KEMAS 21 (3) (2026) 639-646

Jurnal Kesehatan Masyarakat

http://journal.unnes.ac.id/nju/index.php/kemas

Integrated Socio Epidemiological Model for Leptospirosis Control in Tidal Flood Prone Areas

Risna Endah Budiati[1,6], Suharyo Hadisaputro[2]✉, Mateus Sakundarno Adi[3], Rr. Anggun Paramita Djati[4], Suhartono[3], Tri Ramadhani[5]

[1]Cendekia Utama Institute of Health Technology
[2]Faculty of Medicine, Universitas Diponegoro, Indonesia
[3]Faculty of Public Health, Universitas Diponegoro, Indonesia
[4]Health Research and Development Unit Banjarnegara, Indonesia
[5]National Research and Innovation Agency, Indonesia
[6]Cendekia Utama Institute of Health Technology, Indonesia

Article Info

Article History:
Submitted July 2025
Accepted November 2025
Published January 2026

Keywords:
Leptospirosis control; Socioepidemiological model; Tidal flood-prone areas

DOI
https://doi.org/10.1529/kemas.v21i3.34323

Abstract

The Elderly populations in tidal flood-prone areas face heightened vulnerability to leptospirosis due to environmental hazards, recurrent inundations, and psychosocial stressors. This study analyzed an integrated socio-epidemiological model that accommodates a community-based intervention, targeting perceived stress, self-efficacy, and clean and healthy living behavior (PHBS), along with a system dynamics simulation to forecast leptospirosis incidence. This quasi-experimental study design was implemented with 70 participants (35 intervention and 35 control). The participants reside in flood-affected villages of Demak Regency, Indonesia, in 2024 (Purwosari, Sriwulan). Perceived stress (PSS-10), self-efficacy, and PHBS scores were measured at pre- and post-intervention. Statistical analyses included Mann-Whitney, Wilcoxon, and paired t-tests. Delta scores were integrated into a stock-flow model (PowerSim Studio 10) incorporating behavioral and environmental risk variables to simulate leptospirosis cases for 2024–2029. The intervention group demonstrated significant improvements in self-efficacy (Δ=+5.69±8.17, $p<0.001$) and PHBS (Δ=+9.37±4.59, $p<0.001$), alongside a non-significant but clinically relevant reduction in perceived stress (Δ=-7.20±8.33, $p=0.733$ vs control). The dynamic model projected a 25–30% reduction in leptospirosis cases over five years with intervention, compared to a ≤5% decline without behavioral programs. Visual validation indicated alignment between simulated and real incidence trends (2020–2024). Integrating psychosocial behavioral interventions with dynamic modeling provides a reliable framework for leptospirosis control in flood-prone populations.

Introduction

Leptospirosis remains a critical public health challenge in tropical, flood-prone regions, where frequent floods damage livelihoods, facilitate zoonotic transmission, and exacerbate psychosocial distress (Allan *et al.*, 2015; Sulistyawati, Nirmalawati and Mardenta, 2016; Marbawati and Pramestuti, 2017; Ab Rahman *et al.*, 2018; Kurniawati and Nuryati, 2018; Sijid *et al.*, 2022; Dwisiswanarum *et al.*, 2024). Coastal communities in Indonesia, particularly elderly populations, face amplified risks due to chronic exposure, limited mobility, and inadequate health system access. While prior research highlights environmental and biological determinants, few models integrate psychosocial and behavioral dimensions to inform interventions and predictive tools (Convertino *et al.*, 2021). This study bridges this gap by evaluating a dual-pronged strategy:

✉ Correspondence Address:
Faculty of Medicine, Universitas Diponegoro, Indonesia
Email: prof_haryo@yahoo.co.id

pISSN 1858-1196
eISSN 2355-3596

(1) a community-based intervention enhancing stress management, self-efficacy, and PHBS among elderly residents, and (2) a system dynamics model projecting leptospirosis incidence under intervention versus control scenarios. The findings aim to inform evidence-based, multi-sectoral health policies for disaster-prone regions.

In addition to the risk of physical infection, prolonged tidal flooding (rob) triggers significant psychosocial impacts (Budiati, RE.; Hadisaputro, S; Sakundarno, 2025). Communities in these areas must continuously adapt to environmental changes, the threat of livelihood loss, and limited access to clean water (Aksa and Afrian, 2022). Preliminary studies conducted in Bedono Village revealed relatively high stress levels, with the majority of residents experiencing moderate to severe stress. Elevated perceived stress can compromise the immune system, increase vulnerability to infection, and negatively affect the community's clean and healthy living behaviors (PHBS). Various leptospirosis control efforts have been implemented through surveillance, rodent control, and cross-sectoral health education(Peters *et al.*, 2017; Santos *et al.*, 2018). However, evaluations indicate that existing approaches have not comprehensively integrated the psychosocial factors experienced by communities living under chronic rob conditions. Control models focusing only on environmental or biological aspects have proven insufficient to reduce disease incidence significantly (Djati *et al.*, 2020).

Given these conditions, this study employed an integrated socio-epidemiological approach combining social determinants, psychological aspects (perceived stress and self-efficacy), PHBS behaviors, and the environmental context of rob into a unified control framework. Through a module-based educational intervention, the program is expected to reduce infection risk and strengthen the community's psychosocial resilience (Shaluhiyah *et al.*, 2021). The model was developed in the previous research (Budiati *et al.*, 2025). The use of dynamic system modeling to estimate leptospirosis incidence aims to project the long-term impact of the intervention, thereby providing practical input for coastal leptospirosis control strategies in rob-affected areas.(Convertino *et al.*, 2021). This study aimed to analyze an integrated socio-epidemiological model in reducing perceived stress, increasing self-efficacy, and improving PHBS among the target community and to estimate leptospirosis incidence using a system dynamics modeling approach.

Methods

This study employed a quasi-experimental design and was conducted from December 2024 to February 2025 in Sayung Subdistrict, Demak Regency, Central Java. The intervention was implemented in Purwosari Village, while Sriwulan Village was the control site. Seventy elderly residents were recruited through purposive sampling and divided equally into intervention (n = 35) and control (n = 35) groups. The intervention group consisted of active community members to ensure effective participation and delivery of the intervention sessions. In contrast, the control group was drawn from a separate village to minimize contamination between groups. Inclusion criteria included being aged 60 years or older, residing for at least 10 years, and not having severe cognitive impairment or medical conditions that would prevent active participation. Ethical considerations were maintained throughout the study, and informed consent was obtained from all participants before data collection.

The intervention consisted of six weekly sessions lasting 100 minutes each. The content included education on flood-related health risks, training on Clean and Healthy Living Behaviors (Perilaku Hidup Bersih dan Sehat—PHBS), stress management techniques such as mindfulness and breathing exercises, and self-efficacy empowerment modules. Conversely, the control group received only standard Ministry of Health informational leaflets concerning flood-related health risks and PHBS. The dependent variables were perceived stress, self-efficacy, PHBS, and environmental parameters used in the dynamic model, including flood frequency, sanitation conditions, and rodent activity. Perceived stress was measured using the Perceived Stress Scale (PSS-10), self-efficacy using the General Self-Efficacy Scale, and PHBS using the standardized questionnaire developed by the Ministry of Health. The independent variable was the health promotion intervention program.

Pre- and post-test data were analyzed using the Wilcoxon signed-rank test for within-group comparisons and the Mann–Whitney U test for between-group differences. A paired t-test was used for PHBS scores when normality assumptions were met. Delta (change) scores were then integrated into a PowerSim stock-flow model calibrated by surveillance data from the Demak Health Office (2020–2024). Two simulation scenarios were applied, comparing community health trends with and without the intervention. This mixed approach, combining psychosocial-behavioral intervention and dynamic modeling, was designed to provide a robust framework for leptospirosis control in flood-prone elderly populations.

Results and Discussion

The participants characteristics were presented in Table 1., including age, gender, education, occupation and marital status.

The outcomes of the intervention on perceived stress, self-efficacy, and PHBS are presented in TABLE 2, comparing pre- and post-intervention scores between the groups.

Table 2 describes perceived stress variables of both groups and shows reductions of post-interventions (intervention Δ=-7.20±8.33, control Δ=-6.60±9.00), with no significant between-group delta difference (p=0.733). Self-efficacy in Intervention participants exhibited a significant increase (Δ=+5.69±8.17, p<0.001) versus a decline in controls (Δ=-1.89±4.64). The PHBS variable in Intervention participants improved by Δ=+9.37±4.59 (p<0.001) compared to minimal change in controls (Δ=+0.51±1.63). The observed changes in perceived stress, self-efficacy, and PHBS served as essential inputs for the next stage, where a system dynamics model was constructed to capture and simulate the intervention's broader impact.

Based on these findings, the subsequent stage involved constructing a system dynamics model to visualize the interrelationships among key variables. Figure 1 presents the Modified Causal Loop Diagram (CLD). The elements

Table 1. Participant Characteristics

Variables	Intervention (n=35)	Control (n=35)	p-value
Age (years)	47±12.66	47±8.68	0.016
Gender (Male/ Female)	12/23	15/20	0.461
Education	Primary–Tertiary	Primary–Tertiary	0.187
Occupation	Mixed (Farmers, IRT, Laborers)	Mixed (Laborers, Traders)	0.001
Marital Status	30 Married, 5 Widowed	34 Married, 1 Single	0.014

Source : primary data, 2025

Table 2. Changes in Perceived Stress, Self-Efficacy, and PHBS (Pre vs Post)

Variables	Pre (Mean±SD)	Post (Mean±SD)	Δ (Mean±SD)	p-value
Perceived Stress	59.60±11.33	52.40±7.59	-7.20±8.33	0.733 (between-group)
Self-Efficacy	71.46±13.63	77.14±8.56	+5.69±8.17	<0.001
PHBS	67.54±7.50	76.91±8.14	+9.37±4.59	<0.001
Control Group Notes	Minimal change across variables			

Source : primary data, 2025

highlighted in pink represent modifications derived from the current study (perceived stress, self-efficacy, and PHBS), expanding upon the original CLD developed by Djati AP *et al*. These additions illustrate how the present research contributes to and refines the existing framework.

The dynamic system model developed in this study provides valuable estimations of the relationship between changes in clean and healthy living behavior (PHBS) and psychosocial factors, namely perceived stress and self-efficacy, with the incidence of leptospirosis in tidal flood-prone areas.

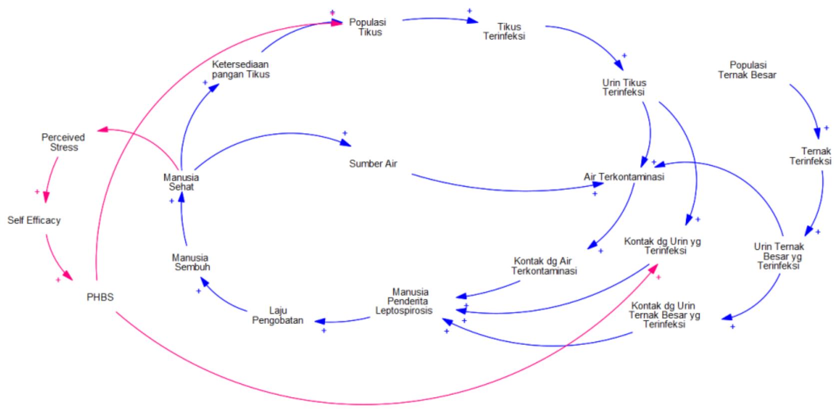

Figure 1. Modified Causal Loop Diagram (CLD)

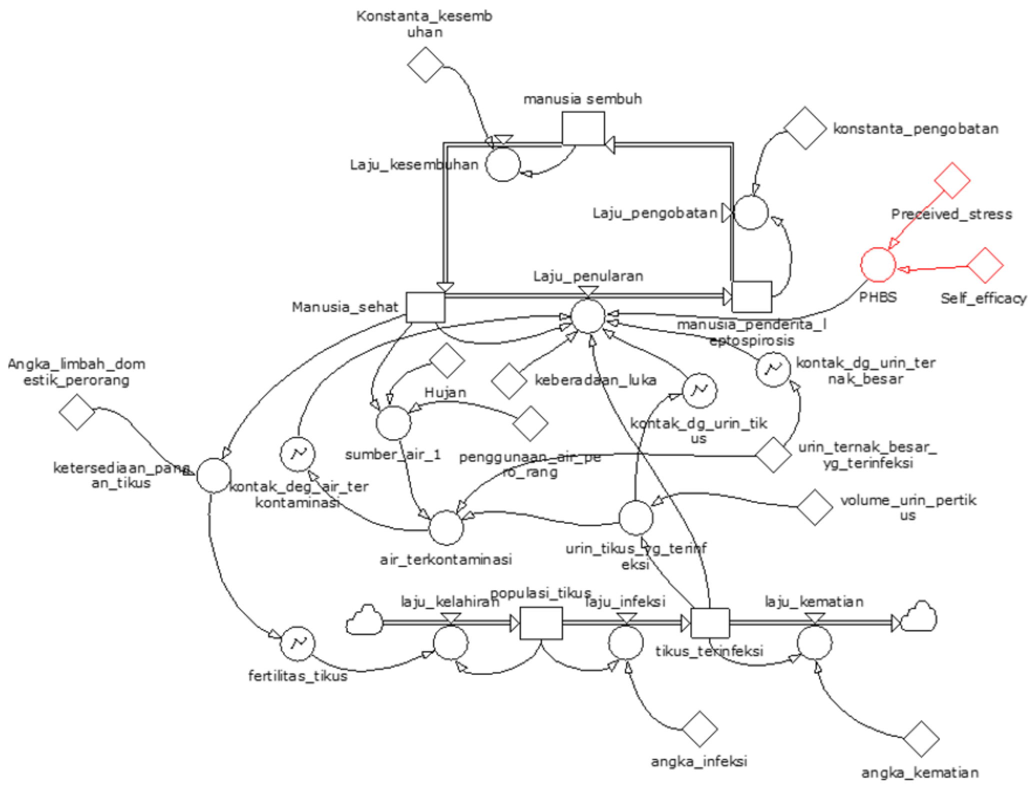

Figure 2. Stock and Flow Diagram (SFD) Incorporating Behavioral Variables and Epidemiological Stocks/Flows

This model also considers other external determinants, such as population density, sanitation conditions, and community habits in maintaining environmental hygiene, thus aligning with a systems-based epidemiological approach that emphasizes the importance of interactions among multiple factors in predicting disease occurrence.

Following the development of the Modified CLD, a Stock and Flow Diagram (SFD) was constructed to translate the feedback structures into quantifiable stocks and flows. Figure 2 illustrates the SFD, which integrates behavioral variables with epidemiological stocks and flows. The use of a stock–flow structure is essential because it allows for the simulation of accumulations and dynamic changes over time, thereby providing a more rigorous representation of how behavioral factors interact with the epidemiological process.

Figure 2 illustrates the SFD, which integrates behavioral variables with epidemiological stocks and flows. The stock–flow structure is crucial because it enables the representation of accumulations (stocks) and movement or transitions (flows) over time, thus allowing dynamic simulations of system behavior. The elements highlighted in red represent new contributions from this study, extending the existing framework by incorporating additional behavioral and epidemiological dynamics identified through the research findings. Simulation output (2024–2029) in projected leptospirosis cases under intervention vs no-intervention scenarios with observed data overlay (2020–2024).

Figure 4 compares Leptospirosis prediction in real data with simulation results for 2020–2024. The real data (dashed line) show a steady upward trend, while the simulation results (solid line) closely follow the observed values up to 2023. The simulation results indicate a decline in leptospirosis cases compared to the projected trend based on real data. It suggests that the predictive model successfully demonstrated the potential impact of the intervention, thereby achieving its intended purpose of reducing the future burden of leptospirosis. This study affirms the critical value of integrating psychosocial and behavioral health components within epidemiological modeling frameworks to address leptospirosis in ecologically vulnerable, flood-prone settings (Djati *et al.*, 2020). By embedding constructs such as perceived stress, self-efficacy, and clean and healthy living behaviors (PHBS) into the design and evaluation of community-based interventions, the study advances the understanding of how psychological resilience and behavioral empowerment can influence infectious disease control (Lopez-Garrido,

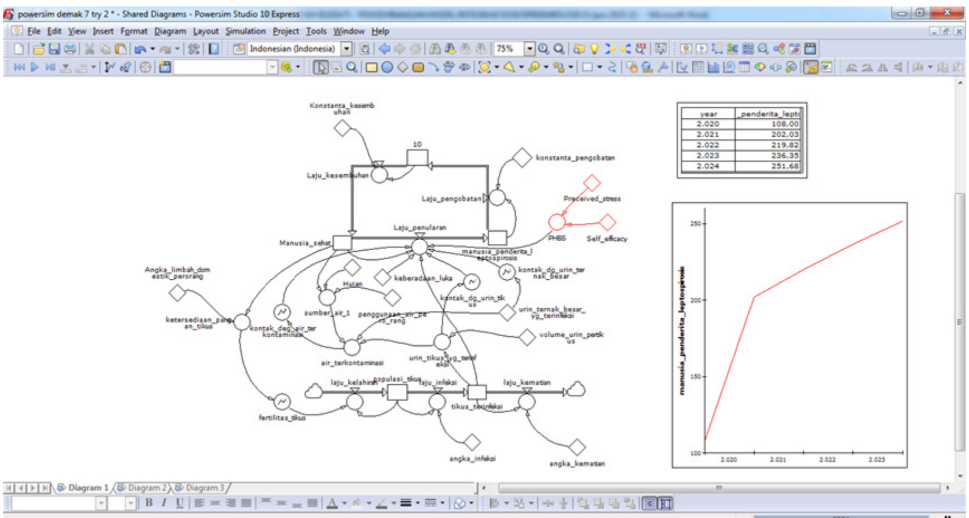

Figure 3. Simulation Output in Predicted Leptospirosis Cases (2024–2029)

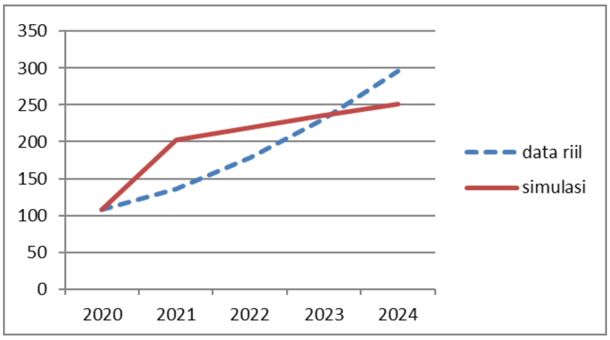

Figure 4. Comparison of Real Data and Simulation Results Incorporating Research Findings

2023; Budiati, RE.; Hadisaputro, S; Sakundarno, 2025).

Although the reduction in perceived stress was not statistically significant, the observed improvement in self-efficacy and PHBS was substantial and aligned with established health behavior theories, particularly Bandura's Social Cognitive Theory (1997)(Lopez-Garrido, 2023), which emphasizes the role of self-belief in driving sustained behavior change. These results also resonate with the World Health Organization's guidelines on community engagement and psychosocial support in emergency settings, highlighting the importance of contextualized, people-centered approaches to health promotion (Zam, Handayani and Sugiharto, 2019; Knight *et al.*, 2021; Meyer *et al.*, 2022). Furthermore, the application of system dynamics modeling provided valuable insight into the potential long-term and population-level impact of the interventions. Causal loop diagrams (CLDs) and simulation-based forecasting illustrated feedback mechanisms between psychosocial determinants, behavior change, and environmental risks, reinforcing the utility of dynamic tools in public health planning. These simulations validated observed outcomes and highlighted intervention points for future policy refinement (Djati *et al.*, 2019; Tam *et al.*, 2020; Graham, Gariépy and Orpana, 2023).

Notably, integrating psychosocial dimensions into leptospirosis forecasting models marks a significant extension of prior work in the field.(Convertino *et al.*, 2021) While conventional epidemiological approaches often focus on environmental and biological risk factors, this study demonstrates the added value of incorporating human behavioral and emotional responses, offering a replicable framework that aligns with the principles of the One Health approach (Djati *et al.*, 2020). In conclusion, sustained and multidimensional interventions—combining health education, psychosocial resilience building, and environmental management—are essential for mitigating the burden of leptospirosis in flood-prone communities. Future research should prioritize longitudinal validation of the model across diverse ecological contexts, as well as the institutionalization of integrated strategies within local health systems to ensure scalability and sustainability (Djati *et al.*, 2020).

Conclusion

The findings of this study demonstrate that the socio-epidemiological integration module for leptospirosis in tidal flood-prone areas can significantly reduce perceived stress, enhance self-efficacy, and improve clean and healthy living behaviors (PHBS) among vulnerable communities. Structured training combined with psychosocial interventions fostered behavioral change and psychological resilience. Moreover, the application of system dynamics modeling enabled accurate estimation of leptospirosis incidence and facilitated the visualization of intervention outcomes under varying environmental conditions. These results indicate that an integrated approach, linking behavioral, psychosocial, and epidemiological strategies, can be a practical and adaptive solution for mitigating leptospirosis risks and strengthening community resilience in coastal areas affected by tidal flooding.

References

Ab Rahman, M.H.A., Hairon, S.M., Hamat, R.A., Jamaluddin, T.Z.M.T., Shafei, M.N., Idris, N., Osman, M., Sukeri, S., Wahab, Z.A., Mohammad, W.M.Z.W., Idris, Z., & Daud, A., 2018. Leptospirosis Health Intervention Module Effect on Knowledge, Attitude, Belief, and Practice Among Wet Market Workers in Northeastern Malaysia: An Intervention Study. *International Journal of Environmental Research and Public Health*, 15(7), pp. 1–12.

Aksa, F.I., & Afrian, R., 2022. Community Adaptation Strategies Toward Tidal Flood: A Case Study in Langsa, Indonesia. *Jamba: Journal of Disaster Risk Studies*, 14(1), pp.1–8.

Allan, K.J., Biggs, H.M., Halliday, J.O.B., Kazwala, R.R., Maro, V.P., Cleaveland, S., & Crump, J.A., 2015. Epidemiology of Leptospirosis in Africa: A Systematic Review of a Neglected Zoonosis and a Paradigm for "One Health" in Africa. *PLoS Neglected Tropical Diseases*, 9(9), pp.1–25.

Budiati, R.E., Hadisaputro, S., & Sakundarno, A., 2025. The Effect of Emotional Freedom Technique (EFT) Training on Perceived Stress Among Communities At Risk of Leptospirosis Affected by Tidal Flooding. *Indonesian Journal of Global Health Research*, 7(4), pp.465–470.

Budiati, R.E., Hadisaputro, S., Adi, M.S., & Wulandari, N.A.D., 2025. Perceived Stress and Self-Efficacy Among the Elderly in Tidal Flood-Prone Communities: A Socioepidemiological Perspective Study. *Proceeding Cendekia International Conference on Health and* Technology, 3, pp. 169–174.

Convertino, M., Reddy, A., Liu, Y., & Munoz-Zanzi, C., 2021. Eco-Epidemiological Scaling of Leptospirosis: Vulnerability Mapping and Early Warning Forecasts. *Science of the Total Environment*, 799, pp.149102.

Djati, A.P., Ramadhani, T., Pramestuti, N., Priyanto, D., Handayani, T., & Soesilo, T.E.B., 2019. System Dynamic Model of Leptospirosis Control in Demak, Indonesia, 2014. *Indian Journal of Public Health Research and Development*, 10(3), pp.753–764.

Djati, R.R.A.P., Kusnoputranto, H., Utomo, S.W., Sakundarno, M., Dewabrata, P.W., Fuad, H.A.H., & Wicaksono, M.A., 2020. Leptospirosis Control Based on Eco-Social Factors: Modeling Combination in Demak, Central Java, Indonesia. *Biodiversitas*, 21(12), pp.5818–5828.

Dwisiswanarum, B., Umniyati, S.R., Qaimumanazalla, H., Wiratama, B.S., & Ramadona, A.L., 2024. Relationship of Environmental Factors with Leptospirosis Incidence in Southeast Asia. *Jurnal Kesehatan Masyarakat*, 19(4), pp.616–622.

Graham, E., Gariépy, G., & Orpana, H., 2023. System Dynamics Models of Depression at the Population Level: A Scoping Review. *Health Research Policy and Systems*, 21(1), pp.1–12.

Knight, E.L., Jiang, Y., Rodriguez-Stanley, J., Almeida, D.M., Engeland, C.G., & Zilioli, S., 2021. Perceived Stress is Linked to Heightened Biomarkers of Inflammation via Diurnal Cortisol in a National Sample of Adults. *Brain, Behavior, and Immunity*, 93, pp.206–213.

Kurniawati, R.D., & Nuryati, S., 2018. The Correlation between Physical Environmental Factors and the Occurrence of Leptospirosis. *Jurnal Kesehatan Masyarakat*, 14(2), pp.223–230.

Lopez-Garrido, G., 2023. Bandura's Self-Efficacy Theory Of Motivation In Psychology. *Simply Psychology*, pp.1–16.

Marbawati, D., & Pramestuti, N., 2017. Leptospirosis: New Emerging Disease in Sukoharjo District. *Jurnal Kesehatan Masyarakat*, 13(2), pp.230–238.

Meyer, N., Meyer, N., Niemand, T., Davila, A., & Kraus, S., 2022. Biting the Bullet: When Self-Efficacy Mediates the Stressful Effects of COVID-19 Beliefs. *Plos One*, 17, pp.1–16.

Peters, A., Vokaty, A., Portch, R., & Gebre, Y., 2017, Leptospirosis in the Caribbean: A Literature Review. *Revista Panamericana de Salud Pública*, pp.1–9.

Santos, I.d-O.C., Landi, M.F.d-A.L., De Lima, E.M.D., Cruz, L.M., Bofill, M.I.R., Dos Santos, D.E., & De Castro, M.B., 2018. Socio-Epidemiological Characterization of Human Leptospirosis in the Federal District, Brazil, 2011-2015. *Revista da Sociedade Brasileira de Medicina Tropical*, 51(3), pp.372–375.

Shaluhiyah, Z., Indraswari, R., Kusumawati, A., & Musthofa, S.B., 2021. Life Skills Education to Improvement of Teenager's Knowledge, Attitude, Self-efficacy. *Jurnal Kesehatan Mayarakat*, 17(1), pp.1–8.

Sijid, S.A., Muthiadin, C., Zulkarnain., Purba, R.A., 2022. Faktor-Faktor Yang Berpengaruh Terhadap Kejadian Leptospirosis Dan Pencegahannya (Review). *Teknosains: Media Informasi Sains dan Teknologi*, 16(2), pp.214–220.

Sulistyawati, S., Nirmalawati, T., & Mardenta, R.N., 2016. Spatial Analysis of Leptospirosis

Disease in Bantul Regency Yogyakarta. *Jurnal Kesehatan Masyarakat*, 12(1), pp.111–119.

Tam, J., Taylor, G.M.J., Zivin, K., Warner, K.E., & Meza, R., 2020. Modeling Smoking-Attributable Mortality Among Adults with Major Depression in the United States. *Preventive Medicine*, 140(April), pp.106241.

Zam, M., Handayani, O.W.K., & Sugiharto, S., 2019. Pos Informasi Leptospirosis Di Kawasan Air Rob Kota Semarang', *Rekayasa*, 16(2), pp.219–228.