Comparative economic value estimation of matsutake mushroom and timber production in Swedish Scots pine forest

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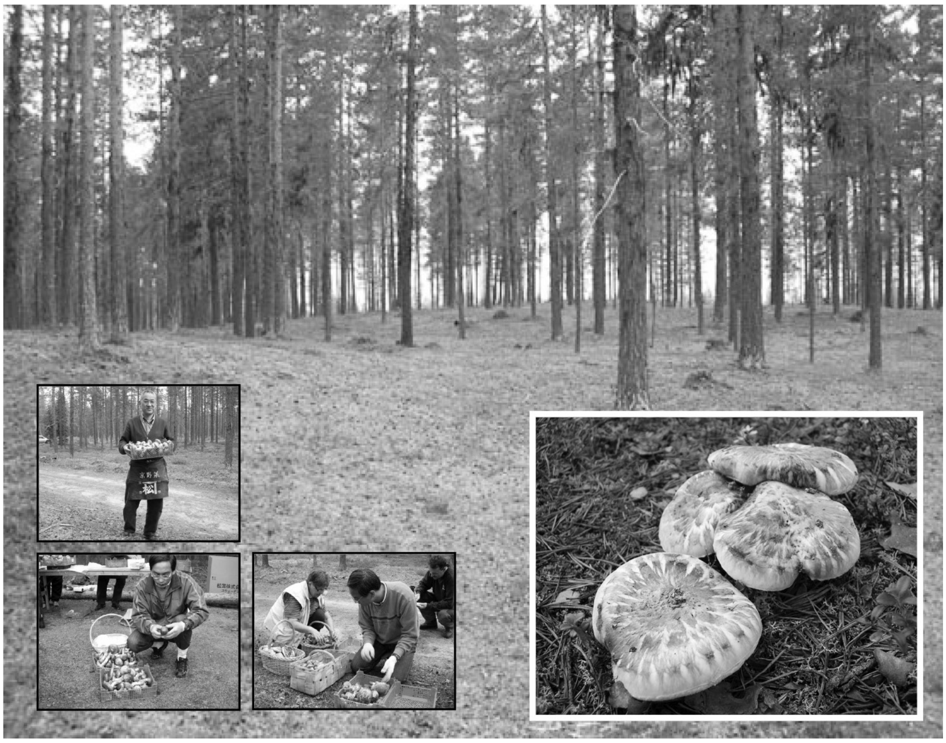

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Abstract

The economic value of Swedish forests is largely linked to the production of timber and pulp. Non-timber forest products such as berries and wild mushrooms have yet been considered commercially less valuable than what the trees produce. In 1990s, DNA analyses revealed that matsutake (*Tricholoma matsutake*), the most expensive edible wild mushroom in Japan, did also occur in Sweden. As a result, commercial matsutake picking in Sweden started in 1998 and since then, small scale export of it to Japan have been taken place. The main objective of this study is to estimate the economic value of Swedish matsutake in comparison with that of Scots pine timber production to figure out how matsutake could potentially contribute to forest management. Cost-benefit analysis is applied as a method. Regarding matsutake production, input data for calculating net present value (NPV) is collected from the matsutake sporocarp inventory survey conducted in between 1998-2012 and a questionnaire was sent to the pickers in 2013. Regarding timber production, state compensation payment for habitat protection that reflects the forest estate value is employed for estimating the NPV. The result shows that the economic values of matsutake at Scots pine sites with high sporocarp productivity is about twice as high as the economic outcome of timber production and it implies that the potential economic value production of matsutake sporocarps at high productivity sites may largely exceed the corresponding economic value of the timber production. This study also suggests that further researches on value estimations of recreational and subsistence use of matsutake and also resource tenure right of it are needed to clarify the cons and prons of forest management with consideration of potential matsutake sporocarp production.

Key words: Cost-benefit analysis, net present value, matsutake, Scots pine timber production

Contents

1. Introduction

Most forests produce timber, non-timber forest products and amenities such as wild berries, recreation and game hunting (Schreckenberg, et al., 2006) (Alexsander, et al., 2002) (Neumann & Hirsch, 2000) although only timber production has long been paid attention apart from game hunting and picking of wild berries in Fennoscandia due to its commercial value (Ezebilo, et al., 2012).

Forestry and forest industry including wood products, pulp, paper and paper products are playing a certain role in Swedish economy. According to the Swedish Statistical Yearbook of Forestry (Swedish Forest Agency, 2012), they covered 2.2 % of total Swedish GDP and 12.7 % of the GDP in manufacturing sector in 2009. Also, these forest products have been main export commodities that covered 12.8 % of total export values in the same year.

Non-timber forest products in Sweden have a long tradition to be used by the public and wild berries and mushrooms have been major non-timber products there. For instance, it is estimated that the quantities of commercially picked wild berries including blueberries, lingonberries and cloudberries in Sweden are between 10 000 and 20 000 tonnes annually, corresponding to about 2-4% of total production of wild berries in Swedish forests (Jonsson & Uddstål, 2002). Also, mushroom picking is appreciated by majority of population and has a tradition of at least 100 years (Ingemarson & Nylund, 2009) (Colby, 1988).

Matsutake (*T. matsutake*) is a wild mushroom that has attracted large interest since late 90s in Sweden (Bergius & Danell, 2000). Presently, matsutake is included in several mushroom guides published in Fennoscandia (Nylén, 2012) (Holmberg & Marklund, 2010) and attempts to export matsutake from Sweden to Japan started in 1998 (Bergius & Danell, 2000). Since then, the export has been operating every year. Similarly, attempts to export matsutake from Finland to Japan started in 2007 (Fennopromo Ltd, 2013) . Nowadays matsutake in Fennoscandia are not only exported to Japan but also increasingly being used by high quality Swedish restaurants. Matsutake hunting has started to become an ecotourism programme that also attracts tourists in Sweden (Slowlife.se, 2013).

Matsutake is the most expensive edible mushroom in Japan due to its large appreciation during almost a millennia and its rapid domestic production decline since 1960. Presently, more than 90 % of the Japanese domestic demand is covered by the import nowadays (Appendix 1). This decrease is due to household energy conversion from firewood including Japanese red pine (*Pinus densiflora*) that is the host tree for *T. matsutake* to the gas so that human intervention to the surrounding pine tree forests diminished, the soil became more fertile and it urged to introduce another tree species (Shinohara, et al., 1987).

Matsutake is a mycorrhizal fungus mainly associated to certain pines. In Sweden, it is confined to old Scots pine forest on sandy soils predominantly in northern Sweden. Its mycelia may potentially become as old as their host trees and continuously and annually produce sporocarps with long-lived mycelia. Due to its dependence of living trees, it does not survive under clear-cut like most ectomycorrhizal fungi and has severe difficulties to re-establish in young forests. A recent study of the characteristics of stands could not report any stand with production sporocarps of matsutake which were younger than 50 years, e.g. in forests that had been clear-cutting (Risberg, et al., 2004).

The potentially high economic value of matsutake sporocarps raises the question of comparing the potential economic profit from matsutake versus timber production from the same stand in Sweden. No such comparative analyses have yet been conducted.

One approach to estimate the economic value is Cost-benefit analysis (CBA) that can clarify the discounted net benefits of both matsutake and timber production. CBA is a policy assessment method that quantifies the value of all consequences of a policy in monetary terms. In the CBA, all input data that would impact the results should be taken into consideration. It compares the total expected gross benefits of each alternative against the total expected costs so that it can provide the basis of comparing scenarios that the policy makers are face with. Hence, it can help social decision making and facilitate more efficient allocation of resources. One advantage of this approach is its outcome shown by monetary basis. It is a normative tool so that it can only provide numerical results that help rational decision making but cannot provide any descriptions and procedures how political and bureaucratic people carry out their decision making (Boardman, et al., 2006).

CBA can be implemented by following steps (Boardman, et al., 2006) and this study applies the same procedure.

1) Specify the set of alternative scenarios
2) Decide whose benefits are cost count
3) Catalogue the impacts quantitatively over the life of the scenario
4) Predict the impacts quantitatively over the life of the scenario
5) Monetize all impacts
6) Discount benefits and costs to obtain present values
7) Compute the net present value of each alternative
8) Perform sensitivity analysis
9) Make a recommendation

The objective of this study is to estimate the economic value of the production of matsutake sporocarps in comparison with that of timber production of Scots pine.

2. Review of economic value estimation on matsutake and its host tree

Matsutake (*T. matsutake*) with the best-quality was sold 1200 SEK per kg in Sweden (per. com. with Niclas Bergius) and 2525 SEK per kg in Japan (Appendix 1) in 2009. In the United States, *T. magnivelare* that is called American matsutake was sold 234 SEK per kg on average between 1992 and 1996 (Alexsander, et al., 2002). Those facts imply that matsutake potentially has a high economic value and several studies regarding the economic value estimation on matsutake and its host tree have already been carried out in the United States and Japan.

In the United States, Alexsander et. al. (Alexsander, et al., 2002) estimated soil expectation value (SEV) of *T. magnivelare* and timber production including several tree species such as western white pine (*Pinus monticola*), sugar pine (*Pinus lambertiana*), lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*) and Shasta red fir (*Abies magnifica var. shastensis*) at Winema National park in Oregon. SEV represents the net present value of an investment through infinite rotations of the same management regime that differs from net present value that stops computation at the end of one rotation period (Bettinger, et al., 2009). It means that the calculated period is perpetuity. Net benefits of both matsutake and timber production were estimated under two alternative silvicultural treatments. The first alternative emphasized current management for development of large-diameter trees and the latter did the management for American matsutake habitat such as host tree selection and understory thinning. Regarding the commercial harvesting ratio with compare to the inventory data, this study assumed 50%. Also, harvest cost was estimated by multiplying subjectively defined fixed ratio with gross benefit from harvesting. The first alternative resulted in 7333 SEK[1] per ha with 50 % harvest cost for matsutake and 7740 SEK[2] for timber The second alternative resulted in 9947 SEK[2] per ha with 50 % harvest cost for matsutake and 8433 SEK[2] for timber. The uniqueness of this study is the comparison of the net benefit of timber production with that of matsutake and also the assumption of commercial harvesting ratio in comparison with the biological sporocarp productivity defined by the inventory survey. This study concluded that the economic value of American matsutake production was almost the same as that of timber production in the study area.

In Japan, Takeuchi (Takeuchi, 2011) estimated a net benefit of *T. matsutake* production from the mean sporocarp inventory data of 28 kg per ha from the result of one experimental site in Nagano prefecture for 45 years. This data was measured by fresh weight basis. In addition, he collected the sales price from official statistics and the costs by the interviews with matsutake forest owners who also have a resource tenure right to

[1] 1 SEK= 0.15 USD (annual average in 2012)

pick up matsutake from their own forests. As a result, daily net benefit with 4-hour working of matsutake management area including self-labour wage was estimated as 2218 SEK[2] per ha with 60 working days in a year. However, he focused only on the commercial sales of matsutake and did not include a recreational value and timber production.

[2] 1 SEK=11.78 JPY (annual average in 2012)

3. Background information on Swedish matsutake and Scots pine

3-1. Swedish matsutake

Since early 1980s, the mushroom *Tricholoma nauseosum* was known in Fennoscandia but not been considered as an edible fungus (Bergius & Danell, 2000) (Kytövuori, 1988). However, DNA analyses investigating the similarities between *T. nauseosum and T. matsutake* were carried out in 90s and showed that these two taxa hade the same ribosomal ITS patterns and concluded it to be the same species (Matsushita, et al., 2005) (Bergius & Danell, 2000). The research result generated a large interest from mushroom picking amateurs in Fennoscandia since mushroom pickers understood that it was an edible and had a huge commercial value like in Japan.

The species commonly named matsutake includes three species; *T. matsutake*, *T. magnivelare* and *T. caligatum*. Only *T. matsutake* has been harvested commercially in Sweden although *T. caligatum* also can be found in Sweden (Bergius & Danell, 2000). In Japan, *T. matsutake* has been recognized as traditional matsutake and other two species are imported as cheaper substitutions to *T. matsutake* (Yun, et al., 1997). It is an ectomychorrhizal (ECM) fungus associating with Scots pine *Pinus sylvestris* in Fennoscandia (Risberg, et al., 2004) (Bergius & Danell, 2000) (Kytövuori, 1988). The habitat for Swedish matsutake is acidic and well drained Scots pine forest on sandy soils with poor nutrient status (Yun, et al., 1997). Matsutake predominantly occurs above north of 64° N. (Figure 1) .The forests with the highest sporocarp production of matsutake are Scots pine forest with an average age of more than 120 years or more (Bergius & Danell, 2000).

Near Skellefteå (photo: Niclas Bergius)

Near Luleå (photo: Niclas Bergius)

Figure 1. Two examples of Scots pine forest stands where matsutake grows in Sweden.

Matsutake, as in principal all other edible ECM fungi, cannot be cultivated to produce sporocarps (Hogetsu, et al., 2008) (Yun & Hall, 2004). Hence all consumption of matsutake relies on picking wild mushrooms in forests.

Matsutake forms a dense mat of fungal mycelia associated to host plant fine roots and soil particles. This mycorrhizal mycelial aggregate is called *shiro* (Vaario, et al., 2011) (Hogetsu, et al., 2008) (Amaranthus, et al., 2000). *Shiro* is formed up to 25-30cm deep and over 60cm wide in the ring and it expands gradually and radially each year (Hogetsu, et al., 2008) (Palm & Chapela, 1997). *Shiro* is a perennial mycelial aggregate, representing a fungal genotype. In Japan, the longetivity of some *shiro*s or fungal individuals, along with *Pinus densiflora* was estimated over 100 years (Ogawa, 1977). This means that matsutake can be harvested from same location over decades if host trees remain. Genotypes of ECM fungi in general are considered to be long-lived if their host trees remain even though the individual hypha that forms mycelia is short-lived. The sporocarp production of mushrooms including matsutake largely varies, 10- fold or more, among years due to the weather condition, e.g. precipitation and temperature (Martínez-Peña, et al., 2012).

3-2. Swedish forestry and Scots pine

From the forest industries' point of view, Scots pine can be used for various purposes including sawn logs, materials for wood board, plywood, chips and bioenergy source and has been a stable raw material to be provided due to its large standing volume stocks in Swedish forests (Swedish Forest Agency, 2012).

Forestry is an important economic sector in Sweden. As already mentioned, it covered 2.2 % of total Swedish GDP and 12.7 % of the GDP in manufacturing sector in 2009 and forest products have been main export commodities that covered 12.8 % of total export values in the same year (Swedish Forest Agency, 2012). In addition, forestry and forest industry provides a certain amount of employment opportunities. They provide direct employment to around 76 thousands in Sweden. In several counties, they account for more than 20 % of employment in 2010 (Swedish Forest Industries Federation, 2011).

Scots pine has been a main productive tree species in Swedish forestry as well as Norway spruce. Scots pine has the second biggest standing volume in Sweden. It covers 39% of total standing volume next to the 42% of Norway spruce (Swedish Forest Agency, 2012). Scots pine is a dominant species that covers half of total standing volume in the region (Swedish Forest Agency, 2012).

4. Material and method

4-1. Estimation of matsutake production

Since the sporocarp production vary among years due to fluctuating weather conditions, this study uses the mean value obtained from the inventory survey in between 1998-2012 for CBA. Also, the sales price and costs are assumed to stay the same. As a result, time-series net benefit of matsutake production (NB_m) can be depicted as in Figure 2. NB_m is calculated by gross benefit of matsutake production minus costs of matsutake harvest and shipment each year till the end of the period, 100 years. Also, this study assumes that NB_m in each year has the same amount of economic value before discounting.

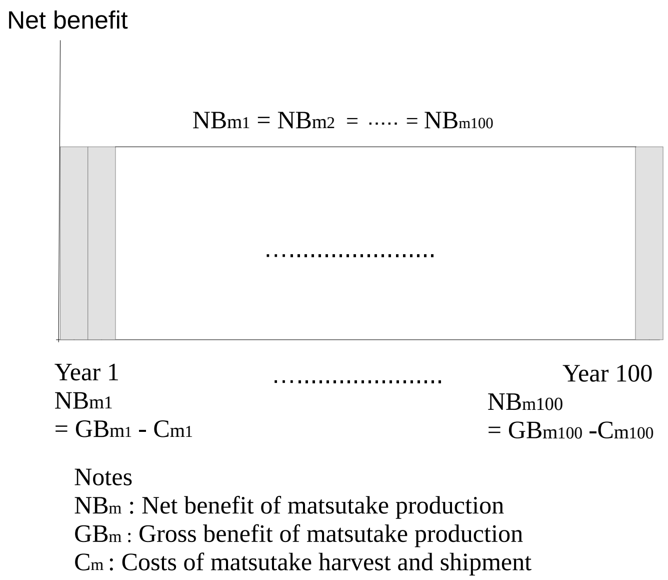

Figure 2. Model for the CBA of matsutake picking

4-2. Data collection

Estimations of matsutake sporocarp production were based on the inventory survey at 51 sampling sites selected according to the occurrence of matsutake in 1998 and then followed over the years in northern Sweden between Umeå and Kiruna till 2012 provided by Niclas Bergius. This inventory covers only the best-quality grade sporocarps and the number of sporocarp is counted and recorded every year (pers. comm. with Niclas Bergius). In this study, inventory results of these sampling sites were divided into three categories (high, medium, low) according to the productivity in each site to see how the result changes according to the different productivity of the sporocarps. The first 17 sites that were recorded as the highest average productivity of matsutake sporocarps are applied to the high productivity sites, the next 17 sites belong to medium and the rest is low, respectively. The average quantity of annual sporocarp in the high productivity sites is 4.2 kg per ha, the medium is 2.5 kg per ha and the low is 1.2 kg (Appendix 2).

A questionnaire was distributed to as many active matsutake pickers as possible in Sweden with the help of Niclas Bergius. It was sent to 35 matsutake pickers in Norrbotten and Västerbotten counties in March and April in 2013 aiming to get estimations on pickers' allocation of time and costs for picking (Appendix 3). Nine of them answered the questionnaire. The questionnaire in principle had four parts; 1) background information on pickers 2) usage of picked matsutake 3) volume of harvest 4) hours of picking and transporting. Details are shown in Appendix 3.

4-3. Gross benefits (GB_m) for matsutake production

Mushroom picking has three objectives such as commercial sales, recreation and subsistence use of picked mushrooms. However, this study excludes the last objective due to the lack of the estimation value for subsistence use of wild mushrooms.

- Matsutake commercial sales = $P_m \times Q_{mi}$

  where,

  P_m is the sales price of matsutake

  Q_{mi} is the volume production of matsutake

  i=1, 2, 3: High, medium and low sporocarp productivity

Sales price of matsutake (P_m) was set to 1200 SEK per kg that was the market price in 2012 (per. comm. with Niclas Bergius).

Annual matsutake sporocarp production, $Q_{m1, 2, 3}$, is calculated by the mean value from the sporocarp inventory data (Appendix 2). These data reflects only the best-quality matsutake sporocarps (pers. com. with Niclas Bergius). Q_{m1} represents a high matsutake sporocarp productivity sites Q_{m2}, represents medium matsutake productivity and Q_{m3} low matsutake productivity.

- Recreational value from matsutake picking = $A \times D$

  where,

  A is a recreational value per day of mushroom picking

  D is an annual number of days when the picker goes out for picking

Theoretically, there are three main methods for estimating a recreational value for which the market does not exist. These are hednic pricing and travel cost method that are so-called revealed preference methods and contingent valuation method that is called stated preference methods (Kuriyama, 1998). However, since there has been lack of research results on recreational value estimation of mushroom picking in Fennoscandia, this study employs an existing research result conducted in Spain (de Frutos, et al., 2009). It estimated recreational value of non-commercial wild mushroom picking in the public forest called Pinar Grande. The study area is mainly comprised of pure Scots pine stands. This employed travel cost method that directly estimates the recreational value from the paid travel costs by each picker in between 1997-2005. As a result, marginal consumer surplus for recreational mushroom picking was estimated from the minimum amount of 12.23 EUR in 2005 per one visit to the maximum of 28.81 EUR in 2001 and median is 21.27 EUR in 1999 (de Frutos, et al., 2009). For the CBA, the median is employed.

In addition, estimating the annual mean matsutake harvest area for pickers is necessary to calculate input data by per ha basis. The questionnaire asked 'How many forests did you visit these years for picking matsutake?' but not directly asked the total harvest area since they usually do not need to be careful about the harvest area but only volume and places of harvest. Therefore, the estimated annual mean harvest areas for them are calculated from the results of the questionnaire and the sporocarp inventory as follows;

Annual mean harvest area of matsutake for matsutake pickers
= (mean total production from the results of the questionnaire) / (mean per ha production from the inventory)
= 20.9 kg / 2.6 (kg/ha)
= 7.9 ha

As a result, a recreational value per day of mushroom picking is calculated from the result in Spain with foreign exchange rate and consumer price index (CPI) adjustments such as,

A [SEK/visit day/ha]
= {21.27 EUR × (CPI 1999 Sweden/ CPI 1999 Spain) × (SEK/EUR 1999) × (CPI 2012 Sweden/ CPI 1999 Sweden)}/ 7.9 ha
= 43.7

Mean annual number of days when the picker goes out for picking (D) is collected from the questionnaire (Appendix 4).

4-4. Costs (C_m) for matsutake production

Cost compositions for matsutake picking are divided into four subcategories such as picking costs, transport costs, fuel and maintenance costs and shipment costs.

- Picking cost: labour costs derived from actual matsutake picking hours

  $C_p = H_p \times L$

  where,

  H_p is picking hours for matsutake

  L is the hourly manual wage

  Eastimation of picking hours (H_p) was calculated from the questionnaires (Appendix 4). With respect to the hourly manual wage (L), average hourly wage in private sector at Övre Norrland region is used as an opportunity cost for mushroom picking. The data was collected official statistics from Statistics Sweden (Statistiska centralbyrån, 2012). Since there is no available data for 2012 at the time of research period, it is assigned the same as in 2011.

- Transport cost: labour costs derived from transport hours to matsutake stands

  $C_t = H_c \times L$

  where,

  H_c is transport hours for matsutake picking

  Transport hours (H_c) for picking were calculated from the results of the questionnaire (Appendix 4) by the annual travelling distance (TD) divided by 60 km/h.

- Fuel and maintenance cost: gasoline costs for transportation including depreciation and repairing

  $C_f = (TD / M) \times F$

  where,

  TD is annual travelling distance for matsutake picking

  M is a fuel mileage for a picker’s vehicle to matsutake forest stands

  F is a unit fuel price

Fuel and maintenance costs, $(TD / M) \times F = TD \times (F / M)$, can be calculated as follows. This study assumes that all matsutake mushroom pickers travel individually by their own car to the forest stands with matstake during the harvest season. TD is annual transport distance for matsutake and other edible mushroom picking collected by the questionnaire. For F / M where F is a unit fuel price and M is a fuel mileage, this study employs the Tax-free mileage allowance according to the Swedish Tax Agency that is 18.50 SEK per Scandinavian mile (1.85 SEK per km) in 2012. This includes gasoline, depreciation and repairing.

- Shipment cost: shipment costs to matsutake buyers
  C_s
  This is considered only when mushroom pickers send matsutake to restaurants in Sweden. No shipment cost is necessary for export since it is fully covered by buyers (Niclas Bergius pers. comm.). For calculation, the Post Packet service offered by Swedish Post is employed. It costs 135 SEK per one package up to 3 kg (Posten AB, 2013) with the assumption that matsutake pickers send one package a year to a restaurant in Sweden.

				reference
Pm	Sales price	SEK/kg	1,200	section 4-3
Qm1	Sporocarp production (high)	kg/ha	4.22	Appendix 4
Qm2	Sporocarp production (medium)	kg/ha	2.47	Appendix 4
Qm3	Sporocarp production (low)	kg/ha	1.22	Appendix 4
A	Recreational value	SEK/day	43.7	section 4-3
D	Days for picking	day/year	9.0	Appendix 4
Cp	Picking cost	SEK/ha	619	section 4-4
Ct	Transport cost	SEK/ha	123	section 4-4
Cf	Fuel and maintenance cost	SEK/ha	106	section 4-4
Cs	Shipment cost	SEK/ha	17	section 4-4
NBm_high	Annual estimated net benefit of matsutake with high sporocarp production	SEK/ha	4,594	-
NBm_med	Annual estimated net benefit of matsutake with medium sporocarp production	SEK/ha	2,494	-
NBm_low	Annual estimated net benefit of matsutake with low sporocarp production	SEK/ha	994	-

Note: Qm1 reflects the inventory result of high sporocarp productivity, Qm2 does middle and Qm3 does low, respectively.

Table 1. Input data for matsutake NPV calculation

All input data for matsutake NPV calculation is summarized in Table 1.

4-5. Estimation of timber production

This study uses the state compensation for habitat protection (Swedish Forest Agency, 2012) as an estimate for the value of forest land. This compensation payment covers infinity once it is paid and it is assumed to be paid at the beginning of the first year. The total amount of compensation payment is calculated from the assessed value of forest land and trees growing on it. The valuation methods which are primarily adopted for taxation have remained largely unchanged since 1957 (Swedish Forest Agency, 2012).

Also, this study assumes that annual estimated net benefit of timber production (AR_f) calculated from the habitat protection compensation is assigned with the same amount every year (Figure 3) like the assumption of matsutake net benefit. It can be calculated by the total amount of state compensation for habitat protection which is paid at the beginning of the period multiplies the predefined social discount rate[3]. The social

[3] It applies the concept of calculating present value of perpetuity (Boardman, et al., 2006). Given that PV is present value that is the same as the state compensation for habitat protection fully paid at

discount rate is applied as 4.0 % following a guideline of Swedish government (Nordic Council of Ministers, 2007).

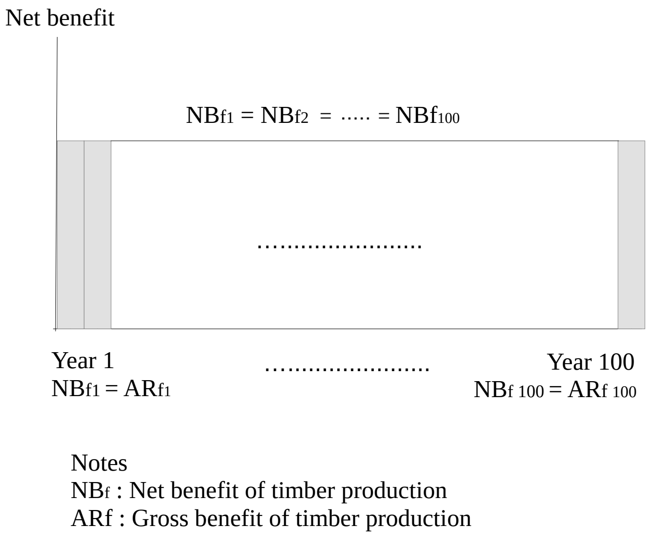

Figure 3. Model for the CBA of timber production

The average amount of the payments in Norrbotten and Västerbotten counties in 2011 that is the latest available data (Swedish Forest Agency, 2012) is applied with the adjustment of consumer price index on the basis of 2012 that is the same year of the applied matsutake sales price. The data is also discounted by 20 % that was added as a premium that is enforced on all habitat protection compensation agreement since the 1st of August 2010 by the government (pers. com. with Tove Thomasson, Swedish Forest Agency). As a result, the annual net benefit of timber production ($NB_f = AR_f$) is estimated as 2240 SEK per ha that is calculated from the total amount of habitat protection compensation payment.

4-6. Net present value calculation

Net present value (NPV) is a calculated present value from future net benefits (gross benefits minus costs) on the basis of today's currency value during the predefined period. It can be calculated by compound social discount rate (Bettinger, et al., 2009).

The social discount rate is applied as 4.0 % in this study and the time span as 100 years since the optimal rotation period of Scots pine forest in northern Sweden is around 100 years according to the yield table (Persson, 1992). All results are calculated by per

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the beginning, A is annuity that is the same as AR_f and r is discount rate, then PV can be calculated by A divided by r. As a result, A can be calculated by PV multiplies r.

hectare and SEK.

NPV of matsutake and timber production can be calculated such as,

NPV_{mi} =

$$\sum_{t=1}^{100} \frac{NB_{mit}}{(1+0.04)^{t}}$$

=

$$\sum_{t=1}^{100} \frac{(P_{mit} \times Q_{mit} + A \times D_{t}) - (C_{pt} + C_{tt} + C_{ft} + C_{st})}{(1+0.04)^{t}}$$

where,

NPV_{m}: NPV of matsutake production

i : matsutake sporocarp productivity (1: high, 2: medium, 3: low)

t : number of years

NPV_{f} =

$$\sum_{t=1}^{100} \frac{NB_{ft}}{(1+0.04)^{t}}$$

=

$$\sum_{t=1}^{100} \frac{AR_{ft}}{(1+0.04)^{t}}$$

where,

NPV_{fi}: NPV of timber production

4-7. Sensitivity analysis

Net benefits can vary since all the input data may fluctuate to some extent since they would be influenced by external risks. In order to recognize the underlying risks, sensitivity analysis is essential (Boardman, et al., 2006).

Two methods are employed. First one is worst- and best-case analysis that assumes the best and worst cases under the available range of input data. In other words, it assumes the most optimistic and pessimistic initial conditions and check how the net benefits change respectively.

The other one is Monte Carlo sensitivity analysis that analyses the relationship between the risks shown by standard deviation and expected net benefits. In this analysis, all input data are assumed stochastic and the most plausible probability distribution is specified with certain range to each input data as a variable at first. Secondly, all variables are assigned by a certain number randomly and generate a result of net benefit. Finally, the simulation is conducted 1000 times repeatedly.

The definitions for the plausible range of variables are as follows;

Matsutake gross benefits:

P_m: Subjectively defined $\pm 20\%$ from 1200 SEK that is the actual price in 2012.
Q_m: Defined by the matsutake sporocarp inventory data in between 1998-2012.
A: Defined by the case study in Spain (de Frutos, et al., 2009) in between 1997-2005.
D: Defined by the results of the questionnaire.

Matsutake costs:

C_p, C_t, C_f: The worst and the best plausible costs are picked up from the empirical results in between 1998-2012.
C_s: Assuming that only one shipment to restaurants would occur annually so that the shipment cost is always the same.

Timber production:

AR_f: Subjectively defined $\pm 20\%$ from 2240 SEK that is applied for the NPV calculation of timber production.

Each range of variables is summarized above in this section in Table 2.

Matsutake			Min	Max
Pm	Sales price	SEK/kg	960	1,440
Qm1	Sporocarp production (High)	kg/ha	0.0	12.5
Qm2	Sporocarp production (Medium)	kg/ha	0.0	7.5
Qm3	Sporocarp production (Low)	kg/ha	0.0	3.3
A	Recreational value	SEK/day	17.1	58.1
D	Days for picking	day/year	8.1	9.9
Cp	Picking cost	SEK/ha	387	873
Ct	Transport cost	SEK/ha	82	164
Cf	Fuel and maintenance cost	SEK/ha	84	119
Cs	Shipment cost	SEK/ha	17	17
Timber				
ARf	Annual estimated net benefit of timber production	SEK/ha	1,792	2,688

Note: Qm1 reflects the inventory result of high sporocarp productivity, Qm2 does middle and Qm3 does low, respectively.

Table 2. Input data for sensitivity analysis

In addition, sensitivity analyses are conducted under following assumptions in this study.

Worst- and best- case analysis:

- For the worst-case analysis, low sporocarp productivity and maximum amount of costs that are shown in Table 2 are assigned.
- For the best-case analysis, high sporocarp productivity and minimum amount of costs that are shown in Table 2 are assigned.

Monte Carlo sensitivity analysis:

- Distribution for variables: uniform distribution with predefined ranges for all variables in Table 2.
- Simulation: 1000 times bootstrapping by R programming

5. Result

5-1. Calculated NPVs of matsutake and timber production

The result shows that NPVs of matsutake production with high and medium sporocarp productivity go over that of timber production. NPV of matsutake production reaches 113K SEK per ha with the high productivity site, 61K SEK per ha with the medium and 24K SEK per ha with the low. On the other hand, NPV of timber production is 55K SEK per ha (Figure 4).

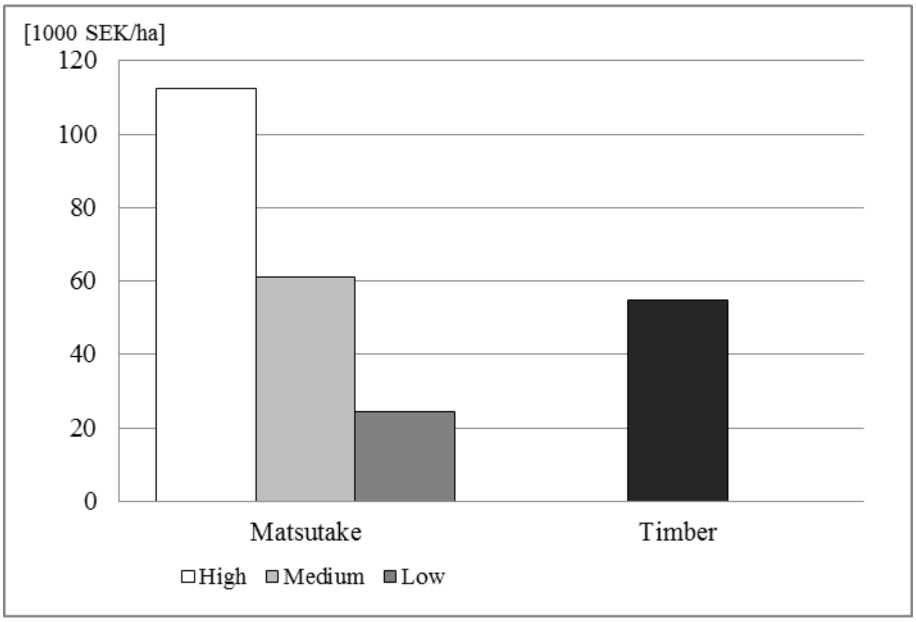

Figure 4. NPVs of matsutake with different sporocarp productivity and timber production

The result shows that net benefit / sales ratio that can be calculated by the amount of net benefit divided by that of gross benefit (sales) is 84 % with high sporocarp productivity site, 74 % with medium and 53 % with low (Figure 5). In addition, it shows that picking cost is the largest among all costs that covers 72 % of total costs in every site.

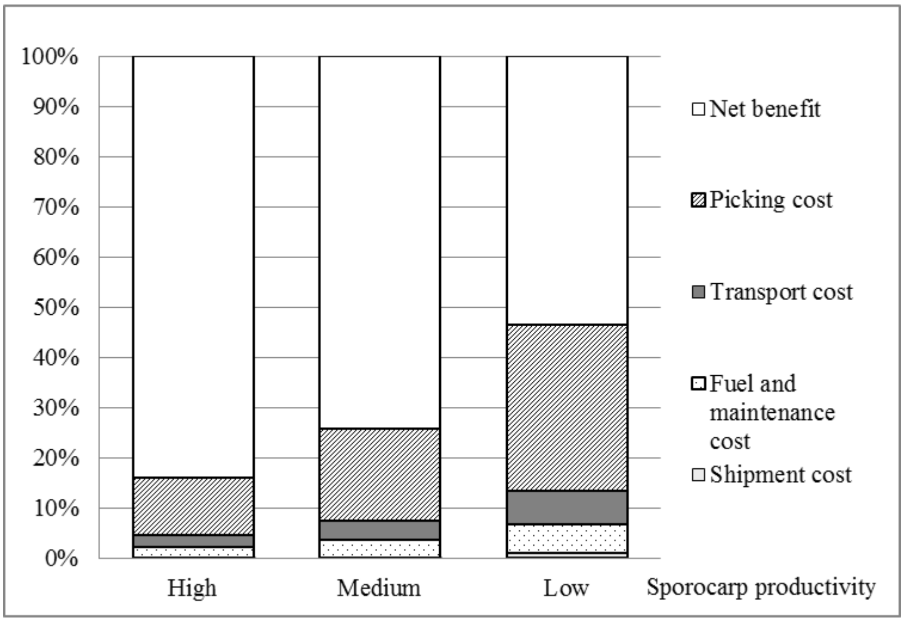

Figure 5. Net benefit and costs composition of matsutake production with different sporocarp productivity.

5-2. Sensitivity analysis

The worst- and best- case analysis reveals that the NPV can vary from -25K SEK per ha to 441K SEK per ha for matsutake production. Also, it can do from 44K SEK per ha to 66K SEK per ha for timber production (Figure 6).

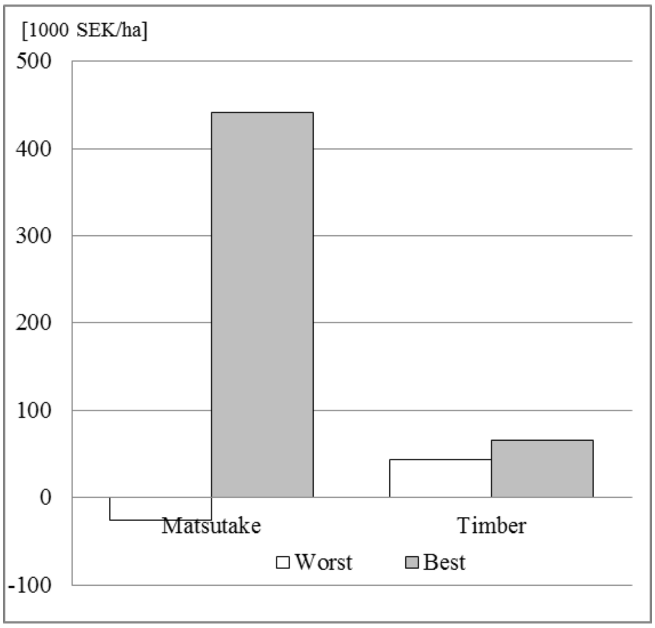

Figure 6. NPVs of matsutake and timber production under worst- and best-case analysis

The result of Monte Carlo sensitivity analysis indicates that the higher the calculated NPVs of matsutake become, the larger the risks are. Also, it shows that the risk of timber production is always lower than those of matsutake production (Figure 7).

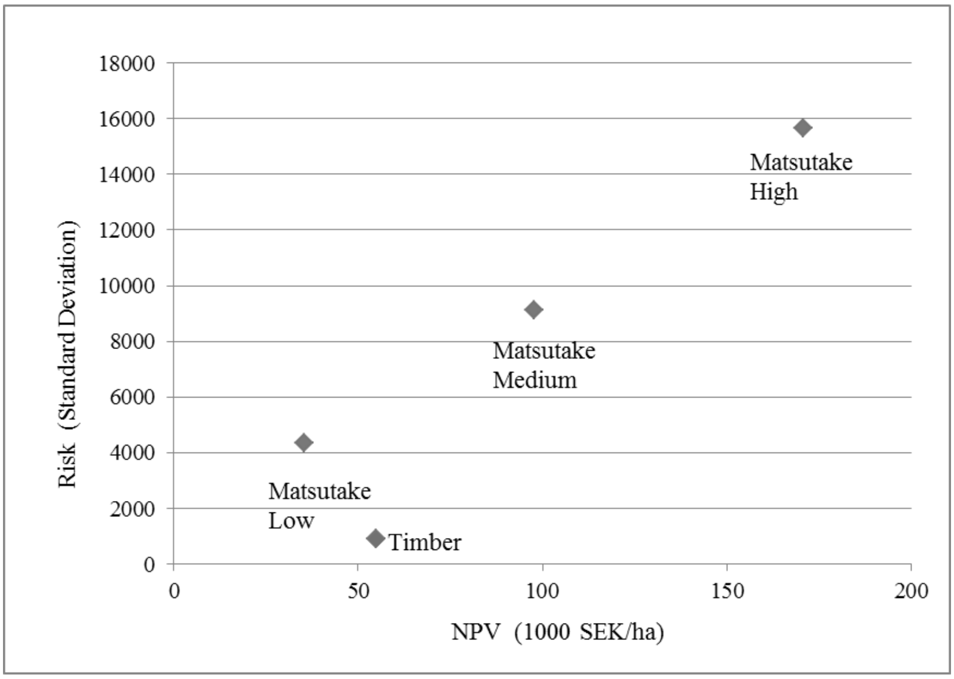

Figure 7. Relationship between calculated NPVs and risks of matsutake with different sporocarp productivity and timber production by Monte Carlo sensitivity analysis

6. Discussion

This study reveals that the economic values of matsutake at Scots pine sites with high sporocarp productivity can be about twice as high as the economic outcome of timber production. At sites with ordinary or sparse production of matsutake sporpcarp, the economic value was estimated to be at about the same level or half of that of the timber. This indicates that the potential economic value production of matsutake sporocarps at high productivity sites may largely exceed the corresponding economic value of the timber production. Also, this study figures out the cost structure for matsutake harvesting and distribution. Picking turns out to be largest cost factor for matsutake that covers 72 %. This study also shows that net benefit/ sales ratio of matsutake production is 84 % with high sporocarp productivity site, 74 % with medium and 53 % with low.

The only previous study regarding the comparative economic value estimation of matsutake and timber production was conducted in Oregon with the American matsutake (*T. Magnivalare*) (Alexsander, et al., 2002). The result in the United States suggested that the net benefit of American matsutake is almost the same as timber production. The case in Sweden shows the potential economic value of matsutake to be considered for future forest management.

There might be a gap between the calculated NPV results shown in this study and in practice. One crucial point to explain it might be the assumption of the sporocarp production in this study. It assumes that matsutake pickers would pick up all matsutake sporocarps shown by the inventory survey, however it might not be easy to pick up all of them in practice when harvesting. For instance, if we assume that the commercial sporocarp picking possibility rate is a half of the result from the inventory survey, the NPV of matsutake would be lowered to less than half. On the other hand, there is also another possibility to also pick up two other highly and widely appreciated edible wild mushroom species, pine bolete (*Boletus pinicola*) and velvet bolete (*Suillus variegatus*), when picking matsutake (pers. comm. with Niclas Bergius). This would give a positive impact to the net benefits for mushroom pickers.

Moreover, there are three other constraints to regulate the result of this study. First one is the limitation of the primary data collection. Although the results of the questionnaire are crucial in this study, only 9 answers could be collected out of 35 matsutake mushroom pickers. Second one is the accuracy of the data from the questionnaire. All answers were self-reported by the respondents so that the measurement methods might differ among them. Finally, lack of the estimations on recreational value and subsistence use of mushroom picking in Fennoscandia also would affect the results.

Finally, resource tenure right system might be a key factor when considering future matsutake sites management. In Sweden, to keep the resource tenure right of wild mushrooms including matsutake is not allowed in principle due to the everyone’s right or *allemansrätten* (Ingemarson & Nylund, 2009) (Colby, 1988). In principle, it allows everyone to visit and be at any private or public land except at gardens or in the immediate vicinity of houses. It also allows anybody to pick wild berries and mushrooms at these lands. Due to the *allemansrätten,* no one can hold the exclusive resource tenure right of wild mushrooms including matsutake. This is probably one reason why forest owners have not expressed any interest in harvest or managing for wild berries or wild mushrooms, e.g. matsutake. Potentially, forest sites with a high production of matsutake sporocarps could be managed differently than traditional clear-cut, e.g. management with retention trees, in order to maintain the benefit of matsutake. Such forest sites could either be set aside or probably managed by some type of sparse selective cutting, green tree retention management. Also, they might decide to carry out clear-cut as final felling treatment that would destroy the current matsutake habitat and matsutake pickers have no right to intervene the decision-making process for forest owners even if they would lose all future net benefits of matsutake. The result of this study could point out that further research on resource tenure right of matsutake might also be crucial to enhance the motivation for forest owners to manage the matsutake sites.

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Appendix 1. Matsutake in Japan

Table A1. Prices of major domestic edible mushrooms (*) in Japan

English name	Binomial name	Price(**) [SEK/kg]
Shiitake(***)	*Lentinula edodes*	82
Nameko	*Pholiota nameko*	32
Enokitake	*Flammulina velutipes*	20
Oyster mushroom	*Pleurotus ostreatus*	36
Buna shimeji	*Hypsizigus tessellatus*	43
Ram's Head	*Grifola frondosa*	56
King trumpet mushroom	*Pleurotus eryngii*	50
Matsutake	*Tricholoma matsutake*	2 525

Notes:

* Only these mushrooms have been shown in the statistic sheet continuously in between 2005-2009.

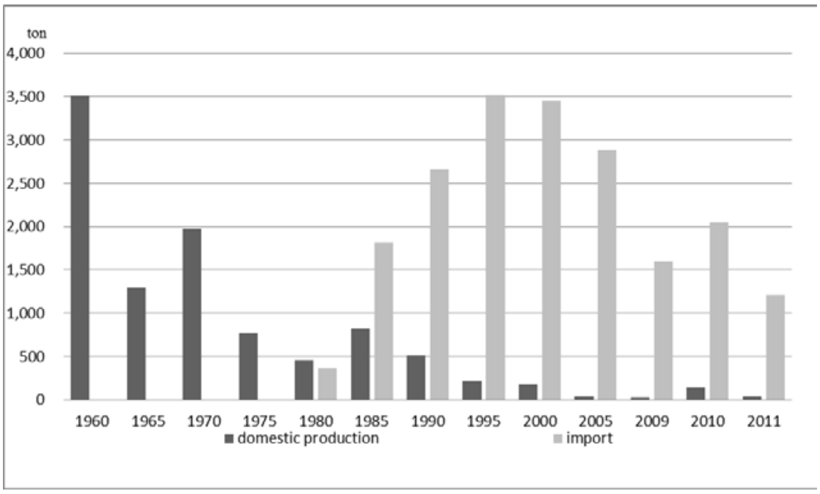
** Annual average price at Tokyo Metropolitan Central Wholesale Market in 2009.

1SEK = 12.22JPY (2009/12/31)

*** Raw Shiitake, not dried.

Source: (Japan Forestry Agency, 2010)

Figure A1. Matsutake domestic production and import in Japan 1960-2011



Source: (Japan Forestry Agency, 2012), (Ministry of Finance, 2012)

Appendix 2. Matsutake sporocarp inventory data

Matsutake stand category	high productivity		medium		low	
Year	N of fruit bodies (ha)	kg	N of fruit bodies (ha)	kg	N of fruit bodies (ha)	kg
1998	150	12.5	90	7.5	40	3.3
1999	0	0.0	0	0.0	0	0.0
2000	80	6.7	45	3.8	25	2.1
2001	40	3.3	25	2.1	10	0.8
2002	30	2.5	15	1.3	10	0.8
2003	50	4.2	30	2.5	20	1.7
2004	70	5.8	40	3.3	25	2.1
2005	60	5.0	40	3.3	20	1.7
2006	0	0.0	0	0.0	0	0.0
2007	130	10.8	75	6.3	35	2.9
2008	20	1.7	10	0.8	5	0.4
2009	40	3.3	25	2.1	10	0.8
2010	20	1.7	10	0.8	5	0.4
2011	50	4.2	30	2.5	10	0.8
2012	20	1.7	10	0.8	5	0.4
mean	50.7	4.2	29.7	2.5	14.7	1.2

Note: 1kg matsutake consists of 12 fruit bodies with the best quality (Niclas Bergius pers, comm.)

Source: Niclas Bergius et. al. (unpublished)

Appendix 3. Questionnaire

2013-03-25

Enkät om plockning av goliatmusseron

Under våren 2013 gör Kenji Nagasaka ett examensarbete vid SLU i Uppsala som ska undersöka värdet av goliatmusseron och jämföra detta med värdet av virket i de skogar där svampen växer. Arbetet skall vara klart i juni 2013 och handleds av Anders Dahlberg svampforskare vid SLU, Ing-Marie Green professor i miljöekonomi vid SLU och mig Niclas Bergius. Läs mer om oss via länkarna i slutet av brevet.

Syftet med examensarbetet är beräkna den potentiella ekonomin i att plocka goliatmusseronen och jämföra detta med värdet av skogsskötsel. För att kunna få in bra underlag kring plockning av goliatmusseron och göra dessa beräkningar är vi i stort behov av att få in uppgifter från er. Vi har valt ut Dig att besvara denna enkät eftersom vi tror att du kan bidra med väldigt viktiga grunddata kring plockning av goliatmusseron

Vi är mycket tacksamma för om Du kan ta dig tid att fylla i denna enkät och om möjligt senast den 4 april sända svar till oss via Niclas Bergius e-post (niclas.bergius@lansstyrelsen.se) eller via vanligt brev.

Några frågor? E-posta eller ring (070-239 39 13) till Niclas Bergius.

Med hjälp av svaren i enkäten kommer vi bättre kunna beräkna ekonomin i att plocka goliatmusseron: hur mycket tid och pengar går det åt för att samla in goliatmusseron och vad det kan bli för intäkter. Vi kommer komplettera dessa beräkningar med uppgifter från Finland och även jämföra dem med motsvarande uppgifter från nordvästra USA och Japan.

Enkäten nedan har först några mer allmänna frågor. Därefter följer några mer specifika frågor för hur mycket tid och resor du bedömer att du lagt ner för att plocka goliatmusseron och hur mycket du kunnat skörda olika goda år. Vi är tacksamma om du försöker svara så gott du kan på alla frågorna.

Vi kommer skicka ut examensarbetet med resultaten till alla er som medverkar i undersökningen när det är klart.

1. **Vilket år började du plocka plockat goliatmusseron?**

2. **Plockar du varje år?**

3. **Hur använder du svampen du plockar?** (försöka att ange i procent för de olika alternativen, totalsumman ska bli 100 %).

Hur använder du svampen du plockar?	**Fyll i som %** (summan skall bli 100%)
Privat konsumtion	
Ger bort till vänner och bekanta	
Säljer till lokala restauranger och eller marknader	
Säljer till restauranger i större orter, ffa i södra Sverige	
Säljer för vidare export till Japan	
Annat (skriv ut vad)	

4. Skiljer sig svaret i fråga 3 åt om det är ett riktigt bra år för goliatmusseron i jämförelse med om det är ett sämre år? Hur då?

Nedan ber vi dig försöka uppskatta hur mycket tid du lägger ner på att plocka goliatmusseron olika bra år och hur stora skördar du får. Vi ställer samma frågor för tre olika scenarier; (1) år det är mycket gott om goliatmusseron, (2) normalår för goliatmusseron, och (3) år som är dåliga för goliatmusseron. Plockar du bara när det är mycket gott om goliatmusseron, svara på det scenariet och skriv Med hjälp av svaren kommer vi grovt beräkna hur stora skördar det går att få olika bra år för goliatmusseron och hur stor insats som då krävs för detta i form av plockningstid och bilresor.

I samtliga fall bygger frågorna på besök av oplockade skogar (ingen har varit före dig när din plockning sker). Basera skattningarna på dina erfarenheter, dvs. förmodad skörd om ingen varit och plockat på platsen före ditt besök.

Scenario 1: ett mycket gott år för goliatmusseron, (som 1998 eller 2007).

1. Hur lång tid tar det för dig i genomsnitt när du är på plats i skogen att plocka ett kilo goliatmusseron (alla storlekar och kvaliteter får ingå)?

2. Hur många kilometer färdas du i genomsnitt med bil (enkelväg) för att komma till en skog att plocka goliatmusseron i?

3. Hur många skogar besökte du dessa år per år för att plocka goliatmusseron.

4. Hur många dagar bedömer du att du var ute och plockade goliatmusseron dessa år i genomsnitt?

5. Hur många timmar beräknar du att du var du ute vid varje tillfälle och plockade goliatmusseron (bilresa och tid i skogen).

6. Hur många km bil beräknar du att du sammanlagt har åkt för att plocka goliatmusseron de år det varit gott om goliatmusseron? Ange per år, dvs. hur många km du bedömer att du åkte t ex 1998 och 2007.

7. Hur mycket goliatmusseron av god kvalitet (kg) uppskattar du att du plockade totalt under ett år dessa år i genomsnitt (dvs. under 1 år)?

8. Vilka år bedömer du har varit goda år för goliatmusseron där du plockar?

Scenario 2: ett normalår för goliatmusseronen

Plockar du goliatmusseron när det är ett någorlunda gott för den? Om, ja fortsätt med frågorna nedan.

1. Plockar du goliatmusseron ett normalår? Svara ja eller nej. Om ja, svara även på frågorna nedan.

2. Hur lång tid tar det för dig i genomsnitt när du är på plats i skogen att plocka ett kilo goliatmusseron (alla storlekar och kvaliteter får ingå)?

3. Hur många kilometer färdas du i genomsnitt med bil (enkelväg) för att komma till en skog att plocka goliatmusseron i?

4. Hur många skogar besökte du dessa år per år för att plocka goliatmusseron.

5. Hur många dagar bedömer du att du var ute och plockade goliatmusseron dessa år i genomsnitt?

6. Hur många timmar beräknar du att du var du ute vid varje tillfälle och plockade goliatmusseron (bilresa och tid i skogen).

7. Hur många km beräknar du att du sammanlagt åkt bil för att plocka goliatmusseron dessa år i genomsnitt?

8. Hur mycket goliatmusseron av god kvalitet (kg) uppskattar du att du plockade totalt dessa år i genomsnitt (dvs. under 1 år)?

9. Vilka år bedömer du har varit normal år för goliatmusseron där du plockar (eller kan du ge exempel på några sådana år)?

Scenario 3: Dåligt år för goliatmusseronen (få eller inga fruktkroppar hittas)

1. Plockar du goliatmusseron även ett dåligt år? Svara ja eller nej. Om ja, svara även på frågorna nedan.

2. Hur lång tid tar det för dig i genomsnitt när du är på plats i skogen att plocka ett kilo goliatmusseron (alla storlekar och kvaliteter får ingå)?

3. Hur många kilometer färdas du i genomsnitt med bil (enkelväg) för att komma till en skog att plocka goliatmusseron i?

4. Hur många skogar besökte du dessa år per år för att plocka goliatmusseron.

5. Hur många dagar bedömer du att du var ute och plockade goliatmusseron dessa år i genomsnitt?

6. Hur många timmar beräknar du att du var du ute vid varje tillfälle och plockade goliatmusseron (bilresa och h tid i skogen).

7. Hur många km beräknar du att du sammanlagt åkt bil för att plocka goliat dessa år i genomsnitt?

8. Hur mycket goliatmusseron av god kvalietet (kg) uppskattar du att du plockade totalt dessa år i genomsnitt (dvs. under 1 år)?

9. Vilka år bedömer du har varit dåliga år för goliat där du plockar ((eller kan du ge exempel på några sådana år)?

Ange namn och bostadsort nedan.

Appendix 4. Collected empirical data for the matsutake NPV calculation

	unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean
Qm1	kg/ha	12.5	0.0	6.7	3.3	2.5	4.2	5.8	5.0	0.0	10.8	1.7	3.3	1.7	4.2	1.7	4.2
Qm2	kg/ha	7.5	0.0	3.8	2.1	1.3	2.5	3.3	3.3	0.0	6.3	0.8	2.1	0.8	2.5	0.8	2.5
Qm3	kg/ha	3.3	0.0	2.1	0.8	0.8	1.7	2.1	1.7	0.0	2.9	0.4	0.8	0.4	0.8	0.4	1.2
D	day/yr	9.9	8.1	9.3	9.3	9.3	9.3	9.3	9.3	8.1	9.9	8.1	9.3	8.1	9.3	8.1	9.0
Hp	hour/ha	6.4	3.6	5.2	5.2	5.2	5.2	5.2	5.2	3.6	6.4	3.6	5.2	3.6	5.2	3.6	4.8
L	SEK/hour	105	108	123	113	116	120	124	128	132	137	142	147	150	153	153	130
Hc	hour/ha	1.0	0.8	1.1	1.1	1.1	1.1	1.1	1.1	0.8	1.0	0.8	1.1	0.8	1.1	0.8	1.0
TD	km/ha/yr	57	45	64	64	64	64	64	64	45	57	45	64	45	64	45	57

Note: 1kg matsutake consists of 12 fruit bodies (Niclas Bergius pers, comm.)

Source: $Q_{m;}$ Matsutake sporocarp inventory by Niclas Bergius et. al. (unpublished)

D, H_p, H_c, TD; Questionnaire

L; SCB, average hourly wages in the private sector 1998-2012 at Övre Norrland