Estimation of Optimal Congestion Levels: Deer Hunting in Western Oregon

By

Olvar Bergland, Seung-Woo Kim, Don McLeod and Eirik Romstad*

Department of Agricultural and Resource Economics,

Oregon State University,

Corvallis, OR 97331-3601

* Bergland is Assistant Professor in Department of Agricultural and Resource Economics, Oregon State University, Kim, McLeod and Romstad are Graduate Research Assistants in Department of Agricultural and Resource Economics, Oregon State University. Helpful comments by Richard Adams, Doug Brodie and Rebecca Johnson are much appreciated.
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ABSTRACT

The referendum format of the contingent valuation method is used to find willingness-to-pay (WTP) for reduced deer hunter congestion. The WTP locus was estimated using logistic regression and the 95% confidence intervals were found using bootstrapping techniques. The results suggest a 20-30% reduction in the number of permits issued.

Key words: Contingent Valuation, closed ended bids, dichotomous choice models, logistic regression, bootstrapping, optimal congestion levels.

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Introduction

For any common property resource the collective or cumulative actions of the users influence the individual user's derived welfare. Due to its limited nature the possibility of overuse exists. Situations concerning the over-harvesting of ocean fisheries resources or overgrazing on public land are commonly known occurrences of this phenomenon. Recreational activities also admit of overuse or congestion.

Congestion is a type of externality. Overcrowding serves to alter the site quality originally demanded: harvest success rates in the cases of hunting or fishing, access to various site locations, the opportunity for solitude and the cleanliness or the undisturbed character of the site. An increase in the number of participants is likely to affect the use value of the site to all users.

In the case of hunting on public land the hunters compete with each other for the fugitive resource. They also affect each others pursuit of solitude and observation of nature. Initially, the presence of other hunters helps chase the abundant game from hiding. Increasing numbers of hunters pose the possibility of over harvesting, of conflict over choice of hunting grounds, of increasing the risk of hunter injury or fatality and of chasing the game out of the public area altogether. Overcrowding diminishes the ability of the land to support game and of the hunter to harvest such game.

This paper delineates a set of procedures to estimate willingness-to-pay (WTP) for reduced congestion and more important, determination of an optimal congestion level. The estimated value of WTP for reduced congestion of recreational areas is a random variable with a corresponding unknown distribution. Bootstrapping is therefore used to find the $(1-\alpha)$ confidence intervals of the estimated WTP.

The paper first presents the theoretical foundation to determine the optimal congestion level. Second, it presents an empirical study where the outlined principles are applied. Third, it suggests a set of management strategies of the deer population in the MacDonald-Dunn Forest under various assumptions about hunter success rate as a function of hunter congestion.

Theoretical Background

Congestion or overcrowding is a particular externality which occurs when a number of individuals are utilizing a facility of a fixed size and their presence adversely affect the enjoyment derived by the other users. The cost characteristics of congestion have been widely discussed and depicted (Fisher & Krutilla, 1972; Stankey, 1972; Cicchetti & Smith, 1973, McConnel, 1977; Cesario, 1980; Walsh & Gilman, 1982; Rosenthal et al., 1984; and Cullen, 1985).

Management tools such as queuing, lotteries, permits and fees have been compared in various studies concerning excess demand for recreation sites (Cesario, 1980; Rosenthal et al., 1984; Cullen, 1985; and Wilman, 1988). The use of fees has particular interest, barring undesirable distributional effects (for example, Cory, 1985 or McConnell, 1988), as an allocation device.

Various approaches have been employed to incorporate congestion into recreation demand models. Travel cost models have been proposed which include congestion arguments (Wetzel, 1977; McConnell, 1980; Anderson, 1980; and Smith, 1981). Deyak and Smith (1978) proposed using household production function models which included congestion as a cost associated with recreation activities.

Attempts have been made to directly model the relationship of congestion on willingness to pay (WTP). Fisher and Krutilla (1972) suggested the following specification:

WTP = F(congestion, income, substitution, user days, socioeconomic variables)

They were then able to simulate a relationship between WTP and expected number of encounters among back country recreationists and derive the benefits associated with various use intensities and ultimately arrived at the number of recreation days associated with maximum aggregate WTP, net of congestion disutilities, for a Montana wilderness area. Menz and Mullen (1981) found a negative relationship between willingness to travel to a site and expected encounters with other recreationists.

Walsh et al. (1983) examined the relationship of congestion impacts on WTP at several Colorado ski resorts. Congestion was modelled by the number of skiers per acre and the waiting time at the lift. From this analysis they obtained marginal cost estimates for increased usage of the resorts and marginal WTP as a function of the number of skiers per day. Optimal capacity estimates were obtained from equating marginal cost and marginal WTP.

Dorfman (1984) presents a conceptual model for simultaneously determining price and facility of a congested facility. The resulting constant crowding demand curve was then used to calculate the aggregate consumer surplus of the users. The optimal congestion level is now defined as that level which maximizes the sum of the producer and consumer surpluses. One complication in the models of congestion is the simultaneity between individuals decision about using the facility and the crowding of that site (see

McConnell, 1988, for a further discussion). However if the access is rationed through a binding limit of users, say a fixed number of permits, each potential user's decision will be made conditional on a particular fixed level of crowding. Thus the crowding level assumes the same status as any other quantity rationed commodity, and the standard theory of behavior and welfare change measurement under uncertainty applies, Johansson, 1987; Bergland, 1985). The welfare change associated with a reduction in crowding can then be estimated by the standard version of the referendum format of the contingent valuation method (see Cummings et al., 1986, Hoehn & Randall, 1988).

The MacDonald-Dunn Forest Deer Hunt

The MacDonald-Dunn forest, located north of Corvallis in Western Oregon, serves multiple uses. The primary use is forestry research. As the MacDonald-Dunn forest is located close to an urban area, it is used heavily for recreation. The possibility of seeing deer increases the value of the recreational experience in the forest, and indicates that a large resident deer population is desireable. On the other hand, a high density of deer may not be consistent with ethical considerations of having a healthy deer population, and foraging by the herd could negatively affect the forestry related research activities in the forest. The number of deer harvested has been sufficient to satisfy the above mentioned needs for population control[1].

In the past hunters have complained about overcrowding which reduces their enjoyment of the deer hunt. This raises the question whether too many

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[1] The MacDonald-Dunn forest covers an area of about 11,000 acres, and one estimates the current resident deer population to be 550-600 deer. The last years, approximately 160 deer have been harvested in a special permit deer hunt (Jeff Garver, forest manager, personal communication).

permits are issued, and whether the recreational value of the hunt could be increased by issuing fewer permits. As permits are required for deer hunting, a change in the number of permits issued would constitute no principal difference from today's accepted resource allocation mechanism. Thus we are particularly interested in determining an optimal number of permits to issue. The impression of potential overcrowding was also indicated in the introductory questions to our survey[2]:

Table 1: Effect of current congestion on perceived enjoyment, by hunting result (number of hunters).[3]

Hunting result	Congestion increases enjoyment	Congestion decreases enjoyment	No opinion/ Indifferent
No deer shot	14	43	25
Deer shot	11	17	15

Survey of Deer Hunters

Survey Design and Data Collection

Given the special hunt scenario, hunting opportunities and congestion act as rationed commodities and the welfare effects of changes in any of these can be defined by the Hicksian compensating variation. These can be estimated by the use of contingent valuation techniques.

The data was obtained by an intercept survey with sampling from hunters

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[2] Class project in environmental economics, fall 1988. Intercept survey of 125 deer hunters at the MacDonald-Dunn forest special permit deer hunt.

[3] The question was: "Does the current number of hunters per square mile at the MacDonald Forest Deer Hunt influence your enjoyment of it?".

entering the MacDonald-Dunn Forest hunting area at two of a total of six entry points and from hunters who bagged a deer at the Oregon Department of Fish and Wildlife weigh in station. The subjects were asked two valuation questions, one about the present hunting conditions and one with either a 25, 50 and 75 percent reduction in permits (and thus less crowding). The posted bids ranged from 12 to 313 dollars with more bids clustered towards the lower end.

Model Choice: Structure and Variables

The valuation of reduced congestion is modelled as the probability of obtaining a negative response (a "no" response) for a given bid level. The logarithmic form of the bid was chosen as it is supposed to yield downward sloping Hicksian demand curves (Sellar et al. 1986) and because bids at $ 0.00 would yield a zero probability of rejecting the bid. This latter assumption seems reasonable as the hunters already had paid a ten dollar fee to hunt.

The specified (logit) model can be described as follows:

$$y = H_x(x) = 1/(1 + e^{-f(x)}) \qquad (1)$$

where $H_x(x)$ is a cumulative distribution function indicating the possibility of answering "no" for the given bid prices.

where: y = 1 if answer is 'yes'
0 if answer is 'no'
x_1 = log of bid prices
x_2 = 0 if percent of reduction level is 0
1 " " " " " " 25
2 " " " " " " 50
3 " " " " " " 75

The expected willingness-to-pay (WTP) is calculated as the trimmed mean of the logistic distribution using the following formula:

$$E(WTP) = \int_0^{X_{max}} x \cdot f_x(x)dx$$

where: X_{max} is the maximum bid price, and
$f_x(x)$ is the PDF of x.

Logistic regression results for the discrete specification of % reduction

The logistic regression model was fitted using maximum likelihood estimation techniques[4]. The estimated model was:

$$Pr\{no\} = h[\ln(bid),\% \text{ reduction}] \quad (2)$$

The "hunting result" weighted results from the specified model:

Table 2: Analysis of maximum likelihood estimates from equation (2): Pr{no} = h[ln(bid),% reduction], (-2lnL = 202.27, n = 236)

Source:	Estimate	Asymptotic Std. error
Intercept	-3.7289	1.0112
Ln(bid)	1.6948	0.3302
% reduction: (25)	-1.6351	0.4660
" (50)	-1.2544	0.4530
" (75)	0.6433	0.6133

The estimated coefficients have the expected signs with one exception, "75% reduction" where the probability of a "no" answer to the proposed bid increases rather than decreases. With regard to this particular coefficient it should be noted that the coefficient is not significantly different from zero ($X_1^2 = 1.10$) at 25% level. A possible explanation for this phenomenon may be that some hunters might fear their chances of hunting in the future would be reduced too much if they stated their true preferences with regard to such a large reduction in the number of permits issued, thus introducing some strategic bias. Another possible explanation is that some hunters actually prefer that there are other hunters around as they claim that this helps move the deer and make them easier to spot.

[4] All models were estimated using PROC CATMOD in SAS, version 6.03.

Calculating WTP for the discrete specification of % reduction

Numerical integration methods were used to calculate the individual and aggregate consumer surplus. Before looking at the estimated WTP-measures, recall that the only variables included in the final estimated model were: "intercept", "ln(bid)", and "% reduction". This implies that in the numeric integration procedure yields four surplus measures: one for each reduction level (0, 25, 50, or 75%).

Table 3: Mean and aggregate WTP for the discrete model specification (2).

% reduced congestion	number of permits	Mean WTP	Agr. WTP
0	1,000	15.55	15,554
25	750	36.18	27,137
50	500	29.99	14,995
75	250	10.94	2,734

Table 3 indicates that the maximum aggregate WTP is achieved somewhere around 750 hunters. According to our criterion for a social optimum, this is then the optimal number of permits to issue. A continuous specification of "% reduction" would allow an estimate of this number which was not rounded off to the closest 250 hunters.

Continuous specification of % reduction

As mentioned we would like to find a better estimate of the optimal number of permits to issue than the rounded off estimate obtained by the discrete specification of our model. Tables 2 and 3 suggest a polynomial in

"% reduction" of degree two. To reduce multicollinearity between reduction level and reduction level squared, the reduction levels were normalized by their sample mean (0.2479). The following model was estimated, letting "% reduction" be a continuous variable:

$$\Pr\{no\} = h[\ln(bid), t(\%\ reduction)] \tag{3}$$

where

$$t(\%\ reduction) = \alpha_1+\alpha_2(\%\ red.-mean\ \%\ red)+\alpha_3(\%\ red.-mean\ \%\ red.)^2 \tag{4}$$

Table 4: Analysis of maximum likelihood estimates from equation (3): Pr{no} = h[ln(bid),h(% reduction)], (-2lnL = 202.42, n = 236)

Source:	Estimate	Asymptotic Std. error
Intercept	-5.2502	1.0959
Ln(bid)	1.6930	0.3301
(norm. % red.)	-2.6558	0.8195
(norm. % red.)^2	14.1007	3.2698

Comparing the results in Table 4 with those of Table 2 show that the estimated coefficient and standard error are for all practical purposes the same for the variable "Ln(bid)". The difference in the intercept term can be attributed to (4), where the intercept term in Table 4 also embodies α_1. These comparisons indicate that the choice of functional form (4) which was done after having estimated the model initially with dummy variables representing the reduced hunter congestion, was a reasonable choice. In this connection it should be noted that directly estimating the continuous version, equation (4), would not be possible unless one had prior beliefs about the functional form of t(% reduction) which would be observationally equivalent to the chosen functional form.

From the logistic regression results, the locus of WTP was found using /the same procedure of numeric integration as was done for the discrete specification of the model (2). These results are shown in the following table:

Table 5: Estimated aggregate consumer surplus for 0, 25, 50 and 75 "% reduction" using the continuous specification of reduction level.

% reduced congestion	number of permits	Mean WTP	Agr. WTP
0	1,000	15.69	15,693
25	750	34.50	25,876
50	500	30.60	15,298
75	250	10.53	2,632

A plot of aggregate consumer surplus from the continuous and discrete specifications are shown in Figure 1.

Figure 1 indicates that the optimal number of permits to issue is about 700. However recall that the estimated aggregate WTP is a random variable. In assessing both the optimal deer hunter congestion level and the recreational value of the deer hunt, one should therefore have (1-α) confidence intervals. As the variables in equations (3) and (4) are not perfectly correlated, it is unjustified to insert $\hat{\beta} \pm t_{1-\alpha,k}\, SE(\hat{\beta})$ from the logistic regressions into the numeric integrator to obtain the confidence intervals for mean or aggregate WTP as done by Sellar et al. (1985). Kim et al. (1988) suggest using bootstrapping techniques to obtain the confidence intervals in such cases, a suggestion we adopt here. A plot of the estimated WTP for various reductions in congestion and the corresponding 95% bias corrected (BC) confidence intervals are shown in Figure 2. Kim et al. (1988) shows that in this particular case the more recent developments of bias corrected confidence intervals; the parametric and nonparametric versions BC_α method (Efron, 1987) and the BC_α^o method (DiCiccio and Tibshirani, 1987) are not applicable.

Conclusion

In the case that the optimal congestion level depends only on the recreationists' satisfaction from using the area, optimal congestion is determined to be where aggregate willingness to pay is the highest. This paper shows how the contingent referendum approach, logistic regression and numeric integration can be used to obtain mean and thus aggregate willingness to pay for reduced congestion in recreational areas. As the obtained measures are estimates, the confidence intervals are of interest to the decision maker. We obtained the confidence intervals using the bias corrected bootstrap technique (Efron, 1981; Efron and Tibshirani, 1986).

In the initial regressions, the proposed reduction levels were treated as dummy variables, as little was known in advance regarding the functional relationship between the willingness to pay for the recreational commodity in question and the level of congestion. On the basis of these regressions, a continuous model in reduction level was formulated and estimated (equations 3 and 4).

At the maximum estimated aggregate WTP (approximately 750 hunters), the 95% lower and upper confidence intervals are approximately $ 19,000 and $ 40,000 respectively. This large variation in the estimated aggregate WTP shows that care should be taken in interpreting point estimates of WTP as true welfare measures. Our research also indicates that bootstrap methods are a viable way of obtaining these confidence intervals, even when the distribution of WTP is unknown.

If the management of the MacDonald-Dunn Forest deer population was to be decided solely on the basis of hunter enjoyment derived from the hunt, 700 - 800 permits should be issued. The management objectives for the deer population are however more complex as already stated. One complicating factor in deciding the optimal level of permits to be issued in the MacDonald-Dunn Forest Deer Hunt is that one has little prior information about the effect of reduced congestion on the success rates for the individual hunters. "Hunting result" was not significant on the 10% level in initial regressions, indicating that its influence on estimated WTP and thus on the optimal number of permits to issue, would be small. This applies to our particular data.

In other subsequent studies of this type, the estimated WTP for hunting and reduced congestion may differ considerably between hunters who got and did not get their game. Thus the social optimal congestion level is going to be contingent upon the ex post hunter success rates. As these is not going to be known when initial reductions/increases in permits is made, there will be a transitional stage where one learns about the change in success rates as the number of permits issued is changed. After some time one may then come up with reasonable bond for the optimal number of permits to issue.

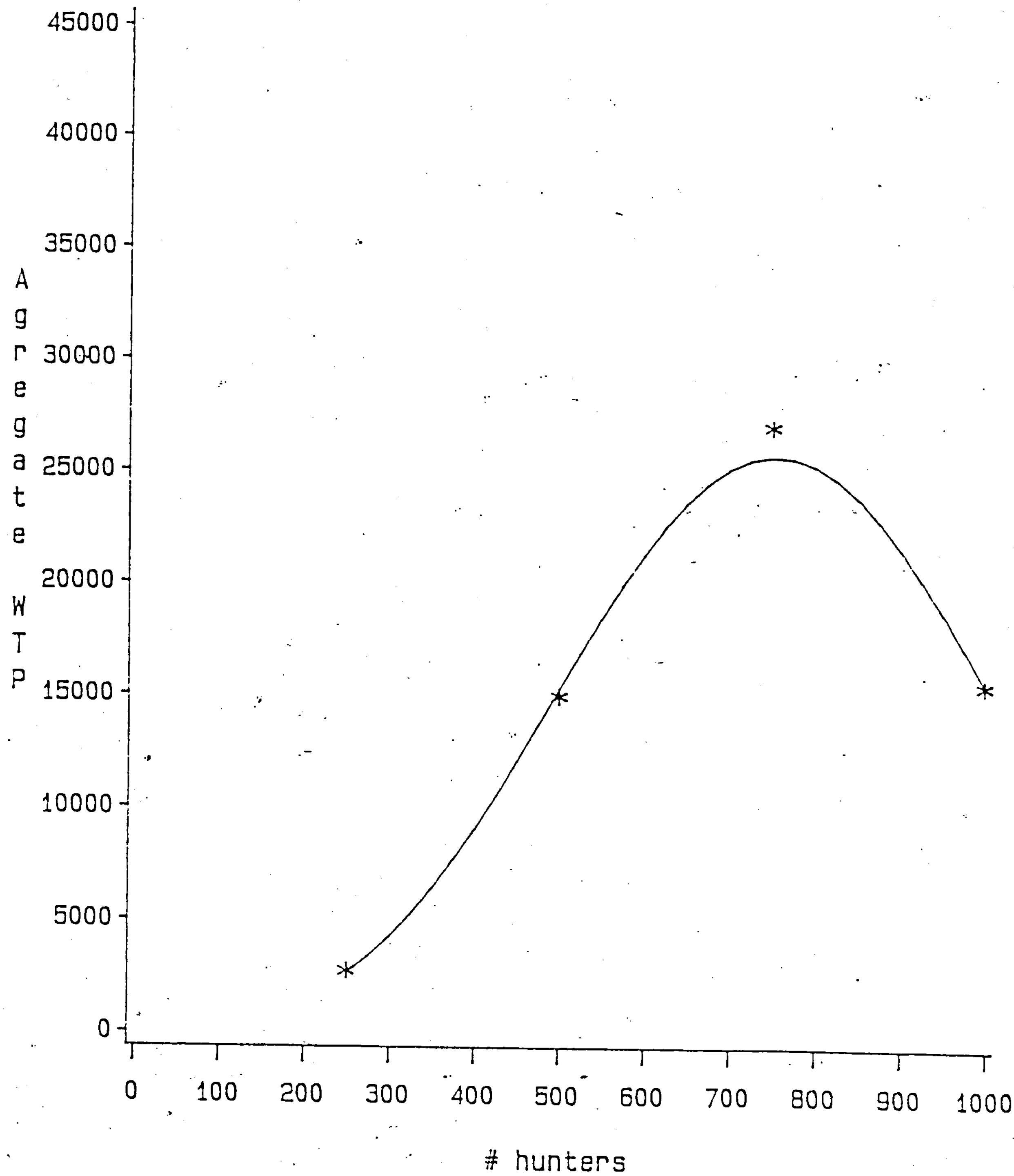

Figure 1: Sample estimate of aggregate WTP by the number of hunters.
*: discrete specification, —— : continuous specification.

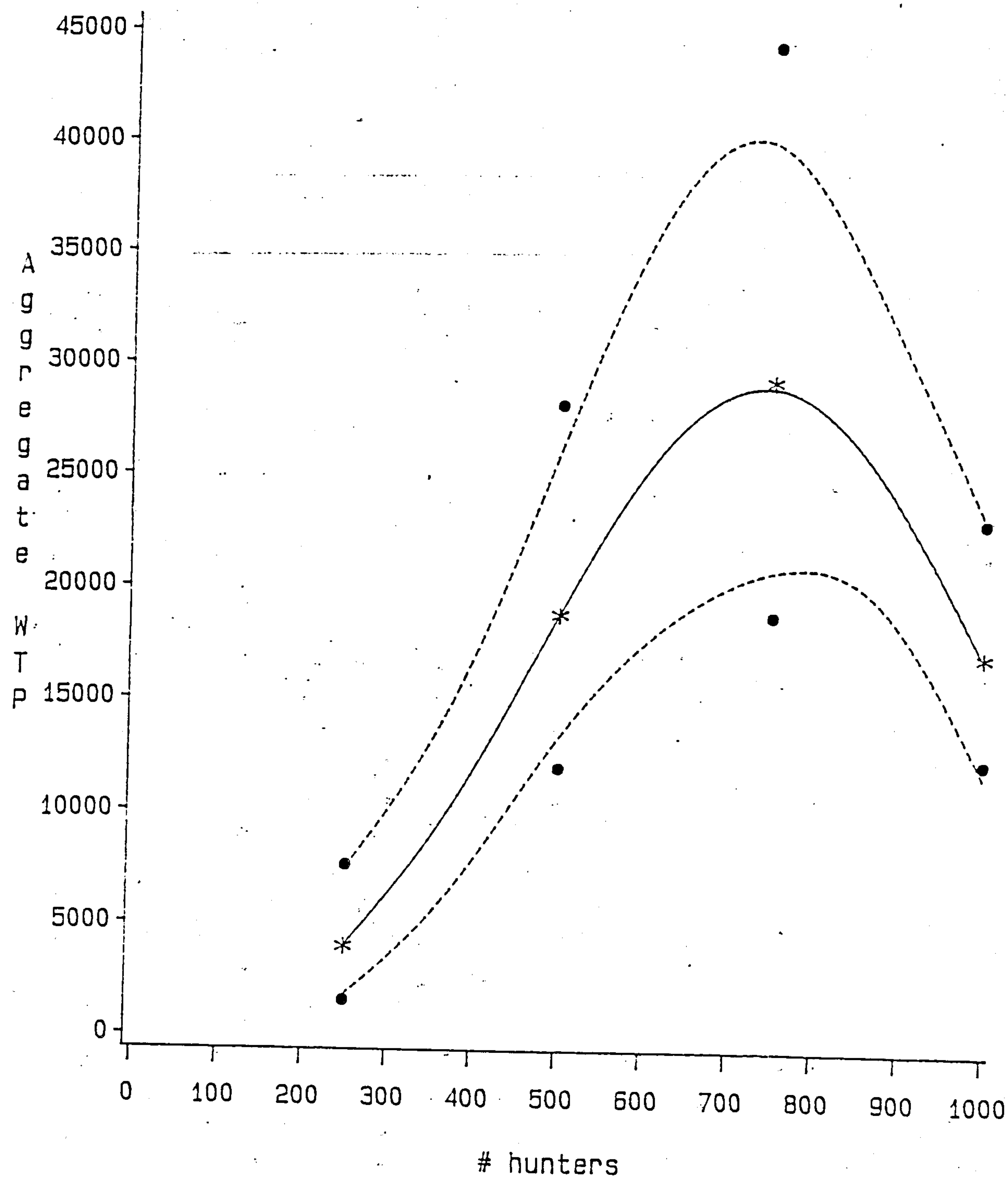

Figure 2: Bootstrap estimate of aggregate WTP by the number of hunters.
Mean: *: discrete specification, —— : continuous specification.
95% CI: •: " " , --- : " "
Number of bootstrap iterations is 2,500.

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