Environ Dev Sustain
DOI 10.1007/s10668-008-9145-4

Sustainability research and practices in enforced residential institutions: collaborations of ecologists and prisoners

Craig Ulrich · Nalini M. Nadkarni

Received: 4 September 2007 / Accepted: 19 March 2008

Abstract Enforced institutional settings such as penitentiaries provide environments to raise awareness, carry out research, and implement and assess practices for sustainable living. Institutions where residence is enforced due to health, recreational, military, or legal reasons (e.g., assisted living centers, summer camps, army bases, prisons) house people who may lack scientific training but have time and need for intellectual stimulation that can be filled by supervised research. These institutions have stable populations, structured social organization, and measurable inputs and outputs of materials and energy to carry out sustainable practices in tasks that affect regional resources such as groundwater quality and landfill use. We report on three examples at a corrections center resulting from partnerships among visiting academic ecology researchers, sustainability practitioners, corrections administrators, and prisoners: (1) research on how to sustainably "farm" moss for the horticulture trade to reduce harvesting pressure on wild moss populations; (2) a vermiculture and thermophilic composting system to reduce the kitchen waste; and (3) a monthly seminar series at the prison. Over 26 months: (1) participants developed methods to optimize moss growth; (2) landfill-bound waste and particulate flow rate destined for wastewater treatment decreased by 50%, to less than 50% of permit limits; (3) resulting compost (ca. 5000 kg) fertilized institutional vegetable gardens; (4) water quality improved so that the prison could return funds allocated to upgrade the prison's water quality. The lectures encouraged intellectual exchange among researchers, convicts, and

Readers should send their comments on this paper to: BhaskarNath@aol.com within 3 months of publication of this issue.

C. Ulrich
DOC 877779, Cedar Creek Corrections Center, P.O. Box 37, Littlerock, WA 98556, USA

Present Address:
C. Ulrich
1496, Dove Court, Gardnerville, NV 89410, USA
e-mail: ak_craig@yahoo.com

N. M. Nadkarni (✉)
The Evergreen State College, 2700 Evergreen Parkway, Olympia, WA 98505, USA
e-mail: nadkarnn@evergreen.edu

guards. Researchers derived new perspectives and broader impacts for their work. This can be a model for other correctional facilities and other enforced residential institutions (ERIs).

Keywords Citizen science · Composting · Corrections center · Enforced residential facility · Prisons · Science literacy · Sustainability · Vermiculture

Abbreviations

ADP	Average daily population
ANOVA	Analysis of variance
BOD-5	Organic loading 5-day biochemical oxygen demand
CBCC	Clallam bay corrections center
CCCC	Cedar creek corrections center
DOC	Department of corrections
DOC	Dissolved oxygen content
ERI	Enforced residential institution
LCC	Larch corrections center
OCC	Olympic corrections center
TESC	The Evergreen State College
TSS	Total suspended solids

1 Introduction

Research on sustainability has traditionally occurred within academic institutions, non-profit organizations concerned with conservation, or government agencies charged with sustainable natural resource use. However, other types of institutions can also be effective venues in which to explore and assess the practices of sustainability (defined as a method of harvesting or using a resource so that the resource is not depleted or permanently damaged). Enforced residential institutions (ERIs), where habitation and some behaviors are regulated due to factors that concern health, recreational, or military matters, include prisons assisted living centers, summer camps, or army bases. These establishments provide arenas in which ecologists can collaborate with staff and residents to carry out research, raise awareness, and implement and assess ecological approaches to sustainability. ERIs are particularly suited to this partnership because they have stable, residential populations, a structured social organization, enforceable regulations for activities and behaviors, and (in some cases) the ability to measure the inputs and outputs of materials and energy. Residents of ERIs often lack scientific training, but have available time and potential drive for intellectual stimulation.

For 18 months, ecologists, sustainability practitioners, and corrections officials developed a partnership to explore how inmates at one type of ERI, a men's prison, could pursue research and enhance sustainability. We chose this venue because inmates typically: (1) have long periods of time available to observe and measure research organisms of interest, and have access to space to carry out certain types of research, (2) are subject to rules that require them to take certain actions (e.g., disposing of food waste) in prescribed ways; and (3) have potentially fresh minds to put forward innovative solutions because they generally have not followed the same academic tracks in which researchers have been steeped. In addition, convicts (and residents of other types of ERIs) have little or no access to nature, and so would gain emotional and social benefits by working with living plants and animals (Robbins 2006).

In this paper, we describe three interconnected and collaborative projects that coincided with a larger trend towards building sustainable infrastructure in the world of corrections. In the past decade, at the directive of the Secretary of the Department of Corrections (DOC), prison administrators have been encouraged to increase sustainability due to the rising rate of incarceration and the political sensitivity and expense associated with building new prisons. (D. Pacholke, personal communication). These activities were part of the Research Ambassador Program, (http://www.researchambassador.com), a broad science outreach effort to train academic scientists to directly disseminate their research to underserved public audiences (Nadkarni 2004, 2006). The central idea is to bring together ecologists and prisoners to carry out research that helps address environmental issues through education and research projects in non-academic venues.

The incarcerated population constitutes a large, growing, but somewhat hidden component of our society. In the past decade, the criminal correctional system of the United States has grown at unprecedented rates. The adult population of the nation's state and federal prisons rose to a record 1.47 million in 2006. Existing inmates are serving longer sentences and failing to win early release. Half the prison population is now serving time for non-violent offenses. In general, the prison population is also aging (U.S. Bureau of Justice Statistics 2007). The cost of incarceration is now perceived to threaten the vitality of higher education, which competes in many states with funds that must be allocated to manage offenders. Thus, prisons house a growing and increasingly stable and "teachable" population of men and women who will eventually be released to live and contribute to the general population, and might carry over sustainable behaviors when they return to non-institutional life.

We present three facets of our work, all of which were implemented at a minimum-security prison in southwestern Washington State: (1) research to develop practices to farm epiphytic mosses to reduce unsustainable harvesting from old-growth forests for the horticulture trade; (2) a composting project to reduce kitchen waste, improve regional groundwater quality, and create fertilizer for the institutional vegetable garden; and (3) a lecture series that brought academic scientists to the prison to discuss ecological aspects of sustainability with prison staff and prisoners. We describe the approaches, methods and results of this study, and discuss how they might become a model for other penal institutions and for other types of ERIs in the future.

1.1 Research project on moss as a sustainable resource

The academic research in this program was aimed to improve the sustainability of an extracted natural resource, canopy-dwelling moss and other bryophytes that grow abundantly on branches and trunks of trees in temperate rainforests (hereafter, moss). This project is part of a nascent effort to counteract the ongoing destructive effects of collecting wild-grown mosses from old-growth forests for the floral and horticultural trade. Since 2000, the industry has grown rapidly, reaching an economic value of over $260 million in 2005 (Muir 2004, 2006a). This has raised great concern among ecologists, because canopy-dwelling mosses fill important ecosystem roles, but are slow to regenerate. Mosses capture and retain atmospheric nutrients, provide habitats for arboreal invertebrates, supply foraging locales for arboreal vertebrates, and infuse a deep aesthetic essence to the forest

(Nadkarni 2002a, b). Recent research has shown that moss communities take decades to re-grow after disturbance, so the current practice of stripping mosses from trees is not sustainable (Peck and McCune 1998; Muir et al. 2006b).

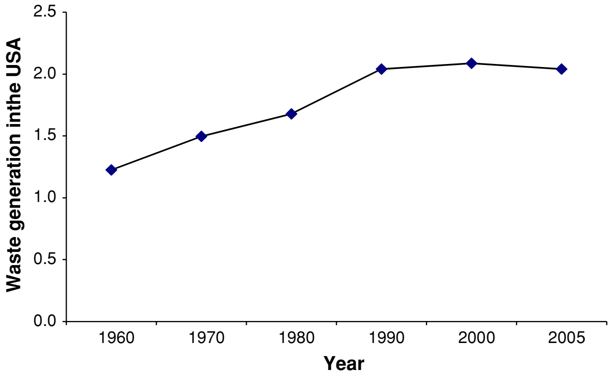
No protocols exist for growing mosses commercially, or in large quantities. However, the biology of mosses makes them suitable subjects of investigation for novice botanists. Moss possesses poikilohydric foliage, which makes them physiologically able to survive drying without damage and to resume growth after re-wetting. This makes them resilient to under- or over-watering, a characteristic that increases the probability that prisoners will experience success in handling plants, which is critical for people who often have histories of destructive or abusive behavior. Carrying out primary research on how to grow mosses in captivity can provide an opportunity for people with no contact to nature, and little opportunity to use their intellects, to learn about the process of research and the rationale for plant conservation. Working with mosses does not require sharp knives or heavy tools, so this project incurs less physical and security risks than raising vegetables for the prison table.

1.2 Sustainable waste management project

Solid waste management is another important sustainability issue in ERI's (Tai and He 2007). The United States annually produces over 100 million metric tons of municipal solid waste, an average of 2 kg per person per day (Fig. 1) (Cunningham et al. 2007), 65% of which can be composted to greatly reduce the amount of waste that ends up in landfills or incinerators (Davis and Masten 2004). The United States spends about $10 billion dollars annually on municipal waste management, which is expected to rise to almost $100 billion annually in the next decade (Cunningham et al. 2007). One way to limit this ecological economic impact in the future is for communities, institutions, and individuals to take an active role in limiting the production of food waste and divert it before it reaches ground water streams and landfills.

Residents in ERIs (in contrast to people living in individual homes or working in independent offices), are controlled to some extent by administrators who can require compliance in such activities as disposal of food and yard waste. For example, a vermi-composting (composting with worms) project at St. John of God Hospital in Perth, Australia was efficient in diverting organic material from the landfill-bound waste stream (Kristiana et al. 2005). Similarly, projects in military communities in Taiwan, who occupy barracks, carry out strict recycling and composting projects (Tai and He 2007). The factors

Fig. 1 Rate of waste generation in the United States (kg per person per day) (Cunningham et al. 2007)



that contributed to success were: strong discipline exerted from the upper administration, focused environmental education, concern with institutional image, management ambition, large scales of waste produced, and effective garbage separation practices (Tai and He 2007).

We implemented a project that would both reduce the amount of kitchen waste entering the groundwater and enhance the organic garden operation. The latter was created to increase the amount of healthy vegetables for inmates, reduce food costs, and train inmates in the practice of gardening. This project also demonstrated the interrelationship between humans, plants, soils, invertebrates, fungi, and the environment, lessons that are critical for society-wide health.

1.3 Sustainability and science lecture series

One of the negative consequences of incarceration is the limitation of mental and intellectual stimulus while behind bars. Because of the risks associated with offenders gaining access to the Internet, it is rare for prisoners to be allowed to take advantage of distance learning opportunities or other Internet-based training programs while they are serving their terms. The few exceptions to these rules, and the record of within-prison higher education programs (e.g., Bard Prison Initiative, http://www.bpi.edu) have proven that access to intellectual stimulation is a highly productive and beneficial activity that can result in reduced rates of recidivism and improved behavior (Tracey 1994; Sherman et al. 2003).

We brought academically challenging and scientifically sound information to the corrections center to expose prison staff and convicts to scientific issues that relate to sustainability for an in-prison lecture series called "Sustainable Living–Sustainable Lives." Visiting lecturers from regional universities and government environmental agencies delivered talks on sustainability, natural history, and ecology. Administrators allowed us to place prison staff and inmates in the same room to hear and ask questions of the speaker; they had hitherto been separated for group events.

2 Methods

2.1 Study venue

After reconnaissance at several regional corrections institutions, administrators at the Cedar Creek Correctional Center (CCCC) proved amenable to our program. This is a minimum-security men's prison in Littlerock, Washington, ca. 50 km south of Olympia (Lat: 46.9019°N Long: 123.0166°W). It is located on land owned by the Washington State Department of Natural Resources. It has an average daily population (ADP) of 400 inmates. All inmates are within 48 months of release, though many have spent previous time in medium- and maximum-security retention; the mean inmate length of stay is 18 months (Fig. 2). The academic team was comprised of a faculty member at the Evergreen State College (TESC), one graduate student, one undergraduate student, and an adult volunteer. This team was complemented by the group from the CCCC: Superintendent and Assistant Superintendent, ca. 10 staff, and ca. 25 inmates who rotated in as their fellow prisoners' sentences ran out for the research and waste management projects, and ca. 60 prisoners for the lecture series.

Fig. 2 The Cedar Creek Correction Center, a minimum security prison, in Littlerock, Washington State

2.2 Research project on moss as a sustainable resource

The specific objective for this research project was to investigate optimal ways to grow mosses for the horticultural trade by developing techniques of growing mosses and measuring their growth rates. At the outset of the project, the academic team collected moss (12 November, 2004) with a U.S. Forest Service permit, from the Brown Creek area, in the North Skokomish river drainage on the east side of the Olympic National Forest (47.4072°N, 123.1400°W). The habitat was a late successional forest dominated by *Tsuga heterophylla* (Western Hemlock) and *Pseudotsuga menziesii* (Douglas-fir), with an understory of *Acer circinatum* (Vine maple). Mosses were taken from the lower trunks, fallen trunks, and forest floor of *Acer macrophylllum* (Bigleaf maple) and *P. menziesii* trees. We collected four of the most common species of moss (*Eurychium oreganum*, *Dicranum fuscesens*, *Isothecium stoloniferum*, and *Metaneckera douglasii*).

We first addressed the most basic question for moss horticulture: what is the relative growth rate of each species? First, we taught the prisoners to identify common moss species with simplified botanical keys, using their scientific names. We then did preliminary work to assess the most viable method of fostering and measuring moss growth (hanging in mesh bags following (Rosso et al. 2001) vs. flats growing them in weighable pieces that rested on stacked shelves). We found that the latter technique was optimal. Staff and inmates separated the collected mosses into 'plugs' (approximately 20 × 10 cm) and placed each plug on a paper towel that covered the base of 17-in. square growing flats. Four plugs were placed to a flat, each of which was labeled with a unique number on an aluminum tag (Fig. 3). All plugs were weighed wet prior to attaching them to the trays with wire strands. To establish a dry weight/wet weight ratio, a random selection of ten plugs from each species was taken to the Forest Canopy Lab at TESC, dried in an oven (105°C), and weighed.

The trays, with plugs attached, were kept in a growing shed/greenhouse, equipped with an overhead irrigation system (installed by the inmates) that ran twice a day for 10 min (Fig. 4). To equalize shade, inmates rotated the trays each month. Inmates ensured that the irrigation system was working on a daily basis. Each inmate was given a notebook and

Fig. 3 Moss sample and tray with four *Isothecium stoloniferum* plugs for cultivating mosses at the Cedar Creek Corrections Center (December 2004)

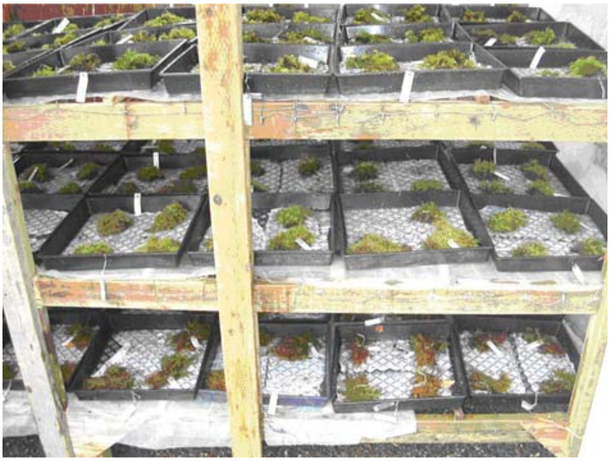


Fig. 4 Moss growing rack constructed at the Cedar Creek Corrections Center to incubate experimental mosses. Three lower shelves of growing shed with *Eurynchium*. (upper shelf), *Isothecium* (middle shelf), and *Metaneckera* (bottom shelf) (December 2005)

pencil and asked to take notes on the operation, on any general or unusual patterns he observed.

From November 2005 to March 2005 on a monthly basis, and thereafter until November 2005, every other month we measured growth. The inmates collected a random subsample of ten plugs of each species each month. These were photographed individually at the CCCC greenhouse yard using a stand. Each sample was then bagged individually, and a member of the academic team transported them to the TESC laboratory, dried them overnight in an oven (105°C), and weighed them. We calculated the growth or reduction in size of each sample by comparing it with the calculated original weight of that sample, based on the wet weight/dry weight ratios we had measured. We carried out ANOVA ($P < 0.05$) to determine if there was a significant species effect for rate of growth. We regularly reviewed the growth rate data and results with the prisoners.

2.3 Sustainable waste management project

The specific goal of the ecological waste management program was to remove the maximal amount of food waste from the inmate kitchen and to process other sources of compost material in the institution (e.g., staff food waste, coffee grounds, plant waste from inmate organic gardens). With the initial guidance of a visiting vermiculture expert, non-inmate volunteers and inmates explored several compost techniques to identify the most efficient methods. Modifications were made based on the volume and materials created by the prison population. The eventual protocol involved vermicomposting with *Eisenia fetida* worms a species that is capable of processing up to half of its body weight in food per day and performs well at the elevated temperatures involved in composting the large amounts of food waste created at CCCC (Edwards and Bohlen 1996).

However, the large amount of food waste produced by the institution on a daily basis combined with a small worm population led to an overabundance of food waste. The next step was to transform the vermicomposting center into a dual thermophilic composting-and-vermicomposting center to handle the food waste that exceeded the vermicomposting operation. Thermophilic composting is the process by which anaerobic organisms break down plant and food matter generating a rudimentary carbon and nitrogen rich fertilizer as well as a copious amount of heat (Tognetti et al. 2005). Some negative side effects of this process occurred: rancid smell, long turnover rate, and a less pure end product than was created via vermicomposting. This led the CCCC to phase down the thermophilic process and to modify the vermicomposting process. The modified vermicomposting system maximized the amount of food that could be processed by use of a stacking shelf system to increase surface area to provide the worms with the most accommodating conditions to breed and compost (Fig. 5).

The vermiculture stacking shelf system that we manufactured from recycled lumber consists of three stacks of six shelves. The dimensions of each shelf are 0.92 m by 0.92 m by 0.20 m. In practice, the shelves are only filled to a depth of 0.15 m to give a volume of 0.75 m^3 per stack. Each shelf has either a collapsible metal bottom or a plywood bottom with 50, 3 cm holes drilled through the plywood to increase aeration and allow excess water to drain.

The earthworm population is highly variable, depending on conditions and seasonal influence. Populations can range from one earthworm to more than 2000 m^{-2} (Edwards and Bohlen 1996). It is possible to maintain almost 90,000 worms m^{-3} equivalent to a population of 31.3 kg of worms per stack. At this level, each stack would have a maximum operating capacity of 15.6 kg of food d^{-1}. If all three stacks were running at full capacity, then the maximum amount of food that can be processed would be 46.9 kg d^{-1}. This is a theoretical maximum that has not yet been achieved in practice.

The stacked shelf system creates a large quantity of worm castings. The castings must be harvested every 2–3 months for ideal breeding and composting conditions. To separate the worms from the castings in order to reintroduce the worms back into the composting system, we designed a hand-cranked sifting device that can efficiently screen the composted material from the worms although some cocoons are lost during the process.

Fig. 5 Incubation racks for thermophilic composting and vermiculture in composting yard

This stacked shelf system was implemented in July 2006, and is currently operating at a sub-maximal level due to varying weather conditions and a less than ideal worm population. However, we anticipate that worm populations will rise and maintain themselves once outside temperatures have stabilized.

The thermophilic composting procedure has gone through several levels of evolution since the initiation of CCCC's composting program. Initially, all food gathered from the kitchen was placed into a pile and allowed to compost, an inefficient process. We tried several variations of windrow composting and have found the following design to be the most efficient. Incoming food waste is first hand chopped into slurry and mixed with sawdust, which is then dumped into a processing cage. The cage is designed to keep vermin from digging in and spreading the compostable material. It consists of a $3 \times 1 \times 1$ m collapsible metal cage set on top of a row of 30 cm cinder blocks stacked 2 blocks high. The top row of cinder blocks is gapped every 0.5 m to allow a 10 cm diameter aerated pipe to pass through the compost. The compost is allowed to sit in the processing cage until it passes from the mesophilic to the thermophilic stage, ca. 50°C, when it is moved into an aerated windrow and allowed to sit for 30–60 days. The windrow is watered to keep the compost moist and is harvested when the temperature passes back down into the mesophilic stage.

2.4 Science and sustainability seminar series

At the outset of the project, the academic team brainstormed a group of topics that would lend themselves to discussions on sustainability to create a monthly lecture/seminar series called "Sustainable Living, Sustainable Lives". The team drew upon local and regional professional contacts to invite a group of academics (mostly professors from state and private institutions of higher education) and sustainability practitioners (mainly consultant and natural resource agency personnel). Individuals were invited to participate in the series by giving a lecture at the prison, distributing handouts, and being open to receiving communication after the presentation. They were presented with the following incentives: (1) $500 as an honorarium (which 60% chose to decline); (2) a letter of thanks for their time and effort from their Department Chair, supervisor, or Provost; and (3) a venue for dissemination of handouts or other materials relevant to their place of work or subject matter.

Each presenter was given detailed descriptions of the nature of the ongoing projects, the prison environment and surroundings, and our past experiences with the prisoners. They were also provided with guidance on the level of talks and graphics that they should present, verbally, and via email. Staff either picked them up or met them at a pre-arranged time at the prison; each speaker was accompanied by a project member as well as by a prison staff. Because the prison required pre-screening for entry into the prison, basic information (citizenship, driver's license number) was requested three weeks before the speaking date.

Both prison staff and prisoners were allowed to occupy the same presentation room (the prison chapel), which was counter to the prevailing practice of separating prisoners and staff. These talks were announced to regional corrections centers via their in-house electronic mail system. At nearly every lecture, staff visitors from other prisons came to hear the lecture. Each member of the audience was given a questionnaire before the lecture, which included questions on the listener's familiarity of the topic, attitude about lectures, and background experience in academics. Each speaker talked for 30–40 min on his/her topic, and then invited questions and discussion. Prisoners and staff asked questions, some of which stimulated further discussion among the listeners. After the talk, a second questionnaire was circulated, and listeners responded to questions designed to detect changes in the understanding of lecture content as well as their attitudes about the activity.

3 Results

3.1 Research project on moss as a sustainable resource

Our greenhouse research project revealed that there was significant potential for farming moss for three of the four moss species we tested. We found striking and significant differences between species in the annual growth rates ($P < 0.001$). The net annual growth (expressed as increased dry weight from November 2004 to October 2005) ranged between −30% (*Isothecium stoloniferum*) to +50% (*Eurhynchium oreganum*) (Table 1). Two of the species grew nearly 50% of their initial weight. We also documented the dynamics of growth rates, with greatest growth rates (as high as 29% mo^{-1}) in the cooler, wetter months of the winter, and much slower rates during the summer (Fig. 6). These observations were consistent with the observations of the prisoners, and with general botanical knowledge of moss growth in wild ecosystems.

Table 1 Annual and monthly rate of gain or loss of dry weight biomass of the four moss species at the Cedar Creek Correctional Center

Species	Annual gain/loss (% dry weight)	Rate of gain/loss (% dry weight per mo)
Eurynchium oregana	49.8 (0.21)	4.5
Dicranum fusescens	6.3 (0.09)	−0.5
Metaneckera douglasii	45.5 (0.27)	4.1
Isothecium stoloniferum	−28.1 (0.11)	−2.5

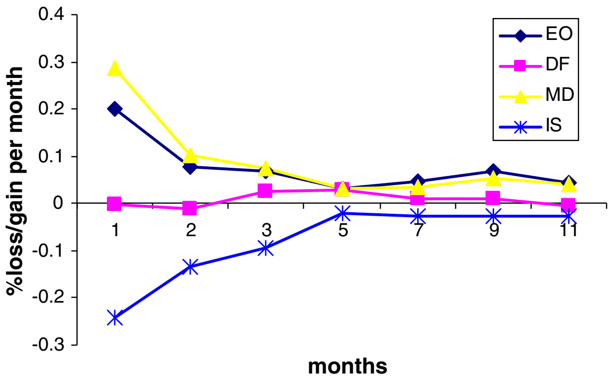


Fig. 6 Monthly rates of growth or loss of biomass of four species of mosses, as a percentage of the original dry mass. EO = *Eurychium oreganum*; DF = *Dicranum fusescens*; MD = *Metaneckera douglasii*; IS = *Isothecium stoloniferum*

3.2 Sustainable waste management project

Overall, administrators and prisoners have found this program to be an efficient way to control the amount of outgoing organic waste from the institution. We report three results: (1) decrease in outgoing food waste from the prison; (2) resultant cost savings for the prison due to decreased need for municipal operations; (3) amelioration of groundwater quality; and (4) creation of high quality fertilizer, an economically and nutritionally beneficial byproduct for improving soils of the CCCC garden.

First, the composting program led to removal of a significant amount of food waste from municipal waste containers. From November 2004 through December 2004, 746 kg of food waste was processed, averaging 373 kg mo^{-1} (Fig. 7). In 2005, the annual amount of food waste removed from the municipal waste containers was 9,120 kg (760 kg mo^{-1}). In 2006, these numbers continued to climb, reaching an annual total of 12,095 kg of food waste removed (1008 kg mo^{-1}). Between November 2004 and December 2006, CCCC had a stable ADP of 400 inmates. In 2006, the composting program removed an average of 30.2 kg per inmate, equivalent to 2.5 kg $inmate^{-1}$ mo^{-1}. Based on the stable inmate population and consistent feeding schedule, we estimated that 2.5 kg $inmate^{-1}$ mo^{-1} was entering the waste stream as landfill bound waste up until the November 2004 initiation of the composting program. Thus, CCCC has enacted a successful program that significantly reduced the amount of landfill bound waste that the institution produces. We attribute the significant increase in the yearly averages to increasing knowledge of how to procure and handle CCCC's food waste.

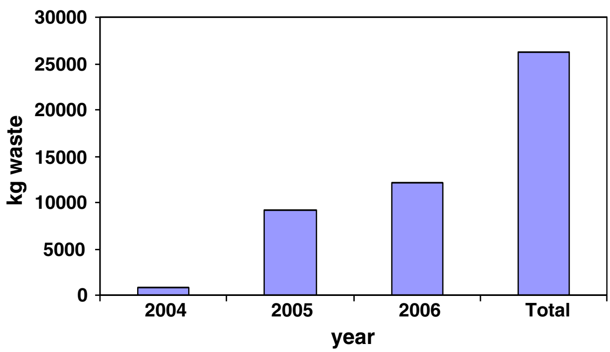


Fig. 7 Annual and total amount of composted food waste (kg) removed from the waste stream and processed either thermophilically or by vermicomposting. The data were recorded from November 2004 to December 2006

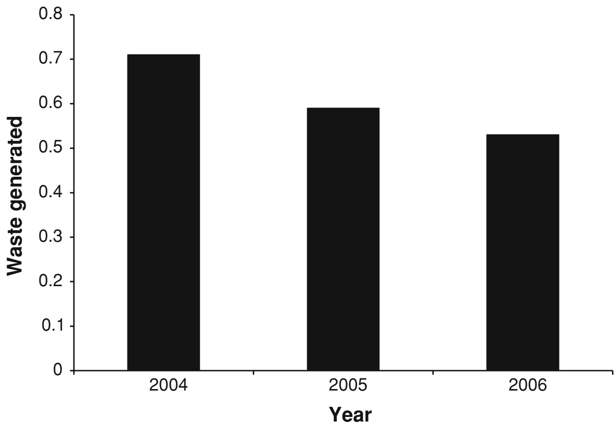


Fig. 8 Average amount of solid waste discarded (kg per inmate per day), reported as the mass removed by garbage service and transported to the local landfill

Second, removal of food waste from the municipal waste containers resulted in significant cost savings for the institution. CCCC started a recycling program in conjunction with the composting program, and this led to a large enough decrease in waste to allow CCCC to downsize its waste management container from a 30.6 m^3 container to a 15.3 m^3 container. Data collected from 2004, which was prior to the implementation of the compost and recycling programs, show that the inmates at CCCC discarded an average waste of 0.71 kg $inmate^{-1}$ day^{-1}. Data collected from the fiscal year of 2005 shows that the amount of waste discarded dropped to 0.59 kg $inmate^{-1}$ day^{-1} and fell even further in 2006 to 0.53 kg $inmate^{-1}$ day^{-1} (Fig. 7). This saved the institution an average of $132 a month on the container alone. Coupled with the decrease in weight, which is charged $0.0016 kg^{-1}, then CCCC saved an average of $200–$500 per month, or up to $6000 y^{-1} (Fig. 8).

The third positive result from this program was that it created unintended positive consequences for other waste management processes. One of the major upsides of the vermicomposting program was an impact on the institution wastewater quality. The wastewater treatment plant at CCCC was designed to treat a design flow of 0.25 million l d^{-1}, with an influent flow organic loading 5-day biochemical oxygen demand (BOD-5) of 68 kg d^{-1}, and an influent flow total suspended solids (TSS) loading of 68 kg d^{-1}. The BOD-5 is a measure of how much dissolved oxygen is being consumed as microbes break down organic matter (European Environmental Agency 2001). The TSS is a dry weight measure of particles trapped by a filter and calculated using the volume of water filtered (Davis and Masten 2004). Both BOD-5 and TSS are influenced by the amount of solid organic matter that is processed by the wastewater treatment plant.

The Washington State DOC planned to increase the ADP of CCCC from 400 to 500 inmates. To accommodate this increase in population, it was originally thought that the wastewater treatment plant would have to be upgraded at a cost of $1.3 million dollars. During the planning and funding allocation process, however, the composting program was having a significant positive impact on both the BOD-5 and TSS levels at CCCC's wastewater treatment plant. In late 2006, water quality inspectors produced a technical memorandum that reported the changes needed to accommodate an expansion of the prison. Based on comparisons of measurements and extrapolations of water quality measurements that had been carried out the previous year, it came to light that the compost program had significantly lowered and stabilized both the influent BOD-5 and TSS. The BOD-5 has been kept between 18 and 41 kg d^{-1} since the enactment of the composting program, far lower than the previous average value of 44 kg d^{-1}. The post-composting TSS value was even lower, ranging between 18 and 36 kg d^{-1} , lower than the previous value to a mean of 39 kg d^{-1}, values that are far below BOD-5 and TSS permit maxima of 68 kg d^{-1}. A secondary indication that wastewater quality has improved in conjunction with the implementation of the vermicomposting program was that the effluent BOD has dropped well below its permit limit of 20 mg l^{-1} and the effluent TSS has remained well below its permit limit of 30 mg l^{-1}.

Fourth, this project created high-grade organic fertilizer that improves the institution's organic gardens. The vermicomposting program processes, on average, 853 kg of organic waste mo^{-1}. Depending on the composition of this organic waste, ca. 65–90% of this weight is composed of water, which is lost during the processing. This leaves 85 to 299 kg mo^{-1} of finished product (in the form of worm castings and/or the less refined thermophilically broken down compost) that can be used to fertilize CCCC's organic gardens. These gardens generated over 5900 kg of produce during 2006. Currently, the organic fertilizer output is sufficient to cover almost all of the institution's fertilizer needs. When the program reaches full capacity, it is expected to produce enough to allow some of the refined product to be donated to nearby Littlerock Elementary School, for their garden projects.

3.3 Science and sustainability lecture series

The seminar series presented appeared to engage and educate the prison audience concerning topics that are germane to sustainability, ecology, environmental health, and the nature of learning. Listeners were attentive and prison staff were helpful in setting up and implementing each of the lectures, including disseminating information about the series to other prisons. The rare occurrence of having prison staff and inmates together in the same room provided all participants with a greater than usual sense of egality in learning about these topics. Staff were able to observe that prisoners asked good questions that were answered with respect by the presenter, and vice versa. This arrangement seemed to enhance the sense of importance to the activities. It also seemed to bolster the morale of the prisoners because they felt on more of an equal and human footing than what they normally encounter within prison walls. The questionnaires that we circulated after each of the lectures contained such statements as: "I understood everything the teacher said;" "Bring someone who can talk about soils next time;" and "How come the mosses don't fall off the trees?" The corrections staff promoted the lecture series, inviting corrections officials from other institutions to attend.

3.4 Other results

The results of the project were dramatic in many realms. In terms of direct rehabilitation, one of the inmates joined the horticulture program at the local community college after his release, with a career goal of opening his own plant nursery. At many occasions, academic staff, prisoners, and prison administrators explored ways to turn these experiences into useful avenues after release. For example, we discussed how we might develop value-added products (e.g., small "moss gardens") that offenders could create that would be of commercial retail value as a specialty product that could be sold via online gift companies. Academic staff approached two companies who are now considering the proposal.

These projects were also of interest to the public and the media, as evidenced by a number of newspaper articles, magazine stories and radio programs about the ways that inmates were carrying out research and sustainability projects. This activity was viewed in a positive way by upper-level officials in the DOC. For example, the Superintendent received a special award for having saved the agency $1.3 million in "cost reduction" for the water treatment facility. In addition, the TESC students and adult volunteer who helped with the project provided over 220 h of volunteer time to train the inmates, process samples, and interpret the data, motivated by their keen interest in both the botanical findings and the opportunity to work with such interesting colleagues.

Another result was more difficult to quantify, but represents positive psychological and social aspects of working directly to enhance sustainability on a day to day basis. One expected result of the project was that the prisoners became engaged in learning about the process of science as well as the actual results of moss growth. For example, on one of the monthly visits to the prison, one of the inmates informed the academic staff that no one ever shared notebooks or notes with him, and vice versa. When asked if this was because of sense of competition, he explained that if he saw what someone else had written, it might affect what he wrote down, and it seemed to him that he should only write down what he himself had seen. This displayed the inmate's induction about the need for objectivity, deriving this basic tenet of the scientific method on his own.

4 Discussion

4.1 Research project on moss as a sustainable resource

Our measurements of moss growth indicated that it is realistic to consider growing certain moss species for the horticulture trade in captivity, rather than relying on wild-grown moss. The rate of nearly 50% growth per year for two of our species is much higher than what has been reported for moss growth in the wild (Rosso et al. 2001; Muir 2004). This experiment was a first attempt at growing moss, and such growth rates might be enhanced by using different watering regimes (administering water in mist vs. droplet form), applying natural throughfall gathered from beneath trees, or providing extra nutrients via liquid fertilizer. The seasonality in the growth rate that we documented (Fig. 6) is an important trend for horticulturists to consider in carrying out moss-farming in the future.

4.2 Sustainable waste management project

We placed the activities and results from the waste management project in the context of other prisons. Wastewater treatment plant data from two other minimum security prisons, Larch Correctional Center (LCC) and Olympic Correctional Center (OCC), was also analyzed as a comparison. Both LCC and OCC have enacted successful composting programs in a different fashion than CCCC. LCC purchased a $250,000 composting machine in 2006 to process their food waste and composted an average of 0.24 kg offender^{-1} d^{-1} for the fiscal year of 2006. OCC constructed a large windrow composting building using offender labor in order to process their organic waste as well as organic waste that is shipped from Clallam Bay Corrections Center (CBCC) which has an ADP of 890 inmates. If OCC and CBCC's offender populations are both considered then OCC's composting program composted an average of 0.24 kg offender^{-1} d^{-1} for the fiscal year of 2006. LCC has an ADP of 400 inmates and OCC has an ADP of 350 inmates so the

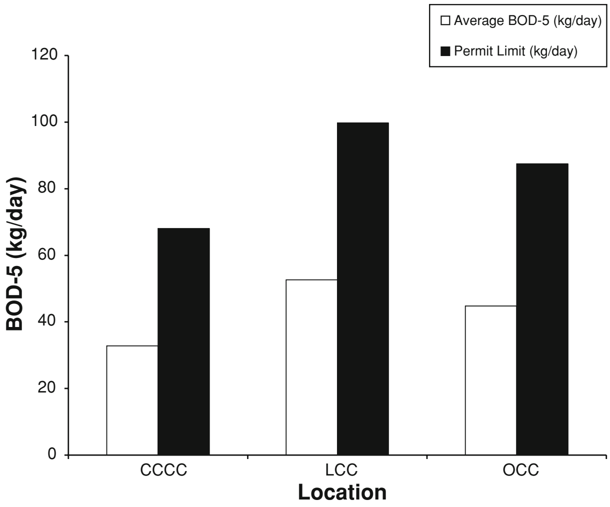


Fig. 9 Comparison of influent BOD-5 permit maximum and BOD-5 average between institutions. Data was analyzed from 2005 and 2006 when all three facilities were running composting programs. CCCC = Cedar Creek Corrections Center, LCC = Larch Correctional Center, OCC = Olympic Correctional Center

wastewater treatment plants service a comparable population to CCCC. Data was available for 2005 and 2006 in which CCCC, OCC, and LCC were all running composting operations. LCC had an average BOD-5 of 52.6 kg d^{-1} (53% of their permit maximum of 99.8 kg d^{-1}). OCC had an average BOD-5 of 44.7 kg d^{-1} (51% of their permit maximum of 87.5 kg d^{-1}.) CCCC had an average BOD-5 of 32.8 kg d^{-1} (48% of their permit maximum of 68 kg d^{-1}) (Fig. 9). Considering that all three institutions have comparable populations, and that CCCC has maintained both lower BOD-5 permit maximum levels and lower average BOD-5 levels, we consider the composting program at CCCC to be a success.

Enactment of the composting program at CCCC has lowered the historical BOD-5 and TSS levels to a low enough point that the estimated increase from a greater inmate population will not exceed the current permit level. The increase in population is estimated to raise the maximum monthly BOD-5 level from an average of 44 kg d^{-1} to 61 kg d^{-1}. The maximum monthly TSS level is expected to rise from an average of 39 kg d^{-1} to 54 kg d^{-1}, both of which are still below the permit max of 68 kg d^{-1} for both BOD-5 and TSS.

We suggest that the main reason that both BOD-5 and TSS have been significantly lowered is due to the way food trays are processed as they leave the cafeteria. With the enactment of the composting program came the standard policy to scrape any food matter that can be composted off the trays before they are rinsed and run through the dishwasher. This small change has had obvious positive consequences on reducing the amount of organic solids that were washed down the drain and transported to the wastewater treatment plant. Confirmation of the positive effect of the compost programs is that the new permit for the wastewater treatment plant is going to require the continuation of the composting program to remove food waste from the influent flow stream. Vermicomposting can be an effective stabilization technique for domestic wastewater residuals (biosolids) (Eastman et al. 2001; Craig and Ankers 2006). We have shown that vermicomposting programs can also help remove a portion of the incoming waste stream decreasing the initial amount of biosolids produced during wastewater treatment. Future research might combine these two techniques to maximize the benefits that vermicomposting can provide.

The small steps taken to enact the composting program have had a major impact on the institution. The amount of organic waste per inmate decreased significantly at CCCC. Not only has the program saved the state the $1.3 million dollars needed for the waste water treatment plant upgrade but has also taken a large amount of organic product out of the waste stream. It has diverted over 2.7 t of landfill-bound food waste that is now used in a sustainable fashion to fertilize the institutions organic gardens. Although this may appear to be an insignificant amount relative to the 107 million metric tons of waste that is generated per year for the nation, extrapolation to the statewide level is significant.

If all private and government institutions enacted programs such as the one at CCCC, a significant amount of waste could be diverted from landfills and converted to useful fertilizer. An ideal extrapolation to all 1.47 million inmates in the U.S. would remove 3.675 million kg mo^{-1} of waste or 44,394 metric tons y^{-1}. This would not only save a large amount of time and money that is spent on transporting the waste such as the $200 to $500 per month savings at CCCC, but would also drastically cut down the environmental impact of storing such large amounts of waste in municipal land fills.

4.3 Science and sustainability lecture series

This aspect of our program presented an opportunity to work on the challenge that faces today's scientists: how can researchers help bridge the gap between scientific knowledge and pro-environmental behavior in people who might not have positive or protective attitudes about nature? The outcomes from the CCCC activities we describe here provide insights into how scientists can participate in solving two major problems facing our society, the growing gap between science and society, and the plummeting awareness of the importance of the health of our planet's biota. Less than 15% of Americans describe themselves as well-informed about science (National Science Board 2002). Typically, scientists play only minor roles in direct dissemination of research to the public, as such work is viewed as being secondary to the "real work" of academics. Instead, scientific outreach is largely facilitiated by informal science education centers, which are geared primarily towards segments of the "scientifically aware" public (Falk and Dierking 2002). Media professionals also contribute to scientific engagement, but they are often hampered by fixed deadlines, lack of expertise in specialized subjects, and the perceived need to sensationalize research (Nelkin 1995).

In general, scientists have much to gain from increasing the public's understanding of science, because of the positive relationship between society's views of science and levels of scientific funding (Miller 2004). Although scientists are often portrayed as being reclusive and obscure, many researchers can be effective disseminators because of their deep passion for and knowledge of what they study (Nadkarni 2004). For example, this project allowed academic researchers and students to investigate horticultural questions to solve an environmental issue, and it provided inmates with the positive activities of using their intellect, learning a potential means of making a legal and sustainable living after release, and working with growing things.

4.4 Attitudes and feedback

The corrections center staff were astonished at the energy, interest, and patience the participants exhibited. The challenges of moss taxonomy and the tedious nature of watering and making observations on non-showy, slow-growing plants would seem to discourage participants, particularly those who lack formal education and come from diverse backgrounds with values that often do not include nature study. Being a physically captive audience (much more so than students in a classroom), one might expect resentment rather than the receptivity we found. Why were the inmates so engaged?

We attributed the positive response to three factors. First, the participatory way the project was presented decreased resistance to doing work that was challenging and repetitious. Rather than being told what to do—the norm of their existence behind bars—the inmates appeared to feel themselves as active and valued participants in an ongoing exploration of how to solve a critical environmental problem. This gave them a real sense of ownership, as evidenced by their taking initiative in experimental design (e.g., choosing to use moss flats instead of mesh bags, designing and constructing the shelves themselves). Second, the project was presented as solving a real life problem that occurs in their home region of the Pacific Northwest. Many of the inmates had previous contact with moss and forest habitats because of their hunting and fishing experiences before they were incarcerated, so this reinforced their existing connections to nature. Third, even though they were jailed for contravening a societal norm, they seemed to be keen to make a difference to society, and the project appeared to serve as a subtle but real form of redemption.

5 Conclusions

The small-scale implementation of research and sustainability projects at one institution has provided a step in reducing municipal waste and should be considered a top option when deciding how to better manage this waste at correctional centers and other residential institutions. State institutions can be role models for how to enact a sustainable life style that will limit their impact on the environment. CCCC has taken a lead role in converting its waste management programs into beneficial, environmentally correct programs such as composting and recycling. These results should be considered in initiating and implementing similar programs in enforced residential programs such as military installations, assisted living quarters for senior citizens and people who are disabled, and children's summer camps.

Acknowledgments We acknowledge the strong support of Superintendent Dan Pacholke, Thomas Matthews, Georgia Harvey, and staff of the Cedar Creek Corrections Center and Washington State Department of Corrections. We also thank Linda Glasier and Janine Bogar (Environmental Unit) and Janet Glover (Budget Manager) of the Department of Corrections. Raymond Price provided the initial critical contact and sustained positive and critical efforts to maintain the project. We also thank Wayne Hudspeth, Adrian Wolf, and Erica Guttman for help. Nancy Parkes, faculty member at The Evergreen State College, provided guidance. The Helen R. Whiteley Center provided support for reflection and synthesis of these activities. Funding was provided by the National Geographic Society Conservation Trust and the Informal Science Education Program at the National Science Foundation (ISE 03-22214).

References

Craig, L., & Ankers, S. (2006). Vermiculture produces EQ class A biosolids at wastewater plant. *BioCycle, 42*, 42–46.

Cunningham, W. P., Cunningham, M. A., & Saigo, B. W. (2007). *Environmental science: A global concern* (9th ed.). New York: Mcgraw-Hill.

Davis, M. L., & Masten, S. J. (2004). *Principles of environmental engineering and science* (1st ed.). New York: Mcgraw-Hill.

Eastman, B. R., Kane, P. N., Edwards, C. A., Trytek, L., Gunadi, B., Stermer, A. L., & Mobley, J. R. (2001). The effectiveness of vermiculture in human pathogen reduction for USEPA biosolids stabilization. *Compost Science & Utilization, 9*, 38–49.

Edwards, C. A., & Bohlen, P. J. (1996). *Biology and ecology of earthworms* (3rd ed.). New York: Chapman and Hall.

Falk, J., & Dierking, L. D. (2002). *Lessons without limit: how free-choice learning is transforming education*. Oxford: AltaMira.

Kristiana, R., Nair, J., Anda, M., & Matthew, K. (2005). Monitoring of the process of composting of kitchen waste in an institutional scale worm farm. *Water Science and Technology, 51*, 171–177.

Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science, 31*, 273–294.

Muir, P. (2004). An assessment of commercial "moss" harvesting from forested lands in the Pacific Northwest region of the United States. Final Report to the U.S. Fish and Wildlife Service, Corvallis, Oregon, USA.

Muir, P. S., Norman, K. N., & Sikes, K. G. (2006a). Quantity and value of commercial moss harvest from forests of the Pacific Northwest and Appalachian regions of the US. *The Bryologist, 109*, 197–214.

Muir, P. S., Rambo, T. R., Kimmerer, R. W., & Keon, D. B. (2006b). Influence of overstory removal on growth of epiphytic mosses and lichens in western Oregon. *Ecological Applications, 16*, 1207–1221.

Nadkarni, N. M. (2002a). In the treetops: life in the rainforest canopy. *World Book Science Year Book* 2003, 54–67.

Nadkarni, N. M. (2002b). When preaching to the choir isn't preaching to the choir: churches, trees, and environmental perspectives. *Environmental Practitioner, 4*, 188–190.

Nadkarni, N. M. (2004). Not preaching to the choir: communicating the importance of forest conservation to nontraditional audiences. *Conservation Biology, 18*, 602–606.

Nadkarni, N. M. (2006). The moss-in-prison project: disseminating science beyond academia. *Frontiers in Ecology and the Environment, 4*, 442–443.

National Science Board. (2002). *Science and engineering indicators 2002*. Washington, DC: U.S. Government Printing Office.

Nelkin, D. (1995). *Selling science: how the press covers science and technology*. New York, New York: W. H. Freeman.

Peck, J. E., & McCune, B. (1998). Commercial moss harvest in northwestern Oregon: biomass and accumulation of epiphytes. *Biological Conservation, 86*, 299–305.

Robbins, N. (2006). Not only plants growing in this garden. San Francisco Chronicle. January 14, 2006.

Rosso, A. L., Muir, P. S., & Rambo, T. R. (2001). Using transplants to measure accumulation rates of epiphytic bryophytes in forests of western Oregon. *The Bryologist, 104*, 430–439.

Sherman, et al. (2003). Preventing crime: what works, what doesn't, what's promising. Research in Brief; National Institute of Justice, U. S. Department of Justice, 1998–2003.

Tai, H.-S., & He, W.-H. (2007). A novel model of organic waste composting in Taiwan military community. *Waste Management, 27*, 664–674.

Technical Memorandum between HDR and Washington Department of Corrections. (2006). Littlerock, WA.

Tognetti, C., Laos, F., Mazzarino, M. J., & Hernández, M. T. (2005). Composting vs. vermicomposting: A comparison of end product quality. *Compost Science & Utilization, 13*, 6–13.

Tracey, E. A. (1994). Review of various outcome studies relating prison education to reduced recidivism. Windham School System, State of Texas.

U.S. Department of Justice. (2007). *Prisoners in 2006*. In W. J. Sabol, H. Couture & P. M. Harrison (Eds.), http://www.ojp.usdoj.gov/bjs/pub/pdf/p06.pdf