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A Model for Public Health Management of the Vector Borne Disease in the District of Pesawaran, Indonesia: Dynamic Systems Approach

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Abstract: This research is designed to take the broad and integrative view as a model of public health study. The case study was conducted in Lampung Province, Indonesia. The method used in this study is analytical networks process for the development of model for the management of malaria. The pathogenesis of the disease under study has a complexity which required an involvement of non health sectors. Various scenarios where the best scenario would be the basis for setting policy of vector-borne disease control. The study shows that the rise of the incidence of malaria was strongly associated to the number of abandoned fishponds in the area of the study. The results of the dynamic systems approach suggests that effective malaria control is to manage the environment in the form of anopheles mosquito by controlling breeding places of mosquitoes, i.e., neglected ponds.

Key words: Malaria, dynamic system, environmental management, inter sector cooperation, community participation

INTRODUCTION

The management of malaria should involve non-health sectors, local specific and requires consideration of a wide range of factors at various scales. Achmadi suggested that malaria occurrence is bounded to its ecosystem and culture of the people, therefore its control should apply spatial management methods which consider the ecosystem and behavioral aspect of the local community. Various human activities in the name of development including those that are related to abandoned ponds, dam construction, tin mining and land clearing for agriculture and animal husbandry will change the environment and creating mosquitoes breeding places. One of the effective ways to control malaria is by the application of vector control (Townson *et al.*, 2005). The formulation of a vector control program in the endemic region must take into account the principle of sustainability (Berg *et al*., 2012). WHO is actively promoting the principles and approaches in the application of an integrated vector management to improve efficiency, the effectiveness of health cost, the ecology and sustainable vector control. The aspect of sustainability includes aspects of the economic, environment and social.

The district of Pesawaran, Lampung Province is malaria endemic area with Annual Parasite Incidence (API) number of 2.97%. Pesawaran has malaria endemic receptive, especially along the coastal areas in the district Pedada, Hanura and Padang Cermin. This is because the number of mosquito breeding places such as forests, lagoons and abandoned ponds.

Currently, the control of malaria in many parts of the country particularly in the district understudy only rely on health sector, while malaria is a disease related to human behavior and the environment. What could be the best model of malaria control in the site of study?

The purpose of this study is designed to take the broad and integrative view of malaria occurances as model of public health study. This is a dynamic system approach study for the development of model for the management of vector-borne disease as the pathogenesis of the disease under study has a high level of complexity which required a model as an abstraction of the real system. Dynamic system model simulate various scenarios where the best scenario would be the basis for setting policy of vector-borne disease control. Malaria can be regarded as a disease that is highly dependent on the mosquito anopheles habitats.

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MATERIALS AND METHODS

Research approach: This research was conducted in the district of Pesawaran, Lampung, Indonesia using ecological study.

Time and location: The locations which were selected for the study were the villages of Sukarame, Sukamaju and Kampung Baru at the sub-district of Punduh Pedada, District Pesawaran, the province of Lampung. The approaches used were both qualitative and quantitative methods. The research was conducted from the month of September 2011 to April 2012.

Research data: Anopheles larvae, anopheles mosquitoes, biotic variables (algae and predators), abiotic variables (salinity, pH, water temperature, dissolved oxygen/DO), weather variables (precipitation, humidity, air temperature) as well as relevant social variables (community, ponds owners, other stakeholders) were set as the population study. Sample selection was done using a purposive sampling method. Primary and secondary data were both used in the research.

In a period of three months, anopheles larvae, the biotic and abiotic and anopheles mosquitoes were collected regularly wherein the collection was made once every fortnight. Weather data was obtained from the district of Pesawaran's Office of Climatology Meteorology and Geophysics Agency. Depth interviews were conducted to collect social variables. Malaria cases were collected from Pedada's Public Health Center and from the results of the national strategy research that was conducted in Punduh Pedada in 2010. The mapping on the abandoned ponds, Breeding Places of Mosquito's location and the occurrence of malaria cases were done using the Global Positioning System (GPS).

The data for selecting the alternatives for the management of abandoned ponds environment were obtained from the results of comparison questioners matched with expert respondents. The data to build the model of malaria control by the application of management of breeding environment were compiled from the data of larvae, biotic and abiotic variables, weather, social, prevalence of malaria cases and other relevant data obtained from literature study. The data analysis includes univariate and bivariate analysis, content analysis, satellite image mapping, Analytic Network Process (ANP) and the dynamic system.

Statistical analysis: The univariate and bivariate analysis were used in the quantitative data to analyze the relationship between the biotic and abiotic environment with the density of anopheles larvae. It was also used to analyze the relationship between larvae and the mosquitoes and the relationship between mosquitoes and the prevalence of malaria cases. The univariate and bivariate analysis was done using stata software. Meanwhile, the content analysis was used for analyzing the qualitative data.

Satellite map imaging was used to predict the relationship between the changes in the environment with the spread of malaria. Data was analyzed using Arc View 3.1 Software using satellite image map from Google earth 2007. The analysis on the relationship between breeding places was based on the buffer zone. The analysis of the data for selecting the alternatives for the management of abandoned ponds environment was done using the Analytical Network Process (ANP) using Super Decision Software. The formulation of the model for malaria control through the application of environmental management of abandoned ponds was done using the dynamic system using Powersim Software.

RESULTS AND DISCUSSION

Causal loop diagram: The SEIR (Susceptible, Exposed, Infectious, Recovered) model containing two groups of variables or sub-systems, namely the variable host (human) and the variable vector is used in the study (Anderson and May, 1991; Chiyaka *et al.*, 2007; Koella and Antia, 2003; Ngwa and Shu, 2000; Pongsumpun and Tang, 2003). The vector subsystem was developed further based on the life cycle of the mosquito whereas the sub-system models of larvae was developed based on variables that influence their life cycles and its control activities in accordance with the problems and conditions of the study site.

The subsystem of mosquitoes has four stages in its growth and development, namely egg, larva, pupa and adult which normally will takes one month (http://www.enchantedlearning.com/subjects/insects/mosquito). In subsystem larvae, larval breeding is also influenced by the presence of predators. The number of larvae and pupae depends on the number of eggs. So that the model allows the natural occurrence of larval mortality due to both natural and intervention.

A Causal Loop Diagram (CLD) showing the relationship between the variables in the control of malaria and malaria vector breeding through environmental management can be seen in Fig. 1.

Model formulation: Referring to the flow chart Stock Flow Diagram (SFD) in Fig. 2, there are 33 main variables contained in the sub-system of mosquitoes, humans and farms displaced as breeding places anopheles mosquito. Data on the model count based on

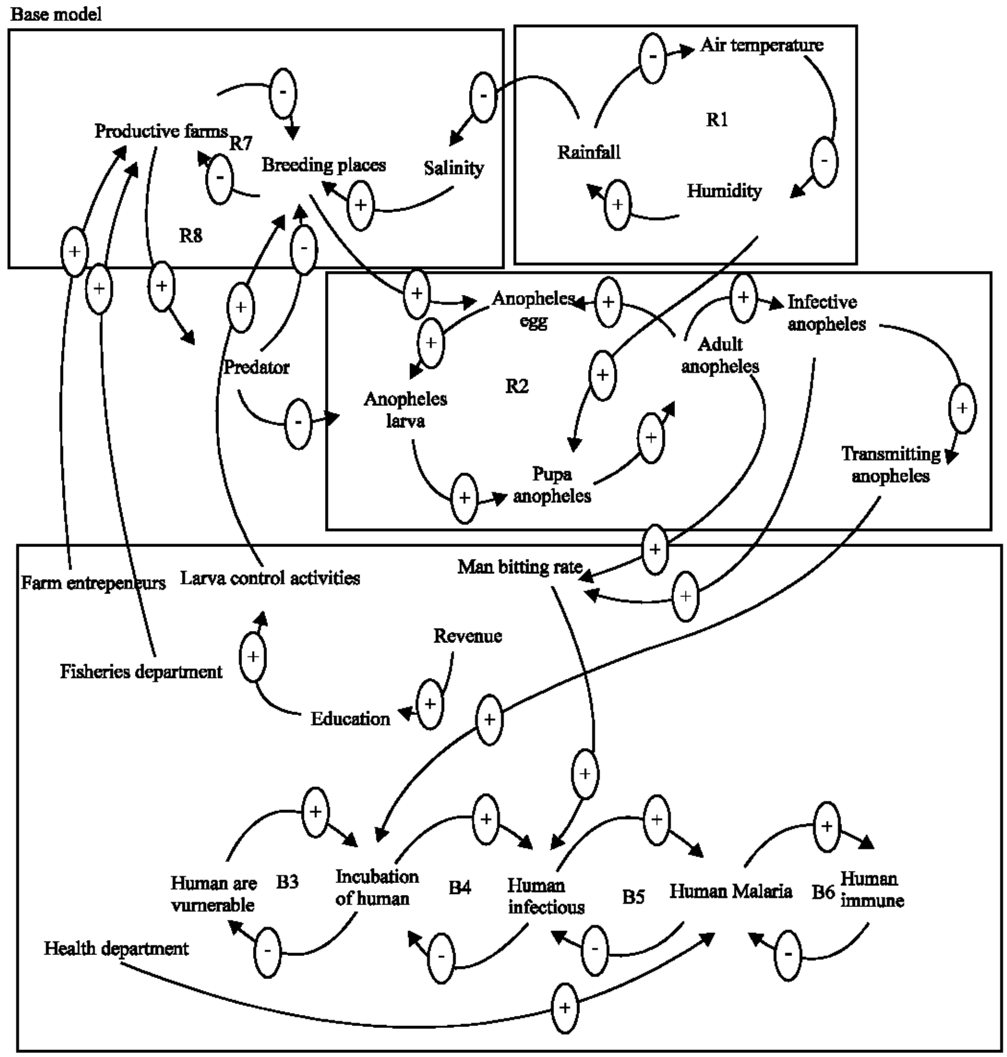

Fig. 1: CLD basic model

an average in a month. Cases of malaria, anopheles larvae, anopheles mosquitoes, salinity, presence of predators, the presence of algae, rainfall, humidity and air temperature are the survey results data at three locations in the village for three months from October to December 2011. As the data used by the survey data were three months then the simulation analysis is performed only for the 24 months period. Such period of time, i.e., 24 months is expected to provide an overview of malaria control through environmental management in the region brood Punduh Pedada, Pesawaran District.

The results of calculations of data on a sub system of anopheles mosquito that is based from the results of the survey are:

- The total number of anopheles larvae in the first month was 750 tail
- The total number of anopheles mosquitoes in the first month is 659 tail
- The average Man Bite Rate (MBR) in three villages 6.8
- The ratio of the number of female anopheles mosquitoes to males is 0.72

The results of calculations of data on the human host subsystem survey results are:

- The number of residents in three rural locations vulnerable to malaria research that some 5106 people
- Host immunity obtained after suffering from malaria. Data obtained 59 people never get sick of malaria in the three study sites during 2011 prior to a simulation run began in 2012

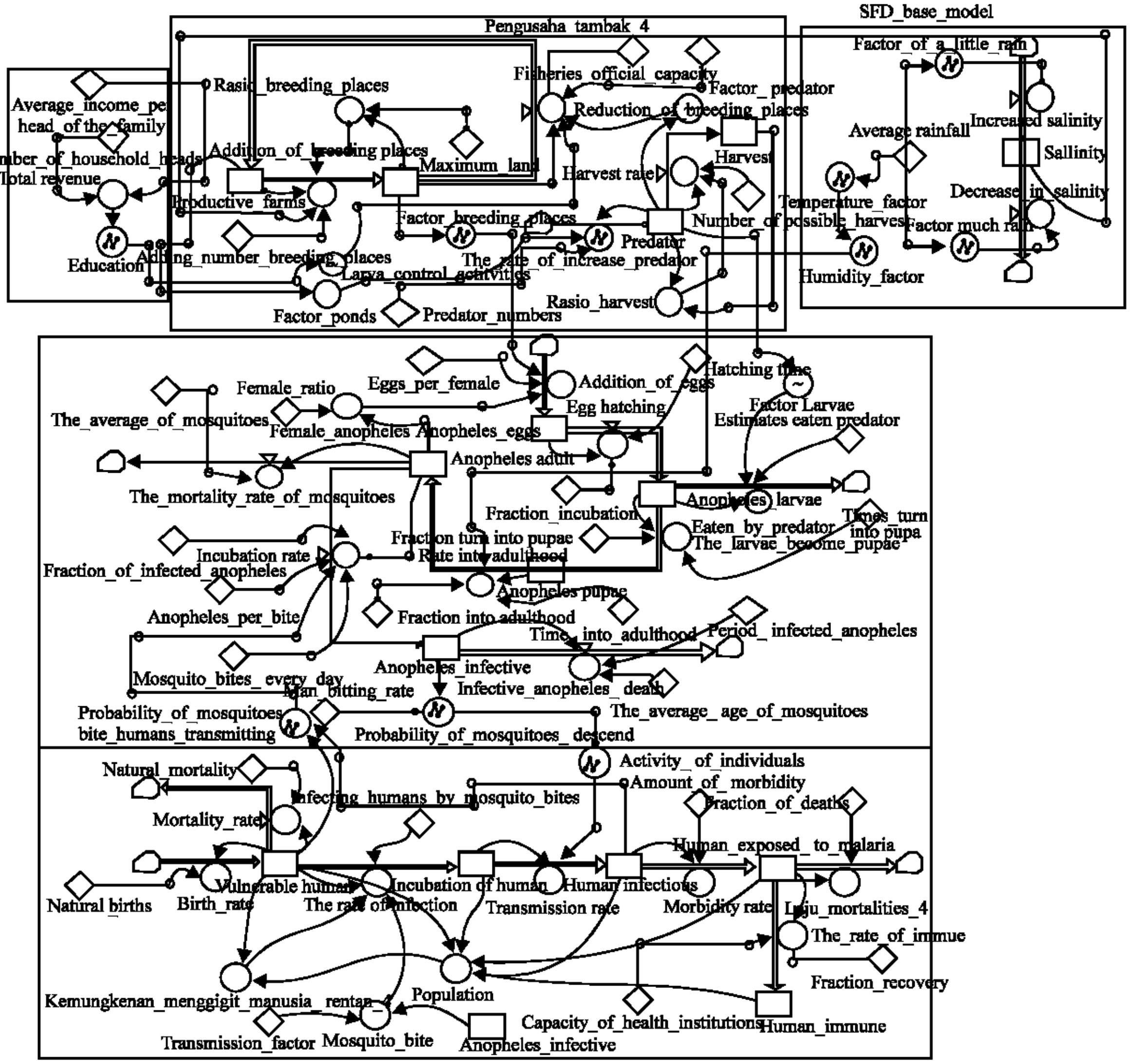

Fig. 2: SFD basic model

- Fraction mortality was 0.0193% as reported by the DHO Pesawaran ever there was one person who died of malaria

The results of the calculation data on farm sub breeding places systems is an area of 38.12 ha of productive farms, the unproductive farms in three villages and potentially a breeding places is 54.129 ha and the average salinity in the three villages of the study was 2%.

The simulation results: In the basic model, we do several scenarios. It is assumed that the number of predators has decreased 10% each month. This means that the number of abandoned farms is increasing from time to time. As the employer made no effort to prevent the pond does not become breeding places so it, is assumed 0%. Fisheries assumed to have a capacity of 30%. Because many of the social problems that cause the increasing number of displaced adds. Such as land disputes, licensing issues, likewise, local government politics which ultimately affects the capacity of local government institutions in the overall Pesawaran including health services. The capacity of public health agencies is only calculated at 50% due to the limited DHO Pesawaran in running programs. The programs that have been implemented by DHO Pesawaran more toward case management and that too is still very limited. DHO Pesawaran suggested that the constraints faced in implementing malaria control

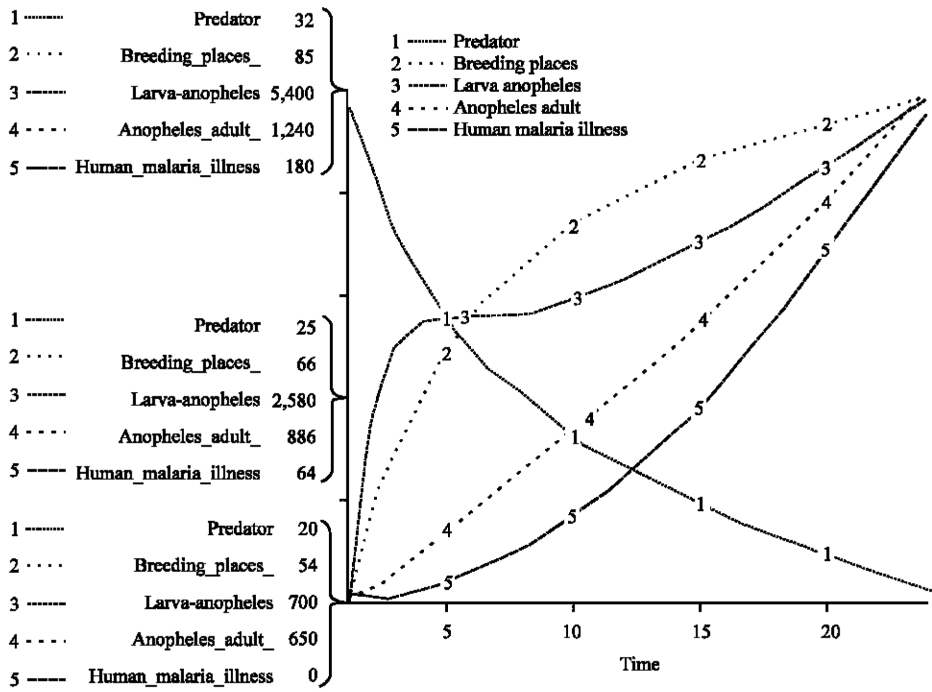

Fig. 3: The relationship between the predator, BP, anopheles larvae and human malaria illness

programs is the limited quality of human resources, lack of infrastructure and the limited number of microscope.

The relationship between the predator, Breeding Places (BP), larvae of anopheles and Malaria on the basis of model simulations behavior shown by the graph in Fig. 3. In Fig. 3 shows, if the predator decreases, would cause BP to rise. If BP increases, the number of anopheles larvae increased. If the larvae of anopheles Malaria increases the number of people contracting malaria will rise.

In CLD basic model (Fig. 1), the relationship between predator and Breeding Places (PC) showed no direct relationship to each other. The behaviour shown in Fig. 3 which shows that the number of predators has decreased every month. At tha predators continue to decrease, then the area of BP will continue to increase. Maximum area of fishponds become a limiting factor in the widespread increase in BP. Thus, the vast BP and productive land will not exceed a total area of fishponds.

Model verification and validity: The further analysis carried out to verify the consistency of dimensional models that aim to ensure that the model has been produced in accordance with the logical framework so that it can function in accordance with the expected goals. How to verify is to examine the workflow model and examine the mathematical equations contained in the model to check whether all the units of the parameters are correct and consistent. Analysis of dimensional consistency can reduce the errors that are logical (logical errors) (Sargent, 2010).

The results verify the dimensional consistency test showed that the model complies with the conditions of reality and can be implemented smoothly and produce output in accordance with the expected output. Examples of dimensional analysis performed are:

Flow in the human population:

Population = Human_immune+human_infectious+human_vulnerable + human_incubation+human_malaria_illness

People = People+people+people+people+people

Flow in anopheles larvae eaten predator:

Larva_Anopheles_Eaten_Predator = Factor_larvae × eaten_by_predator_probability + larvae_Anopheles

Tail/month =Without dimention × Percentage/month × tail

Tail/month = Tail/month

Test the validity of the test is to see the behavior of the model against actual behavior.

Validation is done by looking at the deviation between the output of the simulation with actual data. In this study validated the model using variables human malaria illness. Limit the number of acceptable AME is 5-10%. Absolute Mean Error (AME) validation using. The result means the real calculation and simulation results are:

$$AME = [X_S - X_A] / X_A$$

Where:

X_A = Real data
X_s = Data simulation

Calculation of validity of malaria cases results obtained 3.82% which means the model is valid.

Ecosystem-based malaria control areas: Management of the abandoned fish farms in the site of the study requires cooperation between the health sector and fisheries sectors in accordance with their respective tasks in the implementation of activities in the field. Health authorities would only response if there were malaria cases while the fisheries department will perform an action on farm land that is not productive. Farm owners must also take responsibility for their abandoned pond. While the active participation of the community is expected to control mosquito larvae and adults. Active participation of society is determined by the educational and economic levels of society.

The participation of the community are expected to control larvae with predators. In this study, the predator is tilapia. If the community is active to control larvae with managing ponds with predatory spread the density of anopheles larvae will drop. Active participation of the community is also depending on the level of education and income or the economy. Intervention scenario is a manifestation of the concept-based disease control area where malaria problem is not only a health issue alone but a collective responsibility. Department of Fisheries as the leading sector of the issue abandoned farms with the support of the active participation of the community will be able to control the anopheles larvae that will eventually be able to control the anopheles mosquito and malaria. Likewise, the Department of Forestry as a leading sector mangrove issue.

In this study, the intervention is done by a predator of tilapia production increased by 60% rehabilitation of damaged mangrove 10% capacity fisheries agencies of 30% on the base model increased by 70% employers are expected to consciousness and manages farms farms up to 80% capacity of health institutions from 50% in the base model was increased to 70% and the public expected its activity in the management of derelict ponds up to 50%.

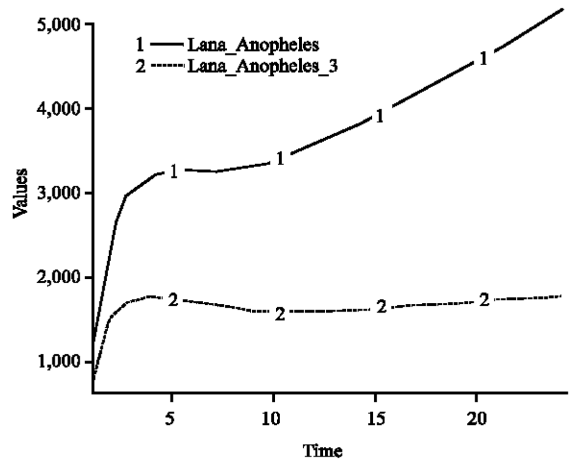

Fig. 4: Anopheles larvae comparison charts on the base model and scenario intervention

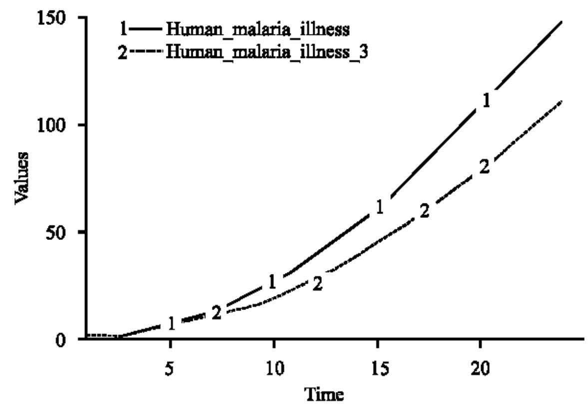

Fig. 5: Graph comparison of humans sick malaria on the base model and scenario intervention

The simulation results after the intervention suggests that the rate of increase in the number of larvae at 55.2% per month. This value is lower than the number of anopheles larvae on the base model (Fig. 4).

Intervention on the institutional capacity of health, education and income provide better results in the reduction of human malaria. Scenario interventions to reduce malaria cases by 25, 78% within 24 months of the simulation period. Thus, the intervention scenario gives better results in the reduction of malaria. Interventions included the optimistic scenario and scenario can be applied.

Interventions including optimistic scenario and scenario can be applied. Intervention scenarios involving multiple parties or cross-sector will be able to reduce the size of BP and reduce the number of people sick with malaria (Fig. 5). Cross-sector collaboration to focus on intervention scenario. Increasing the capacity of local health services and the capacity of institutions in accordance with the corridor fisheries job discs each agency in order to jointly responsible for resolving the issue abandoned the brood pond.

Management of the breeding farms neglected in this study requires cooperation between the health sector and fisheries sectors in accordance with their respective tasks in the implementation of activities in the field. Health authorities would react if there were cases of malaria, while the fisheries department will perform an action on farm land that is not productive. Farm owners must also take responsibility for terbengkelainya pond. While the role of the community are expected to control the predatory larvae of tilapia. If the community is active to control larvae with managing the spread of shrimp ponds, tilapia or milk fish the density of anopheles larvae will drop. In the SFD is seen that the active participation of communities also depend on the level of education and income or the economy of the community.

Vector control is one of effective malaria control strategies in order to determine the transmission of malaria (Shiff, 2002; Townson *et al*., 2005). Vector control through environmental management requires cooperation effective dialogue, between the cross-sector. Among them is the health sector, agriculture, settlement planning, environmentalists, academic institutions (research support) and local communities (Lindsay *et al*., 2004). Larvae of malaria vector control in Africa through environmental management. The goal is to prevent the breeding of larvae. Because covering a wide area in the management of the environment requires the implementation of community participation and intersectoral collaboration. In addition, equally important is the political nature of the approach. The problem of malaria in Lake Victoria could be addressed with an integrated approach. The integrated approach can be realized if there is initial support (social support to strengthen political and financial support) (Downs, 2007). According to the expert of the Department of Fisheries is to turn the derelict ponds with good fish stocking so that, it becomes a natural predator for larvae and re-planting of mangroves along the coast.

Management of the abandoned ponds in this study requires cooperation between the health sector and fisheries sectors in accordance with their respective tasks in the implementation of activities in the field. Health authorities will focus for the case management, while the fisheries department will perform an action on farm land that is not productive. Farm owners must also take responsibility for abandoned fish farms. While the active participation of the community is expected to control mosquito larvae and adults. Active participation of society is determined by the educational and economic levels of society. Mangrove rehabilitation needs attention from the forest service as a leading sector.

CONCLUSION

Intervention scenario is the embodiment of the concept of disease control based on the problem areas where malaria is not only a health sector alone but a collective responsibility. Department of Fisheries as the leading sector of the issue abandoned farms with the support of the active participation of the community will be able to control the anopheles larvae that will eventually be able to control the anopheles mosquito and malaria. Likewise, the Department of Forestry as a leading sector mangrove issue. Integrated planning and budgeting, therefore was suggested.

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REFERENCES

Anderson, R. and R. May, 1991. Infectious Diseases of Humans: Dynamics and Control. Oxford University Press, Oxford.

Berg, H.V.D., R. Velayudhan, A. Ebol, B.H. Catbagan and R. Turingan *et al*., 2012. Operational efficiency and sustainability of vector control of malaria and dengue: Descriptive case studies from the Philippines. Malaria J., 11: 1-269.

Chiyaka, C., W. Garira and S. Dube, 2007. Transmission model of endemic human malaria in a partially immune population. Math. Comput. Mod., 46: 806-822.

Downs, T.J., 2007. A systematic integrated approach for crafting poverty reduction and sustainable development projects. Nat. Resour. Forum, 31: 35-50.

Koella, J.C. and R. Antia, 2003. Epidemiological models for the spread of anti-malarial resistance. Malaria J., 2: 1-3.

Lindsay, S., M. Kirby, E. Baris and R. Bos, 2004. Environmental Management for Malaria Control in the East Asia and Pacific (EAP) Region. The World Bank, Washington, D.C., USA., ISBN: 1-932126-90-2, Pages: 64.

Ngwa, G.A. and W.S. Shu, 2000. A mathematical model for endemic malaria with variable human and mosquito populations. Mathe. Comput. Mod., 32: 747-763.

Pongsumpun, P. and I.M. Tang, 2003. Transmission of dengue hemorrhagic fever in an age structured population. Math. Comput. Mod., 37: 949-961.

Sargent, R.G., 2010. Validation and verification of simulation models. Proceedings of the 2010 Conference on Winter Simulation Conference, December 5-8, 2010, Syracuse, New York, USA., ISBN: 978-1-4244-9866-6, pp: 799-810.

Shiff, C., 2002. Integrated approach to malaria control. Clin. Microbial. Rev., 15: 278-293.

Townson, H., M.B. Nathan, M. Zaim, P. Guillet and L. Manga *et al*., 2005. Exploiting the potential of vector control for disease prevention. Bull. World Health Organiz., 83: 942-947.