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Cost-benefit analysis of mosquito control operations based on microbial control agents in the upper Rhine valley (Germany)

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Abstract

The goal of the German Mosquito Control Organisation (KABS) is to improve the quality of life of the human population across its member communities in the Upper Rhine Valley and to conserve the biodiversity by using environmentally friendly products based on *Bacillus thuringiensis israelensis* and *Bacillus sphaericus*. The effectiveness of its control measures is determined by comparing measurements of the mosquito population in uncontrolled and controlled regions resulting in an overall reduction rate of about 95%. Up to now, however, a cost-benefit analysis, balancing the opinion of the public and valuation of the control measures with the programme's costs, has not been conducted.

This study fills this gap. Results were obtained through a cost-benefit analysis of the mosquito control campaign by assessing the willingness to pay for the campaign using the contingent valuation method. The main finding is that the mean willingness to pay for the campaign per person (€3.50) is 3.8 times higher than the cost of the campaign per person (€0.92). The consumer surplus, the difference between the total value of €8.365 million and the actual costs of €2.2 million, is approximately €6.165 million. This amount is KABS' average contribution to societal welfare in this region during the appraisal.

Key Words: *cost-benefit-analysis, microbial control agents, mosquito control Germany, regional economic implications*

Introduction

The German Mosquito Control Organisation (KABS; Kommunale Aktionsgemeinschaft zur Bekämpfung der Schnakenplage e.V.) was founded in 1976 and today comprises over 100 regional member communities with approximately 2.4 million residents. KABS' mission is to confine the mosquito population in the Upper Rhine Valley while preserving the environment by using ecologically justifiable methods. The potential breeding grounds throughout the KABS

communities comprise an area of approximately 600 km^2 (Becker, 1989). They are regularly treated with various formulations of *Bacillus thuringiensis israelensis* and *B. sphaericus* (Becker, 1997; Becker, 2003; Becker *et al*., 2003).

Successful campaigns using the biological control agent Bti (*Bacillus thuringiensis israelensis*) have contributed significantly to improving the quality of life of residents during the summer months (Becker, 1998), especially regarding residential living conditions, work and leisure. The total cost of the campaign, averaging approximately €2.2 million per year, allocated across all residents in the KABS communities, results in an expenditure of €0.92 per person per year.

Each year, the success of the campaign in the Upper Rhine Valley is ascertained through a comparison of the mosquito populations in controlled and uncontrolled areas. The success rate, or mosquito mortality rate, is approximately 95% (KABS, 2002). Other measures of effectiveness, such as personal benefit for each affected person or the contribution to societal welfare in the region, have not yet been evaluated. Up to now, benefits and costs associated with managing mosquitoes and black flies have been assessed in the US (John *et al*., 1987; Ofiara & Allison, 1985; Reiling *et al.* 1989, 1990) as well as by Fillinger & Lindsay, 2006. This is the first study of the costs and benefits associated with mosquito control in Germany.

Materials and Methods

This study is a cost-benefit analysis of mosquito control measures by KABS in the Upper Rhine Valley. Results were obtained through a cost-benefit analysis of the mosquito control campaign by an assessment of willingness to pay for the campaign using the contingent valuation method. Evaluation criteria were the maximum willingness to pay and the consumer surplus, which is the difference between the maximum total price consumers would be willing to pay and the actual costs (Cummings *et al.*, 1986; Musgrave *et al.*, 1994).

The study determined individual benefit of the campaign for the parameters "residential living conditions", "work" and "leisure", and, by extrapolating these to the total population, its contribution to societal welfare. Individual benefit can only be deduced from a valuation by affected individuals. Therefore, the most important criteria are the personally stated preferences of the residents of the KABS communities. A positive or negative net benefit is calculated by expressing the monetary value as aggregate value and subtracting the costs of the campaign from this (Mühlenkamp, 1994; Pommerehne, 1988; Pommerehne & Römer, 1992).

This study was carried out in 2000, 2001 and 2003. Data were collected by a written survey of 4,608 randomly chosen people from 40 KABS communities. The subjects were randomly selected from public telephone books. The survey was composed of a questionnaire that had been designed according to the NOAA-Panels (Arrow *et al*., 1993). The non-response rate was very low, and 1,922 (43.5%) of the 4,608 questionnaires were evaluated.

The questionnaire was subdivided into five thematic sections, *sensitivity to and protection against mosquitoes*, *benefit of successful mosquito control*, *qualitative evaluation of the campaign*, *individual willingness to pay* and *socio-demographic characteristics*.

The central question regarding the magnitude of the individual willingness to pay was formulated using the contingent valuation method. The benefit to be evaluated, mosquito control, was described in a market situation as realistically and in

as much detail as possible. The respondent was then asked how much he would be willing to pay for this benefit at its present level of quality and at a different defined level (Pruckner, 1995). This type of construction determines the preference for the collective benefit through the willingness to pay. This simulates the market situation necessary for contingent valuation by offering well defined changes in the quality or quantity of the benefit to be bought (Römer, 1991).

As an average measure of willingness to pay, the median was used, since this gives a better indication of central tendency and skewed distribution, and is more robust in the presence of outlier values. The aggregate value of the control programme was obtained by multiplying the individual willingness to pay by the total number of residents in the communities, which demonstrates the contribution of the campaign to societal welfare in the region. The representativeness of the results was evaluated by comparing the variables "age" and "gender" between the sample and the overall population.

In addition to willingness to pay, it was determined whether demographic, social and personal characteristics have an effect on willingness to pay. The effect of single variables was determined by comparing means from subsamples. Since willingness to pay was not normally distributed, non-parametric tests were used, such as the Mann-Whitney-U-Test for two independent samples and the Kruskal-Wallis-H-Test for more than two independent samples (Bühl & Zöfel, 2000).

Regional economic effects were assessed using a telephone survey of 112 randomly chosen restaurants with outdoor seating and a written questionnaire completed by 80 experts in the city councils of the KABS communities. The restaurant owners were asked how the mosquito control programme affected their revenue during the summer months. The experts commented on changes in income from communal facilities such as swimming pools or camping areas.

Statistical analysis was performed using the statistical analysis software SPSS, versions 10 and 11.

Results

The main results of the survey can be presented according to the five thematic sections of the questionnaire.

The first section dealt with the physical and psychological sensitivity of the respondents to mosquitoes, as well as their own or KABS measures to prevent mosquito bites. The most common responses are shown in Table 1.

The answers illustrate that various personal strategies are used to avoid mosquito nuisance. The KABS campaign represents the most important organized control measure in the communities. Comments regarding sensitivity of the respondents demonstrate low tolerance of mosquitoes and confirm that even small numbers of mosquitoes are enough to cause annoyance.

Table 1. Answers regarding *sensitivity and protection against mosquitoes* (results in % are based on a total of 1922 evaluated questionnaires)

Answers	%
Use protective measures such as mosquito nets, sprays or other repellents	78
In favor of communal control measures through KABS	68
Reduce exposure to the outdoors in the summer	58
Have used medicine for mosquito bites	41
Am disturbed by the presence of even a few mosquitoes	39
Have already seen a doctor regarding mosquito bites	19
Sometimes consider moving out of the region due to mosquito nuisance	13

The second part of the questionnaire dealt with private and public benefits of the KABS control programme. The respondents indicated which benefits achieved by successful control measures were the most important for them. The results are shown in Table 2.

Table 2. Answers regarding *benefit of successful mosquito control* for the respondents (results in % are based on a total of 1922 evaluated questionnaires)

Answers	%
Low level of disturbance in the evenings	94
Being able to spend time outside without being annoyed	94
Young children are protected from mosquitoes	92
Improved sleeping conditions	90
Improved living conditions in summer	87
Improved outdoor working conditions	86
Improved possibilities for sport and leisure	85
Economic advantages for gastronomy and tourism	68
Potential increase in property value in the region	46

Respondents indicated that aspects of personal well-being and privacy are most important for them. They document the tremendous gains achieved by successful mosquito control and altogether have an effect on each respondent's willingness to pay. By comparison, economic benefit for gastronomy and tourism is less important. The next section of the questionnaire dealt with evaluating the quality of the campaign. Here, the degree and how well mosquito control measures meet the needs of the public were examined.

Table 3. Answers regarding *qualitative evaluation of the campaign* (results in % are based on a total of 1922 evaluated questionnaires)

Answers	%
Nuisance level last summer was very low	22
Nuisance level last summer was on the low side	41
Nuisance level last summer was on the high side	22
Nuisance level last summer was very high	8
Nuisance level has decreased in the last few years	65
Nuisance level has remained the same in the last few years	15
Nuisance level has increased in the last few years	7
In the future, more mosquito control measures should be employed	29
In the future, the level of mosquito control should remain the same	62
In the future, less mosquito control measures should be employed	3

Based on the predominantly positive results, it can be concluded that the campaign is highly esteemed. The services provided by KABS were evaluated as appropriate and successful. However, it also became clear that there is no such thing as a 100% success rate.

The fourth thematic section of the questionnaire determined the respondents' willingness to pay for mosquito control. The previous questions regarding sensitivity, benefits and evaluation of the campaign were designed to sensitize the respondents for the central question regarding their willingness to pay.

In 1,390 of 1,922 evaluated questionnaires, the amount the respondents were willing to pay was greater than zero. For the yearly KABS mosquito control programme in its current form and level of quality, the average willingness to pay amount was approximately €3.5 per person.

Estimates of the total willingness to pay for the entire population, based on the median individual willingness to pay, were calculated using the total number of residents as well as the total number of households in the KABS communities. This is a conservative estimation method recommended by Hampicke (1991).

Calculations based on the total number of residents in KABS communities resulted in an aggregate value of €8.365 million, whereas calculations based on the total number of households resulted in an aggregate value of €3.983 million.

Table 4. Individual willingness to pay and estimate of mean willingness to pay for the entire population

Individual willingness to pay	Extrapolation to the entire population	Aggregate willingness to pay	Factor
€3.5 (median)	2,390,000 residents in the KABS communities	€8,365,000	3.8
	1,138,000 households in the KABS communities	€3,983,000	1.8

Using the total number of inhabitants as the population base, the aggregate value was higher than the actual yearly costs by approximately €2.2 million, a factor of 3.8. Using the number of households as the population base, aggregate value was 1.8 times higher than the actual costs.

The last section of the questionnaire dealt with residents' socio-demographic characteristics and their effect on willingness to pay. Age, period of time living in the same area and living arrangements were all found to have an effect on the willingness to pay.

Respondents who were willing to pay the most:

- were between 45 and 60 years old ($p = 0.014$).
- had lived in the same area for more than 30 years ($p = 0.032$).
- were homeowners living in a two-person household ($p = 0.073$).

Respondents who were willing to pay the least:

- were between 18 and 25 years old ($p = 0.013$).
- had lived in the same area for less than 10 years ($p = 0.026$).
- were renters living in single-person households ($p = 0.092$).

In addition, sensitivity of the residents and the satisfaction with the control programme both had an effect on the willingness to pay. Respondents willing to pay the most:

- self-treat themselves after a mosquito attack or seek treatment from a doctor ($p = 0.001$).
- use individual mosquito control methods ($p = 0.004$).
- rate themselves as very sensitive to mosquitoes ($p = 0.07$).

Of note is that residents that were either especially satisfied or especially unsatisfied with the control programme both demonstrated a significantly high willingness to pay. Accordingly, respondents that indicated greater willingness to pay:

- were caused little annoyance in the last summer by mosquitoes ($p = 0.027$).
- stated that nuisance had greatly decreased in the last few years ($p = 0.05$).
- were especially satisfied with the campaign ($p = 0.053$).

The following respondents that also exhibited greater willingness to pay:

- stated that nuisance had greatly increased in the last few years ($p = 0.01$).
- were caused great annoyance in the last summer by mosquitoes ($p = 0.033$).
- were especially unsatisfied with the campaign ($p = 0.045$).

Discussion

In the cost-benefit analysis, the costs of the mosquito control programme were balanced against the benefits of the programme. Positive net benefits demonstrated that the KABS campaign contributes to societal welfare in the region. Most striking is the fact, that the overall cost for the control programme is less than 1 Euro/person/year. The main finding is that the mean willingness to pay for the campaign per person (€3.50) is 3.8 times higher than the cost of the campaign per person.

In Table 5, the cost-benefit balance sheet shows the project costs on the left side, €2,200,000, comprising costs for administration, human resources, assets and scientific evaluations. On the right side, project benefits are shown in the form of aggregate willingness to pay, €8,365,000 (estimate of total number of residents) or €3,870,000 (estimate of total number of households).This result was similar to that obtained by John *et al.* (1987) in a cost-benefit analysis of mosquito abatement in the Jefferson County Mosquito Control District in Texas (JCMCD). Using the contingent valuation method, the willingness of the affected population to support the control programme was determined (John *et al.*, 1987, p. 11: "... the bid represents the maximum amount of income the responding household is willing to pay to maintain the current level of mosquito abatement provided by the JCMCD").

In this study, the aggregate total value estimated for the total number of households, $1,923,860, was 1.8 times greater than the costs of the programme, $1,043,636 (John *et al.*, 1987, p. 12: "... the total benefits county residents received from JCMCD mosquito abatement were about 1.8 times as great as costs during the 1982 / 83 fiscal year").

Table 5. Cost-Benefit balance sheet of mosquito control programme

Balance	
Project costs:	Project benefits:
€2,200,000	€8,365,000 (individual residents)
	€3,870,000 (households)
	Consumer surplus:
	€6,165,000
	€1,670,000
Economic costs	Economic value

The consumer surplus, the difference between the total benefits and costs of the project (Takayama, 1984), was estimated at €6,165,000 for the total population based on the number of individuals and €1,670,000 based on the total population of households. These amounts represent a positive net benefit of the campaign and the contribution of KABS to societal welfare in the region. Table 5 illustrates that, aside from the project costs and benefits, the campaign has further economic costs and benefits that could influence the value of the project. Economic costs decrease the net benefits of the campaign, while economic benefits increase net benefits.

For example, net benefit is decreased if the fauna in the floodplains especially mammals and birds, are occasionally compromised by the use of helicopters. As a result of the campaign, the Rhine riverbanks have increasingly become places for recreation and leisure, with the result that some leisure activities have a negative ecological impact.

On the other hand, net benefit is increased when, after a successful campaign, leisure-time facilities and gastronomy experience an increase in their revenue by up to 25%. In addition, communities that are not members of KABS also gain from the control programme. They receive an external benefit and profit as free-loaders without having to provide their own financial support (Marwell & Ames, 1981).

It is difficult in part to assign monetary value to these economic influencing factors. Therefore, they are included in the evaluation as qualitative influencing factors. According to the current results, the net benefit, including these qualitative components, remains positive. Thus, the mosquito control programme contributes to an increase in individual quality of life as well as to an increase in societal welfare in the Upper Rhine Valley.

It should also be considered that cost is not only economic but also ecological. The cost analyses did not consider the additional benefits of using microbial control agents, namely, reducing the use of chemical larvicides and development of resistance, lack of impact on non-target organisms, safety of workers and human population in large.

Fillinger & Lindsay (2006) estimated the costs for a vector-mosquito larval control programme in Africa to suppress malaria less than US$0.9 per person per year and thus in the same ranges or even more cost-effective than ongoing interventions.

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