

A review of the outcomes of a decade of forest health surveillance of state forests in Tasmania

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Summary

Forest health surveillance, involving annual inspection of pine and eucalypt plantations by trained health observers, commenced in Tasmania in 1997. In the ten years since its introduction, forest health surveillance has become fully integrated into Forestry Tasmania's plantation management program. Importantly, forest health surveillance has provided value extending beyond the detection of pest and disease problems and has become a key element of the solutions for the management of health problems. The use of forest health surveillance to assist in the management of health problems at strategic, tactical and operational levels is discussed and illustrated with examples including establishing priorities for research, informing deployment strategies for managing pests or diseases, incursion responses and management in direct response to detection of pests or diseases.

Keywords: forest health; surveillance; pest management; plantations; native forests; *Eucalyptus*; *Pinus*; Tasmania

Introduction

Forest health surveillance (FHS) uses regular, formal inspections of the target forest estate by specially qualified surveyors to detect and describe health problems, particularly those problems caused by pests and pathogens. The introduction of health surveillance in Tasmania in 1997 was predicated on an argument that early detection of health problems, particularly in a young and rapidly developing plantation estate, would provide significant benefits in the management of these problems. Similar arguments were presented by state forest management agencies in Queensland and New South Wales (NSW) to support the establishment of FHS in those states at about the same time. All three states modelled their systems of health surveillance closely on that used at the time in New Zealand (Kershaw 1989). Queensland also incorporated some elements of Canada's now-defunct Forest Insect and Diseases Survey (Ross Wylie, Queensland Department of Primary Industries and Fisheries, *pers. comm.*, 2007).

Over the last two decades in New Zealand the ownership of the plantation estate and responsibility for FHS has almost entirely shifted from government to the private sector. In contrast in Australia, where there is both private and government ownership of the estate, FHS is still primarily done in state-owned plantations and the expertise for conducting FHS resides in government agencies (including corporatised forestry agencies). Tasmania

is the only state where FHS has been adopted by the private industrial forestry sector, although in Victoria private industrial growers have adopted a system of health monitoring using a network of permanent plots (Wardlaw *et al.* 2007). The original operational FHS models adopted in Queensland, NSW and Tasmania have remained relatively unchanged for the softwood estate (Wardlaw *et al.* 2007a). In contrast, those models proved less suited for use in the widely scattered and often small eucalypt plantations in NSW and Queensland, necessitating significant modifications in surveillance design. Tasmania, with its more compact and contiguous eucalypt plantation estate, has been able to use its original surveillance model equally well in both softwood and eucalypt plantations. The FHS system currently used in Tasmania is described by Wotherspoon (2008).

Two explanations have been proposed for operational FHS not being widely adopted by the private industrial forestry sector in Australia. The first is that the plantation estate, and in particular the eucalypt plantation estate, is immature, with an age-class distribution strongly skewed towards young ages (Wardlaw *et al.* 2007a). During the first few years of a plantation crop many routine operational visits are made to the young stands, making it difficult to persuade owners that FHS is necessary to detect health problems. This situation is transitory, however: as the age-class distribution of the plantation estate becomes more uniform, the proportion of the estate inspected frequently as part of routine operations is expected to decline, increasing the strength of arguments for FHS.

The second explanation is that the benefits arising from FHS have not been well articulated and quantified. Initial justification for commencing FHS of plantations in Australia was strongly driven by biosecurity concerns (Wardlaw 2008). However, we are accumulating evidence that FHS in plantations is unlikely to detect new incursions at a sufficiently early stage for eradication to be feasible (Wardlaw *et al.* 2008). It is likely, therefore, that surveillance for forest biosecurity (detecting new incursions of exotic species) will become increasingly focussed towards hazard sites in and around port and devanning facilities in predominantly urban areas (Wylie *et al.* 2008). The justification for FHS in plantations and other forest areas will, accordingly, depend on benefits in the management of established pests and diseases. The following account details how FHS has been integrated with Forestry Tasmania's operational activities, and provides examples of the outcomes of this integration.

Integration of forest health surveillance with forest management

FHS, together with pest-specific management programs, underpins Forestry Tasmania’s approach to maintaining high-value forest assets in a state of health and vigour that meets management objectives¹. Pest-specific management programs have been developed for those pests that regularly attain populations that would cause unacceptable damage in the absence of control measures. Currently, pest-specific management programs are used operationally to manage chrysomelid leaf beetles (*Paropsisterna bimaculata* and, to a lesser extent, *P. agricola*) and browsing mammals, particularly brushtail possums (*Trichosurus vulpecula*), Tasmanian pademelons (*Thilogale billardierii*) and Bennett’s wallabies (*Macropus rufogriseus*). Both of these pest-specific management programs have been developed according to the principles of integrated pest management (IPM). The chrysomelid leaf beetle IPM (Elliott *et al.* 1992) is well established, although refinement is continuing to meet operational needs and corporate objectives of reducing chemical use. The browsing mammal IPM, on the other hand, is in its infancy following the cessation of using 1080 on state forests (from December 2005) and is evolving towards the goal of risk-based integrated management.

FHS complements pest-specific management by informing management of pest and disease problems that are new (established species that are emerging as pests or new introduction of exotic pest species) or of established pests or pathogens that reach damaging levels only periodically. FHS is ideally suited to the unpredictability of these uncommon pest and disease problems because it can regularly inspect an entire estate relatively cheaply and, with an acceptable level of confidence, detect problems at

operationally-relevant damage levels (Wardlaw *et al.* 2008). Once FHS detects a potential problem, decisions can be made on the need for management to limit losses. Figure 1 shows how FHS fits within the overall structure of Forestry Tasmania’s operational health management. The detection, and any assessments arising from the detection, are the unique aspects that FHS provides to operational health management. The resultant management component (monitoring and control) parallels pest-specific management programs.

Initially, this structure for FHS was adopted for plantations where the objectives were to meet economic benchmarks and maximise the area managed for solid-wood products. Increasingly, though, this model is being extended to protect other high-value assets, including conservation assets where protecting biodiversity values has primacy (e.g. wildlife habitat strips, areas containing plant species or communities susceptible to *Phytophthora cinnamomi*).

As well as delivering health management, these elements also form the basis of Forestry Tasmania’s approach to addressing Criterion 5 (Maintaining Ecosystem Health and Vitality) of the Australian Forestry Standard as required for ongoing certification against this standard. Sustainable, multiple-use management of publicly-owned forests has become very complex and tightly regulated in Australia, as elsewhere in the developed world. Moreover, the delivery of that management is under increasing scrutiny. In this environment, management needs to be scientifically valid and decisions need to be evidence-based and transparent. As a result of these factors, FHS in Tasmania has developed very clear objectives, and its methods, processes and outcomes have been thoroughly scrutinised and documented, particularly through independent third-party audits required for certification against the Australian Forestry Standard (AS4708) and the ISO 14001 Environmental Management System.

¹Forestry Tasmania (2008) Ten-year Forest Management Plan: 2008–2018 (in preparation). Forestry Tasmania, Hobart.

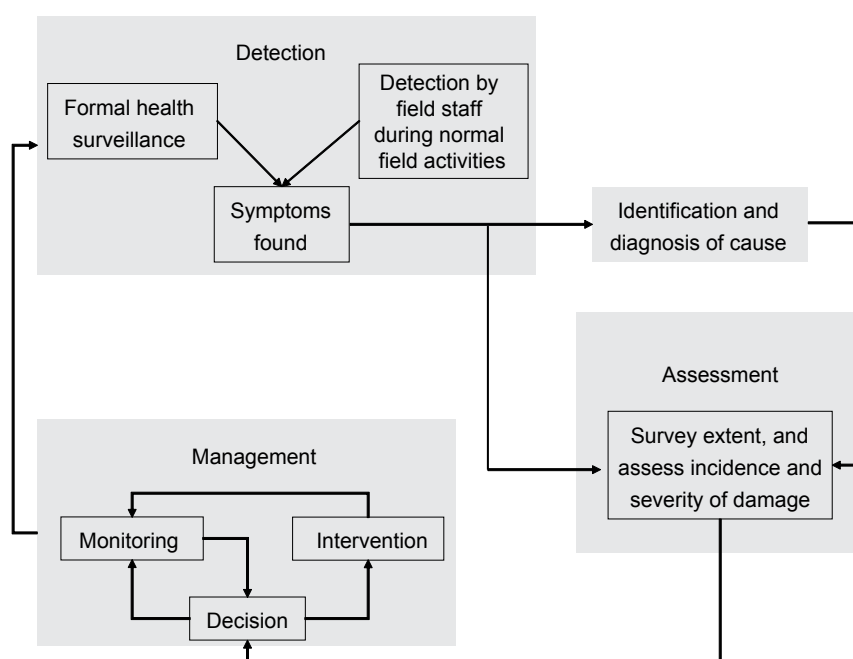


Figure 1. The model of forest health management adopted by Forestry Tasmania showing flow of actions, information and decisions

Outcomes of forest health surveillance

Once a detected problem is rated as significant, a decision needs to be made about whether or not there are opportunities to invoke management actions that will reduce adverse impacts resulting from that problem. This is relatively straightforward for those problems for which there are well-established management protocols, such as *Sirex* wood wasp (Carnegie *et al.* 2005), nutrient deficiencies (Adams *et al.* 2007), exotic invasive weeds (Forestry Tasmania 1999, 2000) and defoliating insects such as autumn gum moth (Elek *et al.* 2003). For such problems, direct management responses can be implemented operationally on a case-by-case basis upon detection. For many problems, however, direct management responses delivered on a case-by-case basis are not appropriate. This is particularly so for problems that are best managed by modifying silvicultural regimes or by breeding to select resistant genotypes. For these problems, management is usually delivered across the whole estate or that portion of the estate at risk from a particular problem. A further subset are those problems for which management actions have not been developed (common for emerging pest problems) or if developed, are not sufficiently effective to prevent significant damage. For such problems, additional research is required to refine or develop methods for their management.

1. Strategic management

Strategic management involves decisions that are made at a high level (organisation-wide, estate-wide) and typically result in changed practices or regimes to address significant pest and disease issues. Some examples of strategic management responses flowing from FHS are:

Developing research priorities to address new or under-managed health issues

Priorities for research are developed at the organisational level and also the national level. The latter is particularly relevant with regards to formulating funding priorities by national Research and Development Corporations. FHS provides an annual ranking of detected health problems based on an objective assessment of their extent and severity (Table 1).

Evidence accumulated over successive years highlights emerging pest and disease problems or established problems for which existing management is providing sub-optimal results. An example of the latter is the IPM for chrysomelid leaf beetles. FHS has accumulated evidence that the IPM, which targets early-season damage by the larval stage, provides insufficient protection against damage from late-season feeding by adult beetles emerging after pupation (Table 2). The adult beetles are highly mobile and are able to fly into plantations from adjoining forest areas, regardless of whether or not the plantations were protected from larval feeding earlier in the season. Research has shown that defoliation late in the growth season causes a more pronounced growth impact than does early-season larval defoliation (Candy 1999), so the consequence of sub-optimally managed late-season adult feeding is potentially serious.

Stemming from the discovery that the leaf beetle IPM is providing sub-optimal control of late-season adult feeding, a research program within the CRC for Forestry (www.crcforestry.com.au Project 4.2.9) to evaluate lethal trap trees as a management option has been developed. The aim of this research is to provide proof-of-concept that rendering lethal (with systemic insecticide)

Table 1. Health problems detected in *Eucalyptus* plantations on Tasmanian state forests in 2005–2006, ranked by damage levels

Cause	Moderate ^A damage (ha)	Severe ^A damage (ha)	Total (ha)
Soil problems	464	711	1175
Multiple causes	424	564	988
Autumn gum moth	538		538
Mammal browsing	41	406	446
<i>Phytophthora cinnamomi</i>	278	35	313
Chrysomelids	262	10	272
Weeds	91	96	187

^ABased on definitions used by Research Working Group 7 (Forest Health) for national reporting

Table 2. Summary of the annual chrysomelid leaf beetle IPM program on Tasmanian state forest for the three seasons 2003–2004 to 2005–2006. Numbers in parentheses are areas as a percentage of total area that was monitored.

Spatial extent	2003–2004	2004–2005	2005–2006
Area monitored for leaf beetles (ha)	13 137	13 698	16 948
Area that was over threshold ^A (ha)	2 612 (20)	5 533 (41)	5 723 (43)
Area over threshold that was sprayed (ha)	955 (7)	3 472 (25)	3 589 (21)
Area suffering moderate or severe ^B leaf beetle defoliation (ha)	1 093	404	272

^AMonitored populations of leaf beetle eggs and larvae that exceed economic injury levels

^BBased on definitions used by Research Working Group 7 (Forest Health) for national reporting

a small number of trees (about 1% of the total plantation) of a species that is attractive to leaf beetles can reduce populations of feeding adult beetles sufficiently to protect the surrounding crop trees from significant defoliation.

Identifying risk factors associated with susceptibility of *Eucalyptus nitens* to *Holocryphia eucalypti*

The chance discovery of an epidemic of the stem canker pathogen *Holocryphia eucalypti* (syn. *Endothia gyrosa*) in a mid-rotation *E. nitens* plantation during an ad hoc visit by the author was a pivotal event leading to the introduction of FHS in Tasmania. The epidemic, which had resulted in a high incidence of severe wounds as well as the death of a small number of pruned trees within an inventory plot, had gone unnoticed by forestry staff during routine mensurational visits. This highlighted the importance of having personnel experienced in the recognition of health problems undertaking regular visits to plantations specifically to find developing problems.

Further investigation following the detection of the stem canker epidemic resulted in the discovery that trees with thick, rough bark had a significantly higher level of canker infection than trees with thinner, smooth bark (Wardlaw 1999). The rough bark characteristic was linked to families originating from southern NSW provenances of *E. nitens*. This knowledge has informed decisions to delete families of southern NSW provenances of *E. nitens* from breeding populations.

2. Tactical management

Tactical management offers the opportunity to use information provided by FHS to determine how and where particular management prescriptions and regimes are implemented operationally. Two examples of tactical management responses arising from FHS are:

Deploying resistant genotypes and silvicultural regimes for managing spring needle cast

Spring needle cast (SNC) is a mid- to late-rotation disease of *Pinus radiata* that results in the premature casting of needles at the end of their first year (Podger and Wardlaw 1990a). The disease is prevalent in plantations growing on high, wet sites in Tasmania, and affected stands suffer reductions in growth that are comparable with those caused by other major needle-cast diseases such as *Dothistroma* needle blight (Podger and Wardlaw

1990b). Management to reduce disease losses can be achieved either silviculturally or through the use of more resistant genotypes. Silviculturally, the aim of management is to reduce the impact of SNC in trees that are retained after thinning to grow-on to produce sawlogs. Two silvicultural regimes can achieve this aim:

- Early thinning (prior to canopy closure) in pruned stands ('clear-wood regime with waste thinning') to delay the onset of SNC (Podger and Wardlaw 1990b), or
- Mid-rotation thinning in unpruned stands ('knot-control regime') in which final crop trees are selected from among those not affected by SNC.

SNC is moderately heritable ($h^2 = 0.37$) and good genetic gains in resistance to SNC are likely to be achieved through the use of an SNC deployment population (Kube and Wardlaw 2002a).

FHS has provided a basis for the deployment of these silvicultural regimes and SNC-resistant genotypes. State-wide assessments of SNC done during FHS in 1997–1998 (Wotherspoon and Wardlaw 1998) allowed the plantation estate to be classified (Table 3) and mapped according to the severity of SNC (Fig. 2). The deployment of the two silvicultural regimes together with SNC-resistant genotypes on sites classified as moderate or high SNC-hazard were calculated to recapture 90% of the estimated 4.4% of the internal rate of return that would have been lost to SNC on high-risk sites using routine management (Kube and Wardlaw 2002b).

Modifying control thresholds for stands at risk of an elevated threat from leaf beetle defoliation

Defoliation by above-threshold populations of the leaf beetle *P. bimaculata* causes significant growth impacts, which are magnified if repeated over consecutive seasons (Candy 1999). Similarly, over-pruning crop trees (removal of >50% of the green crown height) causes significant reductions in growth (Pinkard and Beadle 1998) and may render them vulnerable to sustained growth reductions if they then suffer leaf beetle defoliation in the following season.

One focus of routine FHS of eucalypt plantations during late summer and autumn is to identify plantations that have suffered severe defoliation by leaf beetles (>50% crown loss) and plantations with a high proportion of over-pruned trees (typically these have high inter-tree variability in growth). Once identified, affected plantations are given a higher priority for management to limit defoliation from leaf beetles in the following season. Typically this involves assigning a lower

Table 3. SNC hazard ratings of *P. radiata* stands in Tasmania based on defoliation assessments done during FHS (from Kube and Wardlaw 2002b)

SNC hazard class ^A	Fraction of trees with indicated level of defoliation				Average stand defoliation (% of crown)
	<25%	25–49%	50–90%	>90%	
No infection	100	0	0	0	0
Low infection	75	14	10	1	23
Medium infection	47	23	26	4	36
High infection	24	23	40	13	52

^AHazard class based on predicted stand level growth impact — a function of the proportion of the stand in each of the four defoliation classes

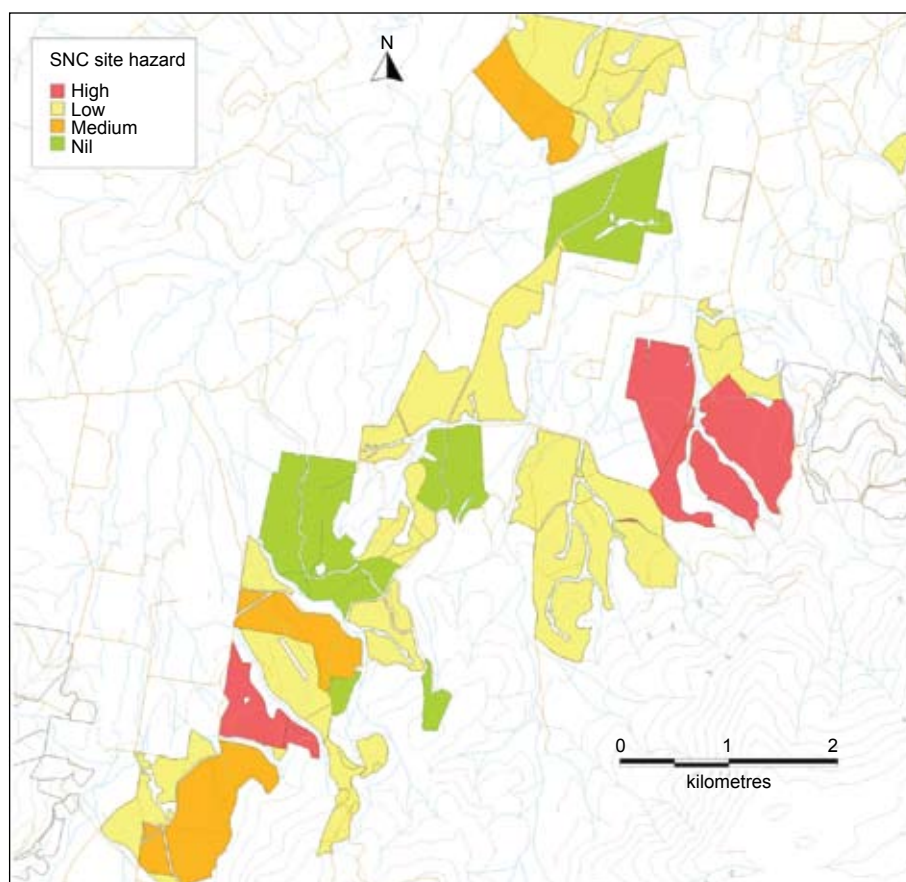


Figure 2. Mapped hazard rating of spring needle cast (as detailed in Table 3) in radiata pine plantations in Springfield Block, north-eastern Tasmania



Figure 3. A stem gall detected on a 3-y-old *Pinus radiata* tree in north-eastern Tasmania in 1999

action threshold for monitored populations of leaf beetle eggs and larvae to trigger spray operations. It usually also involves elevating the operational priority of monitoring leaf beetle populations and of spraying operations, which is particularly important when resources are limited (e.g. during fire-fighting campaigns).

3. Operational management

Operational management occurs at the coupe level and involves decisions to conduct operations to manage particular pest or disease problems that are detected during FHS. Three examples of operational responses to problems detected by FHS are:

Stem galls on *Pinus radiata*

In July 1999 stem galls (Fig. 3) were detected on a 3-y-old *P. radiata* in a plantation in north-eastern Tasmania during routine FHS. This raised immediate concerns because a very small number of pests or diseases cause stem galls on *P. radiata*, and one of them is western gall rust (WGR) caused by the pathogen *Endocronatrium harknessii*. This pathogen, known only from North America, is one of the most serious threats to *P. radiata* in Australasia and is nationally listed as a pathogen of quarantine significance (Mireku and Roach 2000).

The obvious and immediate response to the detection was to treat it as a possible incursion of WGR and follow protocols set down in the Generic Incursion Management Plan for Forest Pests and Diseases (Forest Health Committee 2000). Relevant state and federal officials were notified and a response plan was formulated. The most obvious and pressing task was to confirm whether or not the gall found in Tasmania was WGR. Interim advice was sought from colleagues in Australia and New Zealand who were familiar with the disease. Using only gross morphological characteristics, none were able to exclude WGR as a potential cause for the Tasmanian galls. Ultimately a PCR test, developed by Dr Detlev Vogler (USDA) specifically for this diagnosis showed there was no rust DNA in the Tasmanian galls and the quarantine emergency was discontinued.

While the quarantine emergency was averted, the detection supported the premise that routine FHS plays a valuable role in biosecurity by providing capability for the early detection of exotic pest and pathogen incursions in plantations. Subsequent research, however, has not supported this premise (Wardlaw *et al.* 2008) with the result that capability for the early detection of new incursions is now primarily focussed towards surveillance of hazard sites such as ports and container devanning facilities.

Coincidentally, the detection occurred during the final stages of negotiations for the partial sale of Forestry Tasmania's *P. radiata*

plantation estate. While this resulted in hasty redrafting of purchase contracts in the event the detection proved to be WGR, it also provided some comfort to the potential investors that, in FHS, an effective system was in place to manage biotic risks.

***Sirex* wood wasp**

The aerial inspection component of FHS is able to detect recent mortality at very low incidences (one tree in a thousand) (Wardlaw *et al.* 2008). At this level of resolution, FHS provides an effective early warning of developing outbreaks of the *Sirex* wood wasp. This is particularly valuable when *Sirex* populations have been at low levels for extended periods. Under these circumstances, monitoring using trap trees or static traps (as described by Bashford 2008) is costly and inefficient because, beyond knowledge of sites with a prior history of *Sirex*, there is little intelligence that can be used to deploy monitoring. Sites without a prior history of *Sirex* damage would probably be overlooked.

In 2002–2003, FHS detected the initial stages of *Sirex* outbreaks in several plantations in north-eastern Tasmania. None had a prior history of *Sirex*. Trap tree monitoring immediately began and nematodes were introduced the following year. No subsequent *Sirex* activity has been detected in the treated compartments and populations have since remained low.

Autumn gum moth outbreaks

Autumn is the preferred time for FHS of eucalypt plantations in Tasmania, because the major defoliating insects (managed operationally using an integrated pest management program) are at the end of their season and any damage resulting from sub-optimal management has stabilised. An exception is autumn gum moth (AGM), which is actively feeding during the autumn–early winter months. While outbreaks of AGM are infrequent in Tasmania, the damage they cause can have particularly severe consequences including mortality of heavily defoliated trees. Routine autumn FHS detected a developing AGM outbreak in 526 ha of predominantly 1-y-old *E. nitens* plantations in north-eastern Tasmania (Wotherspoon *et al.* 2006). Assessments done in response to the detection found a moderate to high incidence of trees (30–80%) on which AGM was present, but damage was still relatively low because caterpillars were mostly in early instars. The detection prompted a decision to spray the entire affected area of plantation, potentially averting severe damage with long-lasting growth impacts.

Conclusions

In the ten years since its inception in Tasmania, FHS has delivered substantial benefits in terms of better management of pest and disease problems. While the primary function of FHS has been to detect and then assess health problems, its value is dependent upon a preparedness to use the information it provides pro-actively in achieving better health management. Remedial or control operations initiated directly in response to detected problems are an important outcome of FHS. However, the real value of FHS is achieved when the information it provides is also used to influence strategic or tactical management, because then the future benefit is built in to normal operations applied across the whole estate or strata within that estate.

The purpose of this paper was to describe the diversity of outcomes for health management that has resulted from information gained from FHS. While this is an important starting point for encouraging wider adoption of FHS, particularly among the private plantation sector, the challenge now is to quantify those benefits in economic terms. Only then will plantation managers be able to balance the cost of adopting FHS against the benefits delivered by FHS.

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