Canine Rabies Spread Dynamics under Different Control Interventions and Promotion of Responsible Pet Ownership Using Agent-based Modelling

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DARE TO RESEARCH GRANT

BACKGROUND

- 59,000 estimated annual human rabies deaths in Africa and Asia are primarily due to dog bites.
- The Anti-Rabies Act of 2007 (R.A. 9482) mandates the LGU to ensure that all dogs are properly vaccinated and registered.
- Additional government efforts such as dog impounding, dog castration, and information and education campaigns are being conducted in Davao City, Philippines since 2011.
- Fluctuating incidence of animal rabies cases around Davao City (Fig. 1) challenges the 2022 rabies-free goal of the Philippines.
- Objective: **Simulate the spatiotemporal pattern of the number of rabies cases for various intervention scenarios and to explore the effect of seasonality on the number of rabies cases.**

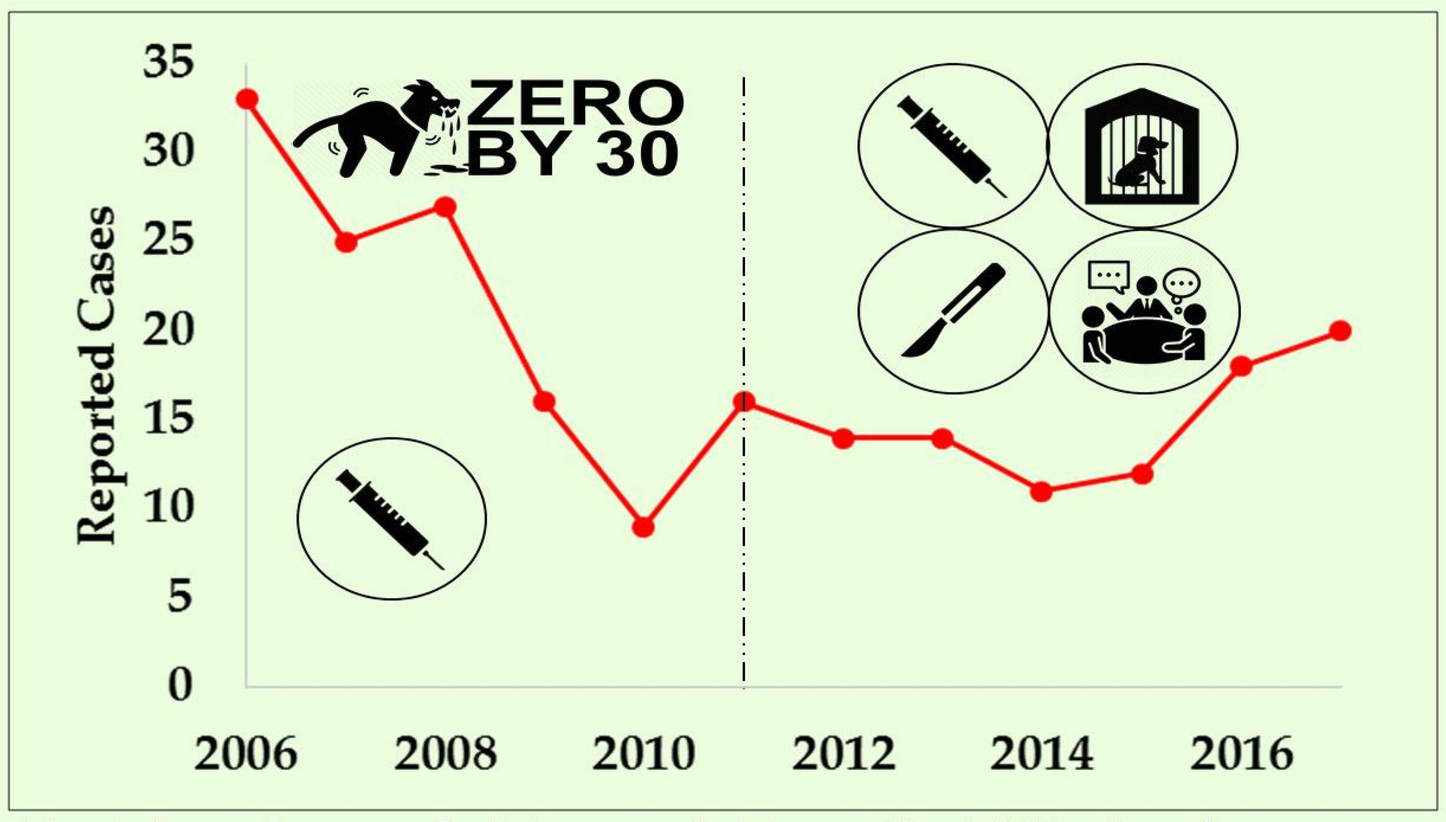

Fig. 1. Annual reported rabies cases in Davao City, Philippines from 2006 to 2007. The Zero-by-30 goal is the international goal to eliminate dog-mediated rabies cases.

AGENT-BASED MODELLING FRAMEWORK

Agents

VACCINATED DOG
an agent that has been vaccinated and is immune to rabies infection for three years.

SUSCEPTIBLE DOG
an agent that is susceptible to rabies exposure.

EXPOSED DOG
an agent infected with rabies virus as a result of exposure to rabid dogs.

RABID DOG
an agent that has the ability to infect only susceptible dogs.

NON-FREE ROAMING OWNED DOG
an agent moving with a small span of area and has a low risk to rabies exposure.

FREE ROAMING OWNED DOG
an agent moving with a large span of area and move back to their former location (e.g. home).

STRAY DOG
an agent moving with a large span of area but do not necessarily move back to their former location.

Environment

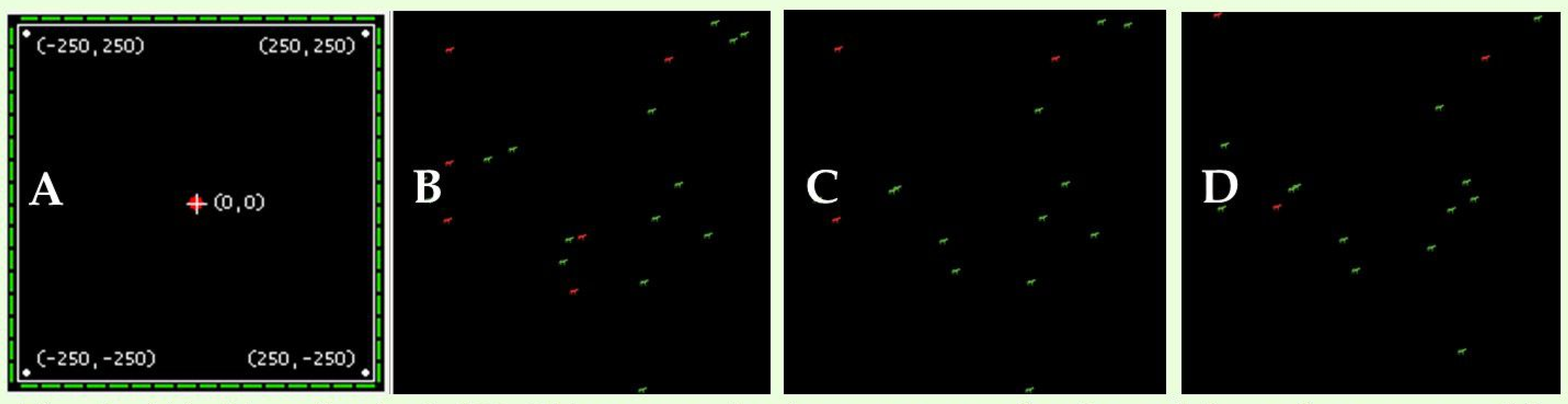

Fig. 2. (A) Hypothetical 500x500 square lattice unconstrained model environment with reflective boundaries and Simulation runs at (B) $t = 0$, (C) $t \sim 1$, and (D) $t \sim 2$.

Interaction

The only interaction between agents is infection. Rabid dog moves to the closest occupied patch within its 20-patch radius as shown in Fig. 3. The condition for the transmission of rabies virus from an rabid dog to a susceptible dog is given by Fig. 4.

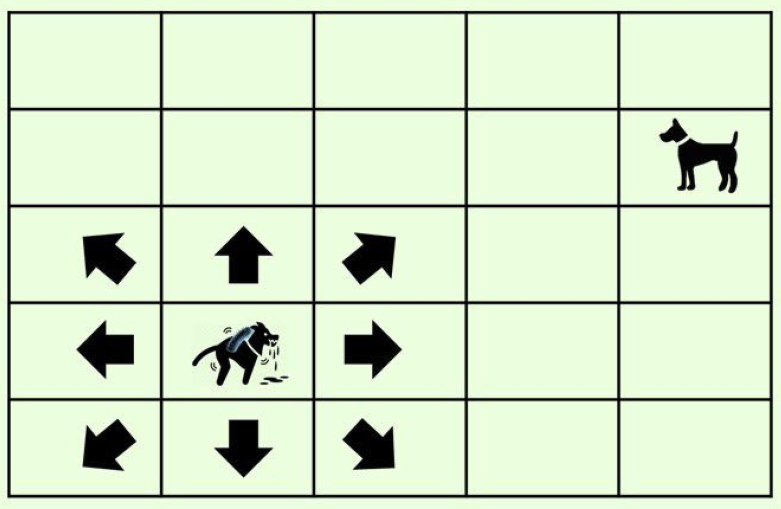

Fig. 3. The movement of a stray dog.

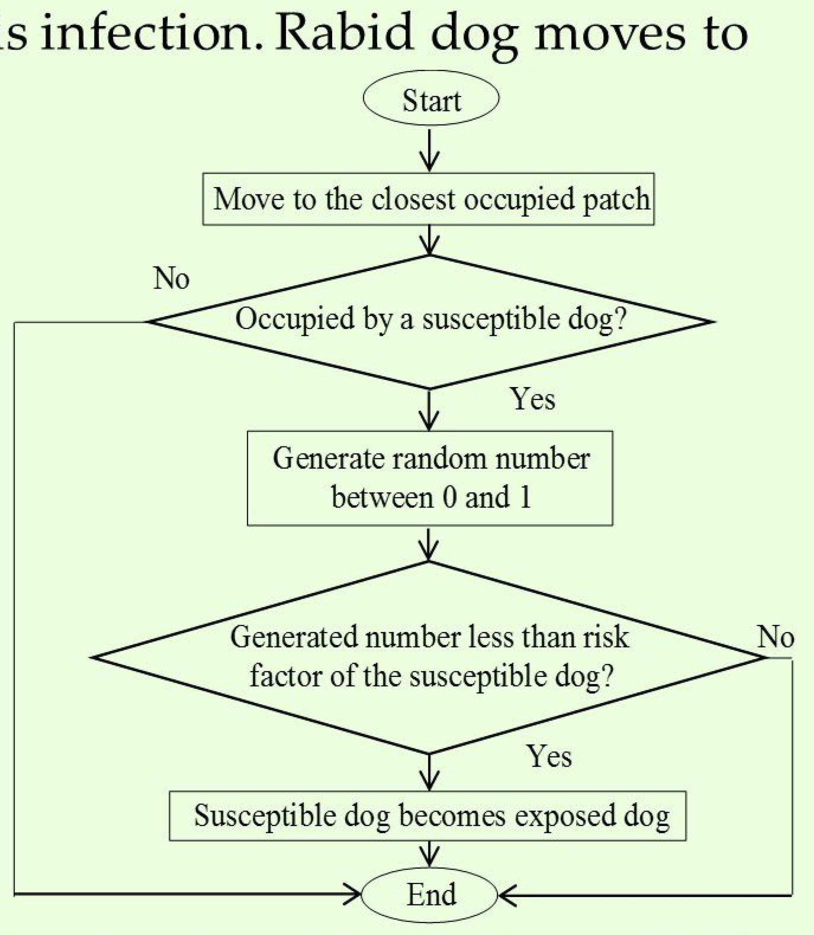

Fig. 4. Flowchart of the infection of rabid dogs.

METHODOLOGY

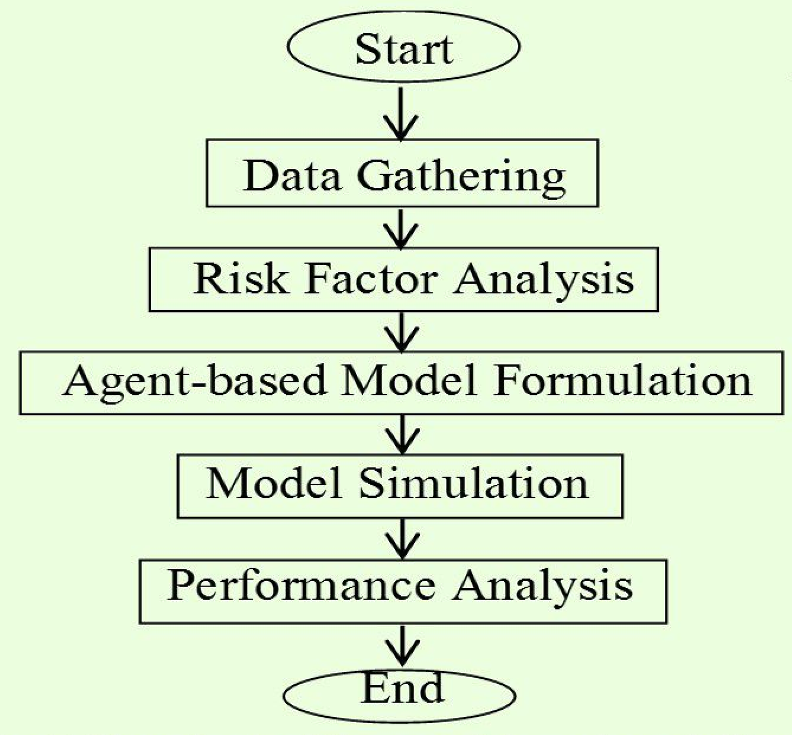

Fig. 5. Flowchart of the agent-based modelling.

Highlights of the Methodology:

- **Risk Factor Analysis** – Probit estimation was used identify a probability distribution for the risk factor assignment for the initialization of the susceptible dogs.
- **Performance Analysis** – the time-averaged number of rabid dogs was computed and statistically compared for each condition using Kruskal-Wallis H test.

RESULTS

Initialization

Table 1. Estimates and marginal effects of the risk factors of positive rabies detection using probit regression.

Risk Factors	Estimates	$(P > \|z\|)$	Marginal Effects	$(P > \|z\|)$
Gender	-0.0997	0.4030	-0.0341	0.406
Ownership	0.3475	0.0700*	0.1259	0.084*
Vaccinationhistory	-0.2962	0.0360**	-0.0963	0.027**
District1	-0.3331	0.0490**	-0.1111	0.044**
District2	-0.2219	0.2680	-0.0741	0.259
Precipitation	-0.0562	0.0200**	-0.0191	0.020**
Humidity	0.0019	0.9330	0.0006	0.933
Temperature	-0.0467	0.6670	-0.0159	0.667
Effort_MassDogVaccination	0.3663	0.1670	0.122	0.156
Effort_DogCastration	-0.0029	0.2950	-0.001	0.295
Effort_DogImpounding	-0.0007	0.1250	-0.0002	0.123
Effort_IECSessions	0.0005	0.8510	0.0002	0.851
_cons	1.2341	0.7720		

n = 536; Pseudo R^2 = 0.0402; Wald chi^2 = 26.28000; Prob > chi = 0.0098; AIC = 649.94; BIC = 705.62.
Probit model was chosen because of lower AIC and BIC relative to logit specification.

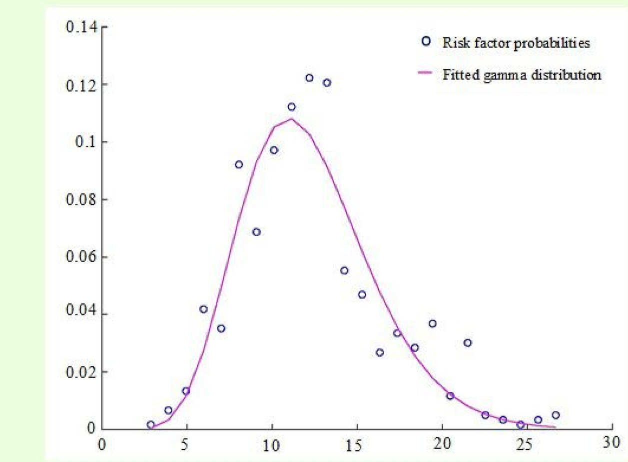

Fig. 6. The histogram of the transformed risks (circles) and the fitted gamma distribution (curve) using ordinary least-squares method. The risks are distributed with the specification $X \sim \frac{1}{39.4122}\Gamma(\alpha \approx 10.0147, \lambda \approx 0.8223)$.

Model Simulations and Performance Analysis

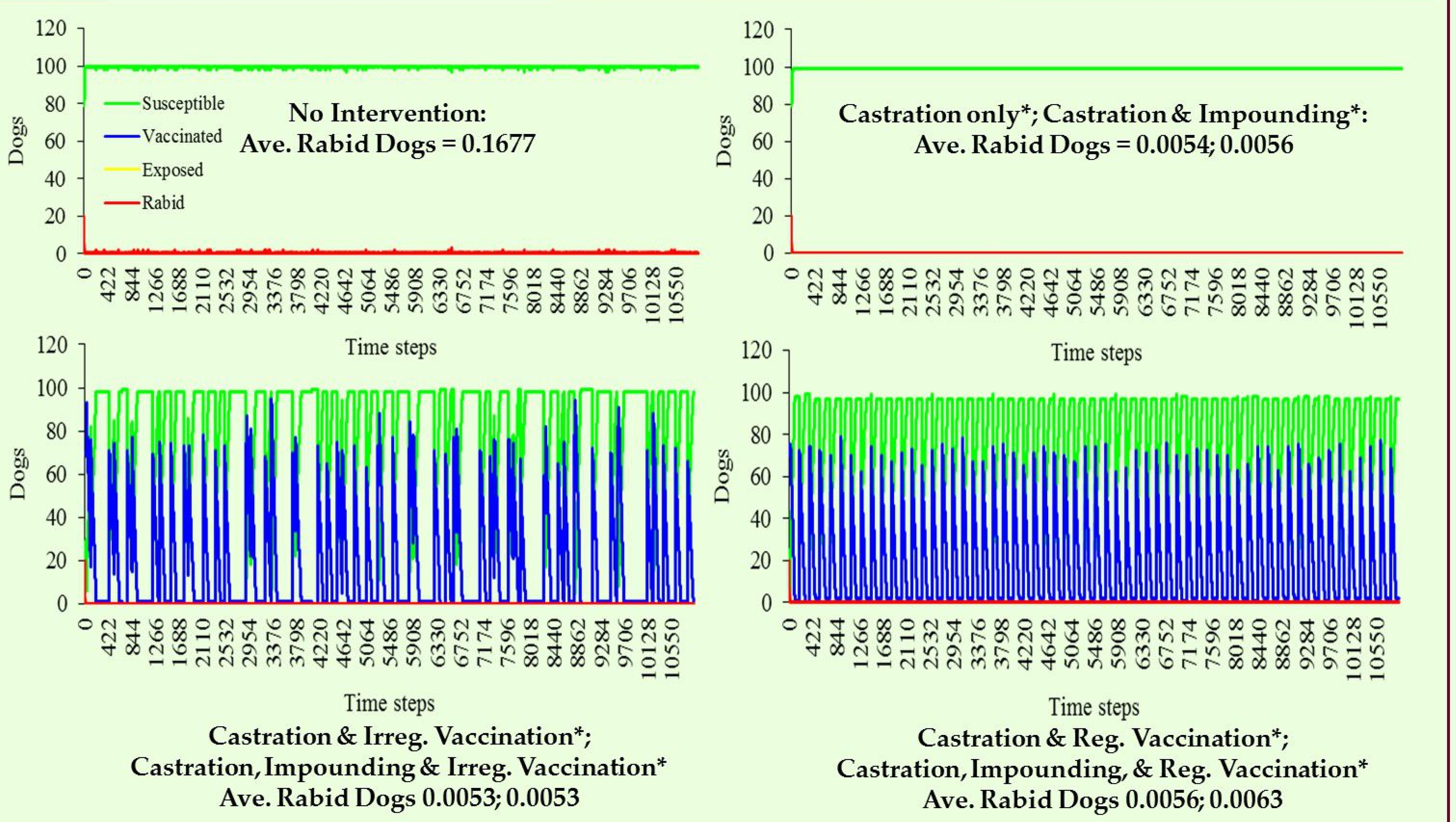

Fig. 7. Plot of a 30 year (10950 time steps) simulation of scenarios where castration was present. * *Significantly different from no intervention scenario at $\alpha = 0.05$.* **Castration parameters:** Birth rate = 1 dog/day, Death rate = 2 dogs/day. **Impounding Parameters:** Birth rate = 2 dogs/day, Death rate = 3 dogs/day. **Vaccination parameters:** 2 vaccinations/year, ON switch for reg. vaccination. Initialization: Dogs = 100, Rabid dogs = 20, Ave. Birth rate = 2 dogs/day, Ave. Death rate = 2 dogs/day.

TAKEAWAYS

- **Castration** statistically lowered the number of rabid dogs in the model. No profound effects were observed on scenarios where vaccination & impounding were present.
- If all dogs in the system were **owned** and 65% of which are **non free-roaming**, then the number of rabid dogs would still decay.
- **Impounding with adoption of impounded dogs** can be a promising approach in eliminating rabies infection

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