Thinning Demonstration of Dwarf Mistletoe-infected Lodgepole Pine Stands in Eastern Idaho: 1983 to 2003 Permanent Plot Results

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Introduction

Dwarf mistletoes are parasitic plants that infect most western conifer species. As true parasites, they extract water and nutrients from the host trees. The effects on the trees include reduced vigor, decreased diameter and height growth, reduction in cone and seed crops, and often mortality (Hawksworth and Johnson 1989).

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. Ex Engelm.), was found infecting 79 percent of all surveyed lodgepole pine stands on the Targhee National Forest during a 1978 forest-wide disease survey (Hoffman and Hobbs 1978). The dwarf mistletoe problem, however, was greatly overshadowed by a mountain pine beetle epidemic (*Dendroctonus ponderosae* Hopkins) that killed most lodgepole pine trees greater than 8 inches in diameter at breast height (d.b.h.), during the period from 1962 to 1979 (Anonymous, 1979). Consequently, after operating a salvage-timber management program for nearly 20 years, managers were faced with trying to replant and/or restore tens of thousands of acres of lodgepole pine stands that were most likely infected with the dwarf mistletoe parasite.

While much is known about the biology of dwarf mistletoes, little quantitative data was available about the long-term growth response of infected lodgepole pine stands to various thinning regimes, outside of Colorado and Wyoming. In these areas, it was demonstrated (Alexander, 1975) that the effects of dwarf mistletoe parasitism are usually greater on poor sites. Managers in eastern Idaho felt their commercial stands of managed lodgepole pine are more productive, and hence, the significance of dwarf mistletoe-induced growth loss demonstrated for the Rocky Mountains may have been overstated for Idaho forests.

Consequently, a 20-year thinning demonstration was established on the Targhee NF in 1983 to provide land managers with cutting guidelines that relate silvicultural spacing requirements to dwarf mistletoe incidence and intensity information. This long-term study had four specific objectives.

1. Determine the effects of pre-commercial thinning on growth of dwarf mistletoe-infected lodgepole pine stands in eastern Idaho.

2. Determine the effects of dwarf mistletoe parasitism on growth and mortality in these stands.

3. Determine the changes in dwarf mistletoe incidence and intensity over time as a result of the silvicultural thinning.

4. Provide data for the validation of dwarf mistletoe models.

Methods

Study Area. The demonstration thinning plots were located in the Coffee Pot area of the Island Park Ranger District in the Targhee NF in eastern Idaho during the summer of 1983 (Figure 1). The area is about 18 miles southwest of West Yellowstone, Montana, in a dormant volcanic caldera that is relatively flat. The regolith is composed of basalt covered with wind-deposited soil. The habitat type is Douglas-fir/pinegrass (*Pseudotsuga douglasii* / *Calamogrostis repens*), but seral lodgepole are often persistent because of frequent bark beetle, logging, and/or fire events. Nearly 6 square miles of lodgepole pine stands in the Coffee Pot area were mostly clearcut in the mid-1950s. Then the whole area was machine-planted with lodgepole pines from 1955 to 1958. A few scattered dwarf mistletoe-infected overstory trees (less than 10 to 15 trees/acre), were retained within the area to provide a forested appearance. These few dispersed trees infected the newly planted lodgepole seedlings. By the time plots were established in 1983, 58 percent of the 28- to 30-year-old planted trees were infected with the plant parasite.

Sample Design and Treatments. Sixteen permanent, 100-tree plots were established, with four replications of four spacing levels. Treatment selection was from a randomized pick of one of the four "treatment" cards out of a hat. The spacing levels are as follows.

1. Eight feet by 8 feet (681 trees/acre),
2. Eleven feet by 11 feet (360 trees/acre),
3. Fourteen feet by 14 feet (222 trees/acre), and
4. Control plots, (average of 950 trees/acre, and not thinned).

Plot size was variable, being dependent upon the ultimate goal of getting 100 trees in a replication treatment. A one-half chain buffer strip was included on the perimeter of each treatment and thinned to the same spacing level.

Plot Establishment. Plot establishment and silvicultural treatments were done from June to September 1983. All plots were located within 2.5-miles of each other to minimize variations of stand and site conditions. Each plot was permanently marked with metal fence posts on the corners, with signs indicating the plot purpose and thinning regime utilized. Following thinning and slash disposal, the remaining trees were marked with a permanently numbered metal tag, fastened to each tree with an aluminum nail at breast height. Data recorded for each tagged tree included:

1. DBH (to nearest 0.1 inch); height (to nearest foot);
2. Hawksworth dwarf mistletoe rating (DMR) (Hawksworth 1977);
3. Crown ratio; and
4. Height of the highest dwarf mistletoe infection within each tree.

Posttreatment Data Collection. In addition to the 1983 establishment and initial data collection, subsequent plot data measurements were taken in 1988, 1993, 1998, and 2003, often by the same field crews. Routine maintenance, such as pulling the nails further out to prevent overgrowth of the tags, was also accomplished during the subsequent readings.

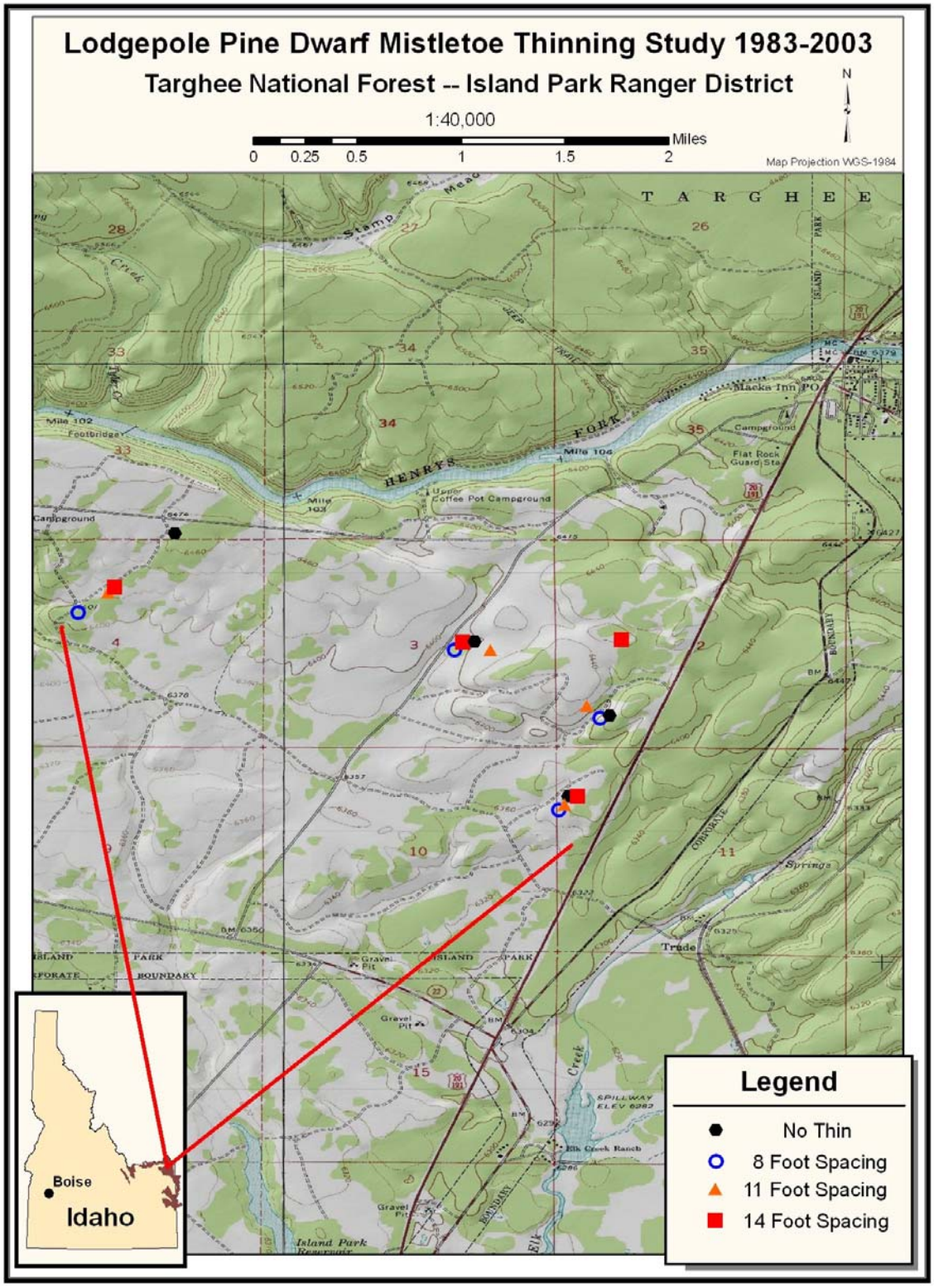

Figure 1. Location map of dwarf mistletoe permanent plots in Island Park, Idaho.

Data Analyses. All data summaries and statistical analyses were performed using the statistical program SPSS, version 9.0.1 for Windows (SPSS, 1999). ANOVA was used to test for differences in the means of variables of interest between plot treatments, and when differences were found, the test of least significant difference (LSD) was used to identify which treatments were significantly different from each other.

Results and Discussion

In 1983, 1,601 trees were tagged and measured during plot establishment. By 1988, 1,498-trees were still alive. Ninety-six trees were killed during a heavy snowfall and wind event that struck the area in the spring of 1984. By 2003, 1,375 live tagged trees remained on the plots. No attempt was made to clean up or dispose of the windthrown, stem-snapped, or otherwise dead and standing trees or those that fell into the plots. None of the dead trees that remained onsite in 2003 were determined to have been killed by dwarf mistletoe parasitism. Hawksworth and Hinds (1964) found less than 5 percent of basal area mortality in stands infested for 40 years. This is about the same age of infection as the Targhee plots. In 1999, 27 tagged trees, mostly from one replication, were cut by a forest thinning crew that wandered into the plots. Excluding these trees, the 20-year mortality rate was 12.5 percent, with windthrow/snow damage being the main cause of the majority of tree death.

Dwarf Mistletoe Spread and Intensification 1983-2003. A comparison of infection data between 1983 and 2003 showed that both incidence and severity (intensification of DMR rating) of dwarf mistletoe infection increased in the 20-year period (Table 1). Based on the unweighted means, the percentage of total trees infected increased from 57.4 to 73.2 percent. In 2003, the percentage of trees infected was significantly greater ($p=0.005$) on all of the thinned plots when compared to the no-thin control. The greatest percentage of infection increase was on the plots receiving the 8-by-8 and 14-by-14 treatment (Table 2). However, when the change in percent trees infected between 1983 and 2003 was analyzed by treatment, the no-thin plots showed a significantly greater increase in the dwarf mistletoe infection rate than all of the other thinning treatments ($p=0.005$). Unthinned plots contain trees proximally closer to each other allowing more rapid lateral expansion of new dwarf mistletoe infections through the stand.

The DMR is the mean dwarf mistletoe rating of all trees in each 100-tree plot; infected and uninfected trees. The average DMR of all trees in all plots increased from 1.27 in 1983 to 2.60 in 2003 (Table 1). Another measure often used in dwarf mistletoe analysis is the dwarf mistletoe index (DMI), which is the average dwarf mistletoe rating of only infected trees in a plot or stand (Geils and Mathiasen, 1990). The average DMI of all plots increased from 2.18 to 2.89 in the 20-year interval (Table 1).

The increase in average DMI was not significantly different ($p=0.005$) between each of the thinning treatments (Table 1). The average DMI decreased slightly on the control plots in the 20-year period. In 2003, the average DMR and average DMI were significantly higher ($p=0.005$) on the plots receiving the 8-by-8 thinning treatment. The increase in average DMR was also significantly greater ($p=0.005$) on plots receiving the

8-by-8 and 14-by-14 thinning treatments. One main factor explains these significant increases in the 8-by-8 plots. The average height of the highest dwarf mistletoe infection in these plots was 34 percent greater than the average highest infection rates in the other treatments. Likely, there was a cluster of infected overstory trees left near one or two of the 8-by-8-plots following the 1950's harvest, which died from windthrow or bark beetles prior to plot establishment.

The average height to the highest dwarf mistletoe infection increased from 14.79 feet in 1983 to 26.85 feet in 2003 (Table 1). This equates to an average annual rate of vertical increase of dwarf mistletoe infection of 0.6 feet/year or 3.0 feet per 5 years at a period when the average age of the trees changed from 27 to 47 years old. The greatest change in the height to the highest infection occurred on both the no-thin plots (13.62 feet) and those receiving the 11-by-11 (13.44 feet) thinning treatments. The greatest change in the average net gain of tree height growth also occurred with the no-thin (17.71 feet) and 11-by-11 (17.03 feet) spaced plots (Table 2).

When infection data were broken down by the number of trees in each DMR class (Table 1), there was a notable increase in the number of trees in the more severe DMR classes from 1983 to 2003. The number of trees in class 5 increased nearly fourfold, and the number of trees in class 6 increased nearly tenfold. The number of trees in DMR classes 1 and 2 actually decreased, presumably as the infection level in these trees intensified and the tree was put into a higher severity class. In 2003, plots that received any thinning treatment had a higher number of trees in classes 5 and 6 when compared to the no-thin control plots.

Tree Growth 1983-2003. A comparison of average tree height and diameter between 1983 and 2003 indicates the trees grew an average of 15.49 feet in height and 2.62 inches in diameter in the 20-year period (Table 3). Independent-samples t tests were used to analyze growth differences between infected trees and uninfected trees (SPSS, 1999). The average height growth for uninfected trees was 19.75 feet and was significantly greater (27.2 percent more) than the average height growth of 14.36 feet for infected trees.

In a comparative study of the effects of dwarf mistletoe on lodgepole pine height growth in northern Idaho and eastern Washington, Weir (1916) found a net reduction of 27 percent in the height growth of dwarf mistletoe-infected stands. Hawksworth and Johnson, (1989) also reported that dwarf mistletoe (*A. americanum)* parasitism had a significant effect on height growth of infected lodgepole pine but a statistically insignificant effect on stem diameter growth reduction. Others agree that lodgepole pine dwarf mistletoe infections result in the least amount of diameter growth reduction of any conifer host-dwarf mistletoe-parasite combination (Hawksworth, Weins, Geils, and Nisley, 1994).

The average height growth (17.71 feet and 17.03) of the control plots and the plots receiving the 11-by-11 thinning treatment, was statistically similar over the 20-year period (Table 3). The height growth was significantly less (p=0.005) for the 8-by-8 and

the 14-by-14 thinning treatments. Tree diameter growth was significantly higher (p=0.005) on all of the thinned plots when compared to the control plots (Table 2). The greatest diameter growth occurred on the 11-by-11 and the 14-by-14 thinning treatments, 3.02 inches and 3.33 inches, respectively.

Recommendations

While National Forest System management objectives may have changed during the 20 years of this study, we can still answer the original four objectives.

1. **Determine the effects of precommercial thinning on growth of dwarf mistletoe-infected lodgepole pine in eastern Idaho.**

Previous growth loss reconstruction studies (Hawksworth and Hinds, 1964 and Baranyay and Safranyik, 1970) in 50- to 150-year-old lodgepole stands found a 35 percent diameter growth loss in the first 70 years of tree life. However, these were naturally seeded unmanaged stands. In this study of managed lodgepole pine stands, the trees were manually planted and various spacing regimes were established at age 27. Twenty years after thinning, dwarf mistletoe parasitism resulted in an average d.b.h. growth loss of slightly more than 0.01 inch/year for all treatments. Therefore, diameter growth loss, up to age 50, caused by *A. americanum* is negligible.

The parasitic effects of lodgepole pine dwarf mistletoe on lodgepole height growth are more pronounced and demonstrable. The average height growth for uninfected trees was 19.75 feet, significantly greater (27.2 percent more) than the average height growth of 14.36 feet for infected trees. This disparity will likely widen even greater in the next two decades as the DMR increases in class 5 and 6 trees. Again, few long-term studies of managed stands are available to indicate when to harvest an infected stand to maximize timber volume. The 11-by-11-foot spacing had the best combination of height and diameter growth. Harvesting by age 80 should both minimize the effects of dwarf mistletoes and eliminate the risk of mountain pine beetle attacks (Alexander, et al., 1983).

2. **Determine the effects dwarf mistletoe parasitism on growth and mortality in these stands.**

In this forest, dwarf mistletoe-infected lodgepole pine was widespread (79 percent infection rate, Hoffman and Hobbs, 1978) making comparison to an uninfected stand in proximity to the studied stands almost impossible. Therefore, from this survey data set, comparison of consequences of dwarf mistletoe parasitism only works to describe differences between the four thinning regimes and not to any uninfected controls.

Even though 14 percent of the trees died (or were accidentally felled), dwarf mistletoes were not thought to be the primary cause of tree death. From other studies (Hawksworth and Johnson, 1989), 90 percent of dwarf mistletoe-caused mortality occurs <u>after</u> a stand age of 70 to 80 years old. So dwarf mistletoe-caused mortality is not likely to occur for about 15 years. If timber volume production is the primary objective of stand

management in the Coffee Pot area, then an overstory harvest around 80 years of age should reduce the impacts of both dwarf mistletoe spread and intensification, and eventual mountain pine beetle attacks.

3. **Determine the changes in dwarf mistletoe incidence and intensity over time as a result of the silvicultural thinning.**

The overall rate of dwarf mistletoe incidence increased from 57.4 percent of all infected living trees in 1983 to 88.7 percent of all living trees infected in 2003. By the numbers, the incidence of the parasite increased from 919 infected trees in 1983 (out of 1,601 total), to 1,220 infected trees (out of 1,375), 20 years later. DMR of the initial plot trees increased from 1.27 in 1983, to 2.60 20 years later.

The DMI (dwarf mistletoe index) which is the average dwarf mistletoe rating of only infected trees is also useful to describe dwarf mistletoe infection intensity within a stand. The DMI rating increased slightly from 2.18 in 1983 to 2.89 in 2003. Lateral spread of mistletoes from infected to noninfected trees results in infections that tend to be in the lower crown area of new host tree giving it a DMR of 1 or 2. This reduces DMI resulting in an almost static condition until nearly all trees within the stand are infected. At that time, the newly infected trees, and the DMR ratings of previous infected trees, will force the DMI to escalate rapidly. This could occur when the lodgepole pine stands exceed 80 years of age (Alexander, et al., 1983).

4. **Provide data for the validation of dwarf mistletoe models.**

The survey data collected from this study have been utilized several times during updates of the Forest Vegetation Simulator to provide more accurate, well-documented estimates of stand growth and yields for decisionmakers. In addition to being a source of volume data, the plots were also designed to be demonstration areas of various thinning regimes and will have value to managers, planners, and functional specialists in the future as evolving displays of forest practices that can be observed, debated, and discussed. Also, the largest trees within the plots are just approaching the minimum diameter for susceptibility to mountain pine beetle attack (Ammon, et al., 1977). As the plots are both well-documented and monumented, they can be a future source of study of the impact of stand density management on future mountain pine beetle outbreaks.

Table 1. Percent trees infected, average dwarf mistletoe rating (DMR), average DMR of infected trees (DMI), average height of the highest dwarf mistletoe infection (DM Hgt.) and number of trees in each DMR class by year within each treatment.

Treatment	**Percent Infected**	**Average DMR**	**Average DMI**	**Average DM Hgt.**	**Number of Infected Trees by DMR Class**					
					1	2	3	4	5	6
No Thin										
1983	43.6	0.92	2.11	12.78	63	58	32	15	7	0
1988	50.5	0.99	1.96	13.63	96	40	39	13	8	0
1993	52.8	1.30	2.46	16.11	60	42	52	31	11	1
1998	66.0	1.58	2.39	21.72	70	62	54	31	12	2
2003	79.0	1.56	1.98	26.40	111	71	38	18	9	1
change 1983-2003	35.4	0.64	-0.13	13.62	48	13	6	3	2	1
8 X 8										
1983	64.9	1.73	2.67	18.23	71	61	46	46	34	1
1988	75.2	1.98	2.63	18.55	68	67	68	49	21	3
1993	77.4	2.60	3.37	20.61	36	41	71	59	59	13
1998	89.5	3.10	3.47	24.97	42	51	58	75	67	24
2003	95.6	3.41	3.57	29.56	50	43	58	49	94	30
change 1983-2003	30.7	1.68	0.90	11.33	-21	-18	12	3	60	29
11 X 11										
1983	58.0	1.08	1.86	13.24	117	55	35	14	5	2
1988	52.7	1.28	2.42	19.98	67	43	38	30	17	0
1993	62.1	1.49	2.39	17.15	72	61	47	29	19	0
1998	75.4	2.06	2.74	23.00	62	71	57	43	35	4
2003	85.0	2.42	2.85	26.68	62	63	86	54	39	3
change 1983-2003	27.0	1.34	0.99	13.44	-55	12	51	40	34	1
14 X 14										
1983	65.7	1.36	2.07	14.90	112	66	43	22	12	2
1988	64.1	1.63	2.55	16.76	63	65	44	40	21	1
1993	71.5	2.04	2.86	17.83	51	70	48	47	41	2
1998	83.9	2.62	3.12	21.70	57	53	69	55	58	11
2003	95.3	3.01	3.16	24.74	66	57	73	61	70	14
change 1983-2003	29.6	1.65	1.09	9.80	-46	-9	30	39	58	12
Total Means										
1983	58.1	1.27	2.18	14.79						
2003	68.0	2.60	2.89	26.85						
Totals										
1983					363	240	156	97	58	5
2003					289	234	255	182	212	48

Table 2. Average tree height and average d.b.h., by year within each treatment.

Treatment	Average Tree Height (feet)	Average DBH (inches)
No Thin		
1983	22.36	3.26
1988	26.87	3.75
1993	30.44	4.16
1998	35.80	4.57
2003	40.07	5.05
change 1983-2003	17.71	1.79
8 X 8		
1983	26.83	3.54
1988	30.14	4.27
1993	32.81	4.81
1998	37.56	5.25
2003	40.71	5.69
change 1983-2003	13.88	2.15
11 X 11		
1983	25.27	3.65
1988	29.88	4.76
1993	32.79	5.53
1998	38.58	6.18
2003	42.30	6.67
change 1983-2003	17.03	3.02
14 X 14		
1983	24.88	3.64
1988	28.08	4.74
1993	29.84	5.62
1998	35.08	6.39
2003	38.23	6.97
change 1983-2003	13.35	3.33
Total Means		
1983	24.84	3.52
2003	40.33	6.10

Table 3. Average height and diameter (d.b.h.) of all trees, infected trees and uninfected from 1983-2003.

Year	Avg. Hgt. (ft) all trees	Avg. Hgt. (ft) uninfected	Avg. Hgt. (ft) infected	Avg. DBH (in.) all trees	Avg. DBH (in.) uninfected	Avg. DBH (in.) infected
1983	24.84	23.15	26.04	3.51	3.39	3.60
1988	28.73	28.65	28.78	4.37	4.40	4.35
1993	31.47	32.13	31.12	5.03	5.02	5.03
1998	36.76	37.92	36.45	5.61	5.58	5.62
2003	40.33	42.70	40.40	6.13	6.15	6.13
Growth 1983-2003	15.49	19.55	14.36	2.62	2.76	2.53

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