-state value of infectious dog population.
- **LHS-PRCC** – sensitivity measure for R_0 and I* to model parameters.
- **GLARMA Process** – the response variable is affected by both its previous observation/s and/or its driver/s. Eq. (5) is used for analysis if there is GLARMA process, otherwise a count regression model (Eq. (6)) is used.

RESULTS

From SEIR Model:

- Basic reproduction number (R_0) and long-term incidence rate (I^*) are both affected **positively** by the annual crop of dogs and the rabies transmission rate, but **negatively** affected by the vaccination rate.
- The outcomes, R_0 and I^*, are both more sensitive to the annual crops of dogs and the rabies transmission rate (i.e., PRCC is closer to 1 or -1) than the vaccination rate.

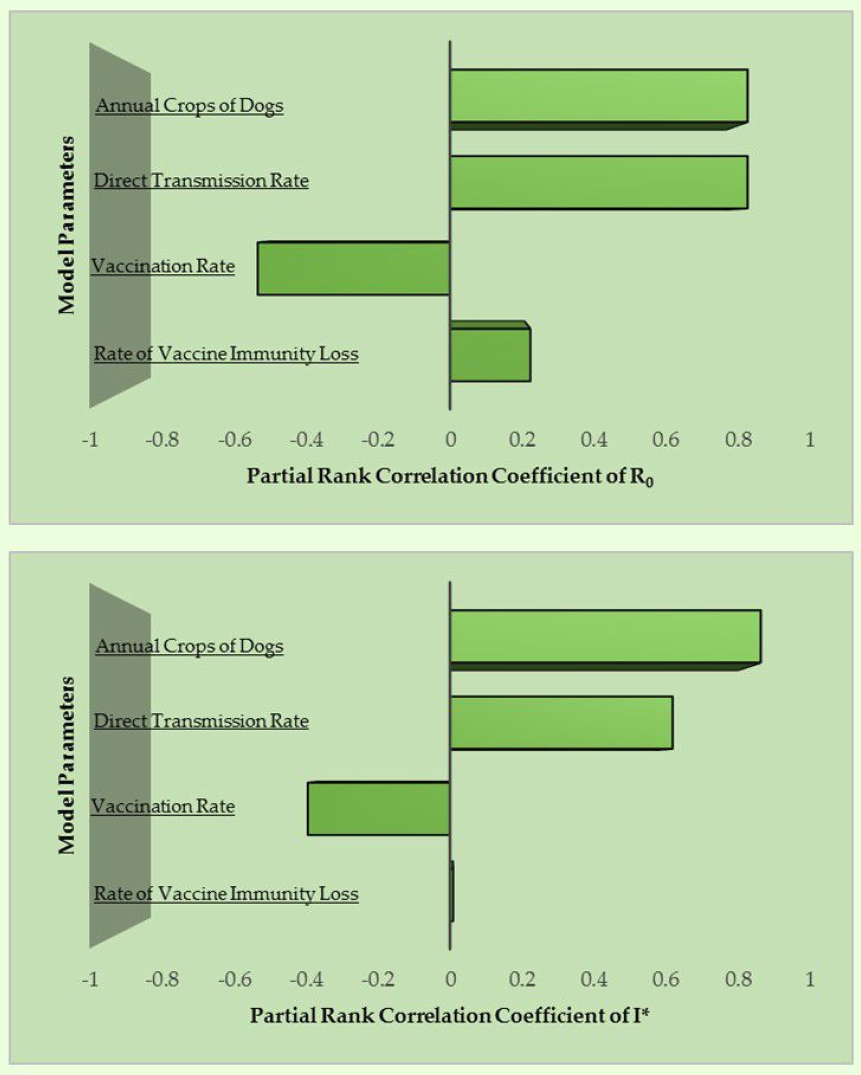

Fig. 5. The sensitivity (in terms of *PRCC*) of R_0 and I* on significant model parameters.

From Regression Model:

- Dog impounding is the only existing government-initiated intervention that significantly decreased the monthly reported rabid dogs.

Table 1. Estimates and marginal effects of drivers of positive rabies cases using censored Poisson regression model.

positiverabiescases	Estimates	*p-value*	Marginal Effects	*p-value*
Vaccinationeffort (0 = No; 1 Yes)	0.077394	0.667	0.000429	0.666
Castrateddogs	0.000508	0.809	2.83E-06	0.809
Impoundeddogs	**-0.00056**	**0.039****	**-3.15E-06**	**0.042****
Iecsessions	0.000333	0.844	1.86E-06	0.844
Interdistrict (0 = No; 1 Yes)	**0.709393**	**0.000*****	**0.004566**	**0.000*****
Ownedonly (0 = No; 1 Yes) [z]	**-0.25438**	**0.006*****	**-0.00142**	**0.007*****
Healthy_dogs(0 = No; 1 Yes) [z]	**-18.9615**	**0.000*****	**-1.82919**	**0.000*****
Precipitationmm	**-0.02858**	**0.061***	**-0.00016**	**0.062***
Humidity	0.00257	0.824	1.43E-05	0.825
Temperaturecelsius	0.04343	0.479	0.000242	0.480
Constant	-0.70463	0.752		

[z] Base Case: Presence of stray dogs. *p-values ≤ 0.1 is significant at the 10% level, **p-values ≤ 0.05 is significant at the 5 % level, and ***p-values ≤ 0.01 is significant at the 1 % level.
Model characteristics for parameter estimates: Wald chi2(10) = 15270.11, Log pseudolikelihood = 138.91762; Prob > chi2 = 0.0000

POLICY IMPLICATION

- Parallel results imply that the local government unit should pay attention to dog population control interventions (e.g. dog impounding or stray dog population regulation) equally with dog mass vaccination.

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