Effects of Salinity Manipulation on the Parasite, *Dermo* (*Perkinsus marinus*), and Water Quality

Tisbury Great Pond, Chilmark and West Tisbury
2001

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Project Scope: The proposal was to assess the feasibility of suppressing the oyster disease, *dermo (Perkinsus marinus)*, by reducing the salinity in the Pond during the growing season and, at the same time, to evaluate the effects of this management process on water quality in the system. The program consisted of placing caged, cultured and wild oysters into both Tisbury Great and Edgartown Great Ponds, which were regularly sampled for determination of the level of infection and mortality over the course of the season. Dr. Roxanna Smolowitz, Marine Biological Lab, analyzed samples for presence and degree of infection with dermo. In addition, sample stations which have been regularly sampled since 1995 were sampled 7 times from April 23 to October 31 to determine the quantity of nutrients, the salinity, dissolved oxygen content and the transparency of the water column. The plan was to have a relatively short duration opening to the pond in the spring and to attempt to hold off opening the pond again until the salinity reached 10 parts per thousand. This salinity level is reported to result in suppression of the parasitic organism in the Chesapeake and elsewhere.

Program Results: The April opening was so short that the Pond built up considerable head and had to be opened about May 21. That opening persisted longer than was planned and the Pond was still open on the June 13 water-quality sampling. It was opened once again on October 9 and remained so until October 31. As a result of the opening cycle, the Pond never freshened up as much as was desired. The average salinity at one-meter depth reached 13.25 PPT on May 18 just prior to the opening and 12.8 PPT on September 18. The bottom salinity did not reach the desired 10 PPT.

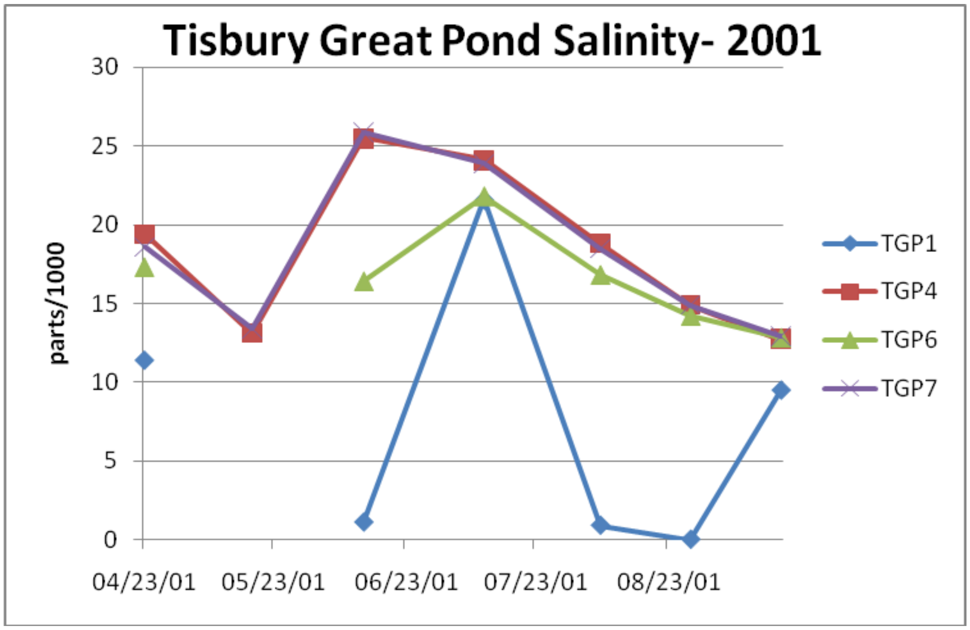
Water Quality: The stations set up for water quality sampling include stations highly influenced by the stream input from Mill Brook (station 1) and the Tiasquam (Station 2), a transitional station (4), a station in the basin that is strongly influenced by the opening (7) and a station in a cove with a bar which can be highly influenced by groundwater discharge when the pond is closed and by the tides when it is open (6). See Figure 1 for station locations.

FIGURE 1

Lab and field data are plotted in the accompanying charts at 1 meter (where this depth is available) for the stations dominated by stream input to the pond (1and 2) and for those in the main basin of the pond (4, 7 and 6). In Figure 2, the salinity plot at all stations shows two peaks associated with the two openings to the ocean (early June and mid-

October). The data indicate that, while the stream dominated stations, experienced salinity well below the target 10 PPT for extended periods of time, those in the main basin where the oyster beds are found did not get below 12 to 13 PPT.

FIGURE 2

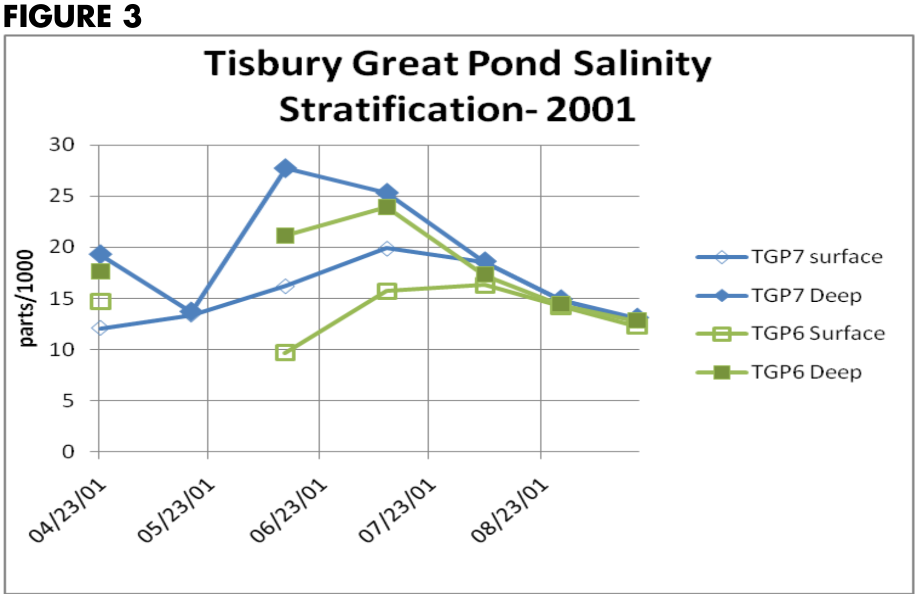


Typically, when the pond is opened, a large volume of fresh water is discharged from the watershed causing the water column at the heads of the coves to become relatively fresh as stream and groundwater discharge dominate. See Figure 2 where the stream-dominated station (TGP1) has very low salinity on June 13, about 10 days after the inlet was cut. By that time, the main basin stations had already responded to the influx of seawater and their average salinity had increased. Despite the average value for the three basin stations increasing, the salinity at Station 6 in Deep Bottom Cove on June 13 was lower than the April value reflecting increased freshwater input. Once tidal exchange is initiated, saline water enters the system and, due to its higher density, may result in a stratified water column at locations midway up the coves such as Station 4 (see Figure 1). The stratification can be enhanced when the wind is moderate out of the south and piles up the fresh water trying to exit the pond at the surface. A stratified water column is stable because the denser water is at the bottom and this bottom water is isolated from the air by the overlying, less-dense water. Eventually, the salty wedge of water makes its way up to the stations further up in the coves such as Stations 1 and 2. Over time, the substantial salinity differences between stream and main-basin stations brought on by the May/June inlet mix until the salinity at all stations is equal on July 11.

Water column stratification creates a potential for water trapped at the bottom to become anoxic under the right conditions. The deeper water receives a steady rain of dying phytoplankton from the surface. This organic matter requires oxygen to decay and diminishes the amount found in the water column. Add to this the demand for oxygen from photosynthetic rooted plants, algae and phytoplankton during the night and the potential develops for early morning oxygen depletion. This developing problem can be resolved by wind mixing which is probably the dominant circulation factor in the pond. During the study period, no harmful oxygen depletion occurred. Hypoxia is defined as occurring when there is less than 2 milligrams per liter (mg/l) of dissolved oxygen in the water column, which translates to about 25% saturation of dissolved oxygen. The limit for fish and other invertebrates is around 4 to 5 mg/l, which would be 40 to 60% saturation.

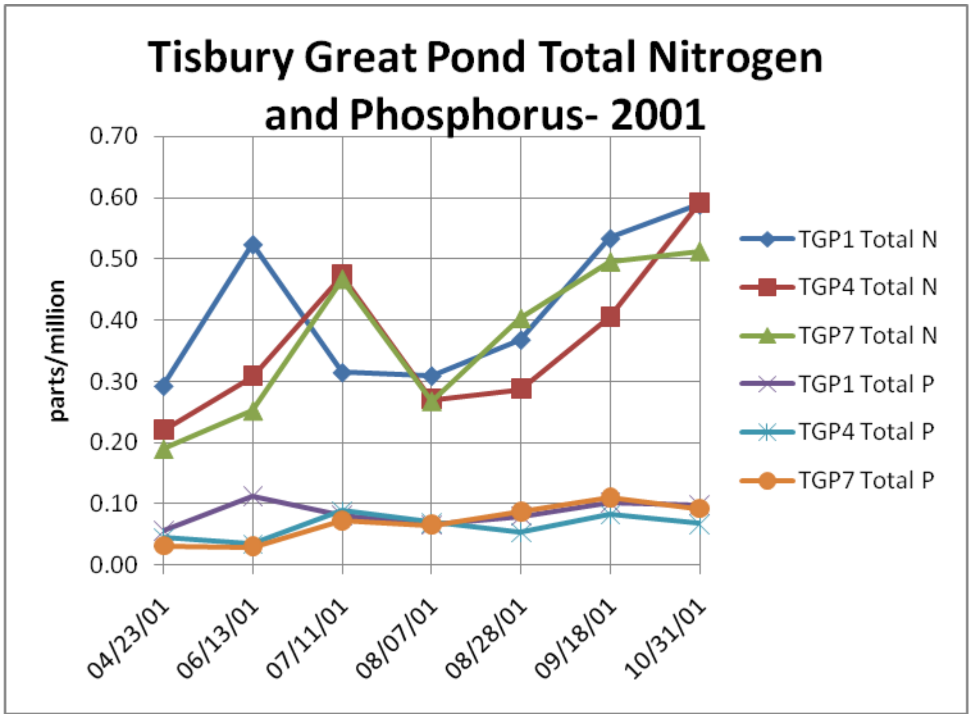
On May 18, the salinity at station TGP 7 was the same at the surface and the bottom indicating there was no stratification. On June 13 at station 7, the salinity at the surface was 16.2 PPT and 28.4 PPT (parts per thousand) at the bottom indicating a stratified water column. (See Figure 3 and Table 1 Field and Lab Data). Dissolved oxygen decreased from 122 % (supersaturated) at the surface to 68.7% at the bottom. By July 11 the salinity gradient had decreased to range from 19.7 PPT at the surface to 25.3 at the bottom and the dissolved oxygen saturation was near 100% top to bottom. In Deep Bottom (TGP6) the salinity driven stratification did not break up until after the July 11 sampling and, on that date, dissolved oxygen saturation was 69%. Dissolved oxygen in this range at the bottom is acceptable however it is probably lower overnight. Stratification extending further into the summer could have undesirable consequences. For example, on August 7 at station 1, the salinity at the surface was 0.9 PPT and 17.4 PPT at ½ meter depth indication a strong stratification. Dissolved oxygen dropped from 80% at the surface to 55% in the bottom water.

FIGURE 3



Total Nitrogen (TN) and Total Phosphorus (TP), show an inverse pattern to salinity, with concentrations peaking at all stations when the stream-dominated stations had their lowest salinity (Figure 4). The peak nitrogen arrives sooner at station TGP1 (May 18 in Figure 4) than it does at stations 4 and 7 reach peak on June 13. This points to the source of these nutrients being the fresh water input to the pond. The ratio of TN to TP tells something about which of the nutrients is a limit to further growth of phytoplankton in the water column. The highest ratios occurred on May 18 when they reached 18 to 20 at stations TGP 4 and 7 indicating that phosphorus might be limiting growth. All other samples have ratios below 16 to 1 indicating probably nitrogen limitation. The ratios were lowest at 4:1 at both the stream influenced and main basin stations at the time of the salinity peak on July 11. This reflects a nitrogen limited situation in the Pond for nearly the entire sampling season and probably stems from the influx of seawater during the opening that has a very low TN/TP ratio.

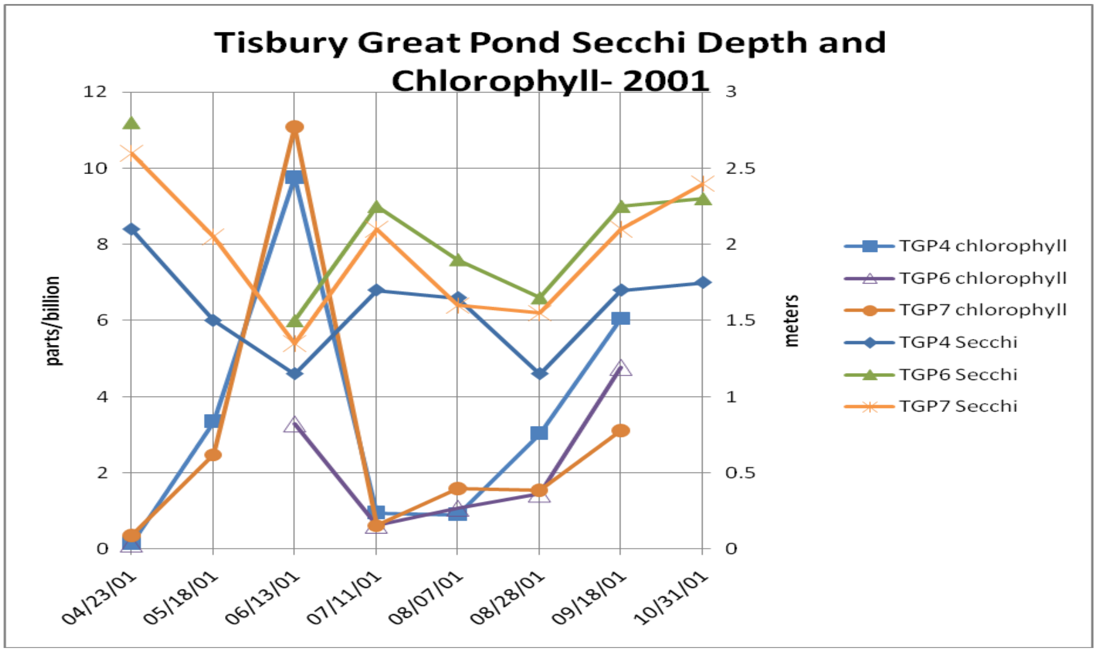
FIGURE 4



In Figure 5, phytoplankton productivity is indicated by the amount of chlorophyll *a* in the water column and is plotted on the left axis. These values are highest on June 13 at all stations. This may have been stimulated by the nutrients brought into the system by the May opening but may also build from natural, seasonal cycles of phytoplankton. The values measured on June 13 at TGP6 are an indication of good water quality but are too high at stations TGP4 and TGP7. The Buzzard's Bay program awards 100 quality points for waters with 3 micrograms per liter (µg/l) and 0 points for waters with10 µg/l.

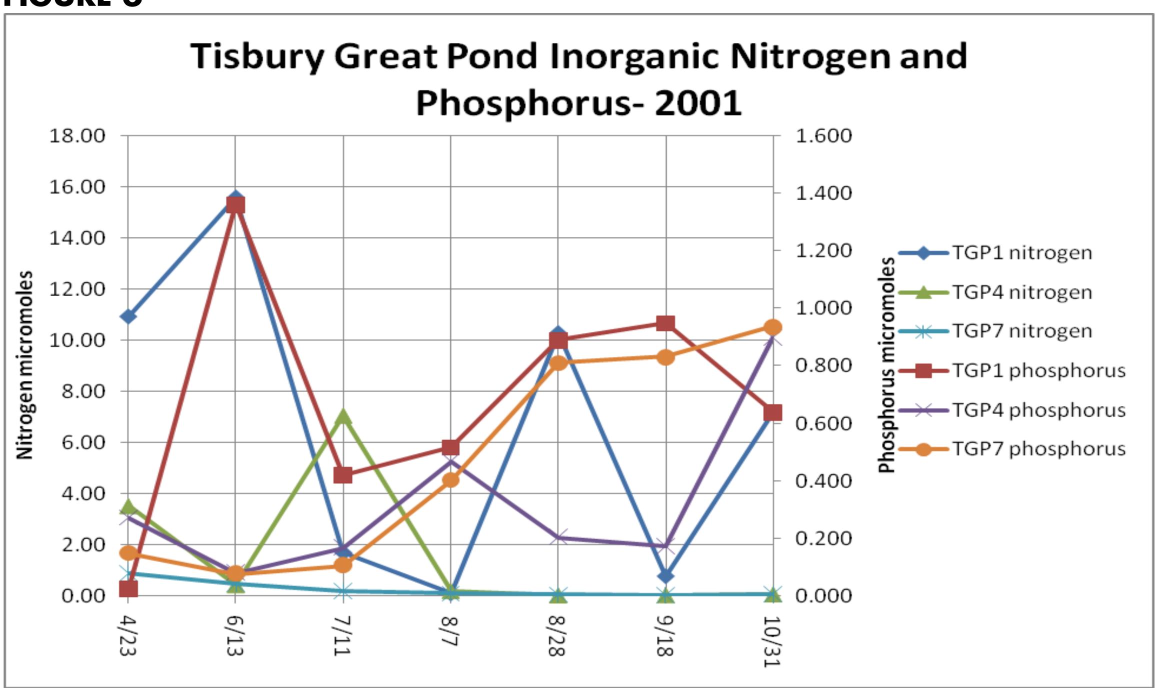
The water column transparency (Secchi depth) in Figure 5 is plotted on the right axis and varies inversely to the amount of chlorophyll *a*. The readings are reported for only those stations where there is sufficient depth to obtain a reading, typically 4, 6 and 7. The Secchi disk extinction average of 1.33 meters on June 13 is somewhat troublesome but does not persist.

FIGURE 5



In Figure 6, the inorganic nitrogen and phosphorus follow a pattern similar to the TN and TP. The curves peak during the time of the inlet on June 13. The peak on August 28 at TGP1 may be a result of a rainy August (6.1 inches in Edgartown) following on a dry summer. The values (particularly nitrogen) are substantially higher at the stream influenced station (TGP1) when compared to the basin stations (TGP7) which emphasizes that the sources are the streams and groundwater input at the head of Town Cove.

FIGURE 6



The ratio of inorganic nitrogen (DIN) to orthophosphate (PO4) is used as another means to determine which of the two nutrients is limiting the growth of phytoplankton. When less than about 16, nitrogen is limiting and when greater than 16, phosphorus is deficient. With rare exception, the ratio was well below 16 and often in single digits indicating that nitrogen was the limiting nutrient. At the stream-dominated stations the ratio peaks at about 11.5 and 16.9 on June 13 indicating that nitrogen is limiting to the system at that time. At the same time in the basin stations, the average is much lower and probably reflects the introduction of seawater, which contains very little nitrogen. Field data and the laboratory results are reported in Table 1.

Summary of Pond Water Quality:
The Buzzard's Bay program has devised a rating system for pond quality that can be used to get a sense of the overall system quality. The parameters that are used include oxygen saturation, Secchi depth, chlorophyll content, dissolved inorganic nitrogen and total organic nitrogen. In Table 2, these parameters are rated for Tisbury Great Pond Stations 4, 6 and 7.

Table 2: Tisbury Great Pond: Water Quality Indicators Ranking for 2001

Parameter	***Zero Value***	***100 Point Value***	***Station number***			***Points***		
			4	***7***	***6***	***4***	***7***	***6***
Oxygen Saturation (lowest 1/3 of readings)	40%	90%	75%	89%	68%	70	100	56
Secchi disk depth	0.6 meters	3 m	1.6m	1.8m	2.0m	40	50	58
Phyto Pigments	10 ug/l	3 ug/l	4.1ug	3.6ug	2.2ug	85	80	100
DIN	10 uM/l	1 uM/l	1.48uM	0.07uM	0.08uM	94	100	100
Total Organic Nitrogen	0.6 mg/l	0.28 mg/l	0.39mg	0.43mg	—	60	53	–

Based on Buzzard's Bay Program Guidance (Costa et al 1996)

In Table 2, the oxygen saturation readings are derived from the 1-meter reading and the bottom values over the July through September records. No surface values were used. The point values for stations 4 and 7 are good while station 6 values are somewhat skewed by the longer lasting stratification which allowed the bottom water dissolved oxygen saturation to drop lower. As the readings were made at three-week intervals, it is possible that even lower saturation values occurred. Station 6 is an indication that, within the coves where stratification may be extended, there is a possibility for hypoxia to impact vertebrate and invertebrate species.

Secchi disk readings are moderate to poor despite good point scores for the chlorophyll content. The Secchi extinction depth averages for July through September were brought lower by low readings in August. Low chlorophyll concentrations during this time indicate that a non-chlorophyll bearing species is responsible for the lowered transparency. Transparency could also be reduced by a source of silt but this is unlikely for these three stations, which are situated far from agricultural sites and sources of road runoff.

At the main basin sample stations, DIN (dissolved inorganic nitrogen) values are low throughout the sampling season leading to high scores. During the period just after the inlet was cut and the pond lowered, the DIN concentrations at Stations 1 and 2 are 10 to 100 times more than at the other three stations. Ratings at these stream-dominated stations would be poor. Evidently this source of nitrogen is converted into biomass so that it is no longer in the soluble inorganic form at the main basin stations.

The creation of excess biomass is reflected in the lower scores for total organic nitrogen, which is the sum of particulate nitrogen and dissolved organic nitrogen.

Oyster (*Crassostrea virginica*) Health Data:

Dermo (Perkinsus marinus) is a parasite that impacts young oysters and often kills them before they reach harvest size. The disease has been prevalent in the Chesapeake for a long period of time where researchers have found that it is suppressed both by very cold winter weather and by the presence of fresh water of salinity less than 10 parts per thousand during the growing season. The disease developed in Edgartown Great Pond in the mid 1990's and only in the last few years in Tisbury great Pond. Recent experience in Edgartown Great Pond has been that only about 50 % of the native oysters in that pond survive to harvest size.

Our initial hypothesis was that cultured, disease-free oysters would take three years to develop the disease to the point where severe mortality would impact potential harvest. By that time a harvest of reasonably sized animals could be taken. Further, we expected that low salinity would limit the pace of infection.

Oyster samples were placed into Tisbury and Edgartown Great Ponds during the third week of June 2001. Oysters were collected in the wild, separated into 7 bags containing 40 oysters each. Test plots with oysters native to the two ponds were set at one location in each pond. In Tisbury Great Pond, these cages were placed at the mouth of Tiah's Cove. For comparison, nine bags of oysters native to Edgartown Great Pond were placed at the mouth of Slough Cove in that pond where the *dermo* problem has been entrenched for a long period of time. These samples of wild oysters were expected to be infected with dermo at the same rate and intensity as the wild population in general in the two ponds. In addition, cultured oysters, free of the disease, were placed in seven bags of 40 animals each at these two test sites and also on the Chilmark side of Tisbury Great Pond.

Samples of 25 animals were collected monthly from the bags within each trial (5 animals each at two wild sites and at three cultured sites) for evaluation for the presence of *dermo.*

The data is reported in Table 3 and graphed in Figure 6. In the initial sample, the cultured oysters had no disease, the Tisbury Great Pond wild sample had 4% infected and the Edgartown Great Pond wild sample had 74% infected.

In Tisbury Great Pond, the percent infected in the wild group rose to 50% in August, 42% in September and declined to 4% in October. The disease-free, cultured sample on the West Tisbury side was 21% infected by August, 75% infected in September and 4% infected in October. The pace of infection of the cultured oysters was very similar in Edgartown Great Pond. By the October sample round, cumulatively 100% of both the wild and the initially disease-free samples were infected in all test sites with the exception of the Chilmark-side cultured, disease-free animals.

On the Chilmark side of the Pond, infection rate of the initially disease-free oysters was slower, reaching 4% in August, jumping to 72% in September and declining to zero infection in October. Total, cumulative infection was 76% by the last sample. See Figure 7 and Table 3.

At the same time, the cages were examined for dead animals. The monthly percent of the population remaining that was deceased is summarized in Table 4 (Monthly Mortality) and shown graphically in Figure 8. The mortality rate is substantially higher in the wild populations in both ponds and, in Edgartown Great Pond, it approached or exceeded 8% in each of the August, September and October inspections. The mortality in the cultured population on the West Tisbury side of the Tisbury Great Pond exceeded 8% by October. The cultured populations in Edgartown Great Pond and on the Chilmark side of the Tisbury Great Pond experienced less than 2% mortality at each monthly inspection for most of the study period.

TABLE 3

Oyster Sample Data	Ave height (mm)	Ave weight (mm)	% positive	Weighed Prevalence	Intensity (Weighed Intensity)	Mortality %	Dead oysters	cumulative	Salinity	Temperature
Tisbury Great Pond (Tiahs Cove) 7/10/0	89.2	75.9	4	0.1					17	23.5
Edgartown Great Pond 7/1/01	74.5	90.9	74	0.9					25	24
Tisbury Great Pond 08/01										
Tiah's cove/ west tisbury side Wild (MBL c	76.7	64.6	54	1	1.9	2.5	7	2.5	19	24
Tiah's cove/ west tisbury side Cultured (MB	42.7	7.4	21	0.2	1.1	2.1	6	2.1		
Chilmark side Cultured (MBL case # 632)	50.1	11.6	4	0.02	0.5	0.7	2	0.7	19	23
Edgartown Great Pond 08/02										
Mouth of Slough Cove Cultured (MBL case	45.5	11.4	17	0.1	0.6	1.1	4	1.11	22	25
Mouth of Slough Cove Wild (MBL case # 6	74.7	67.3	95	1.2	1.3	9.4	34	9.44		
Tisbury Great Pond 8/29/01										
Tiah's cove/ west tisbury side Wild (MBL c	71.7	49.3	96	1.4	1.5	7.7	19	6.7	15	24
Tiah's cove/ west tisbury side Cultured (MB	50.2	13.7	96	2.5	2.6	2.4	6	2.1		
Chilmark side Cultured (MBL case # 671)	51.8	12.9	76	1.3	1.8	0	0	0	15	23.5
Edgartown Great Pond 9/4/01										
Mouth of Slough Cove Cultured (MBL case	53	17.7	92	1.1	1.2	0.3	1	0.3	18	22
Mouth of Slough Cove Wild (MBL case # 6	79.9	82.5	100	2	2	11.3	34	9.4		
Tisbury Great Pond 9/24/01										
Tiah's cove/ west tisbury side Wild (MBL c	74	56.8	100	2	2	9.3	19	6.7	12	20.5
Tiah's cove/ west tisbury side Cultured (MB	53.7	13.8	100	2.3	2.4	9.2	20	7.1		
Chilmark side Cultured (MBL case # 692)	54.4	16.2	76	1.2	1.5	2.3	5	1.7	12	20.5
Edgartown Great Pond 10/02/01										
Mouth of Slough Cove Cultured (MBL case	81.4	82.9	100	2.7	2.7	1.3	4	1.1	22	15
Mouth of Slough Cove Wild (MBL case # 7	59.1	22.9	100	2.2	2.2	11.6	28	7.7		
Tisbury Great Pond 11/1/01										
Tiah's cove/ west tisbury side Wild (MB	82	66.4	100	1.5	1.5	6.9	11	3.9	24	11
Tiah's cove/ west tisbury side Cultured	55.9	16.2	100	1.8	1.8	6.9	12	4.2		
Chilmark side Cultured (MBL case # 74	52.6	17.5	60	1.6	2	1.5	3	1	25.5	11
Edgartown Great Pond 11/1/01										
Mouth of Slough Cove Cultured (MBL	57.2	22.1	100	3.1	3.1	2.5	7	1.9	26	12
Mouth of Slough Cove Wild (MBL case	68.1	58.8	100	3.4	3.4	5.8	11	3		

Weighed Prevalence is the total of the intensities from each positive animal divided by the total number of animals examined in the sample
Intensity is the total of the intensities from each positive animals divided by the total number of positive animals in the sample.

Figure 7 Percent Infection of Crassostrea virginica by Dermo in Edgartown and Tisbury Great pond / Summer 2001

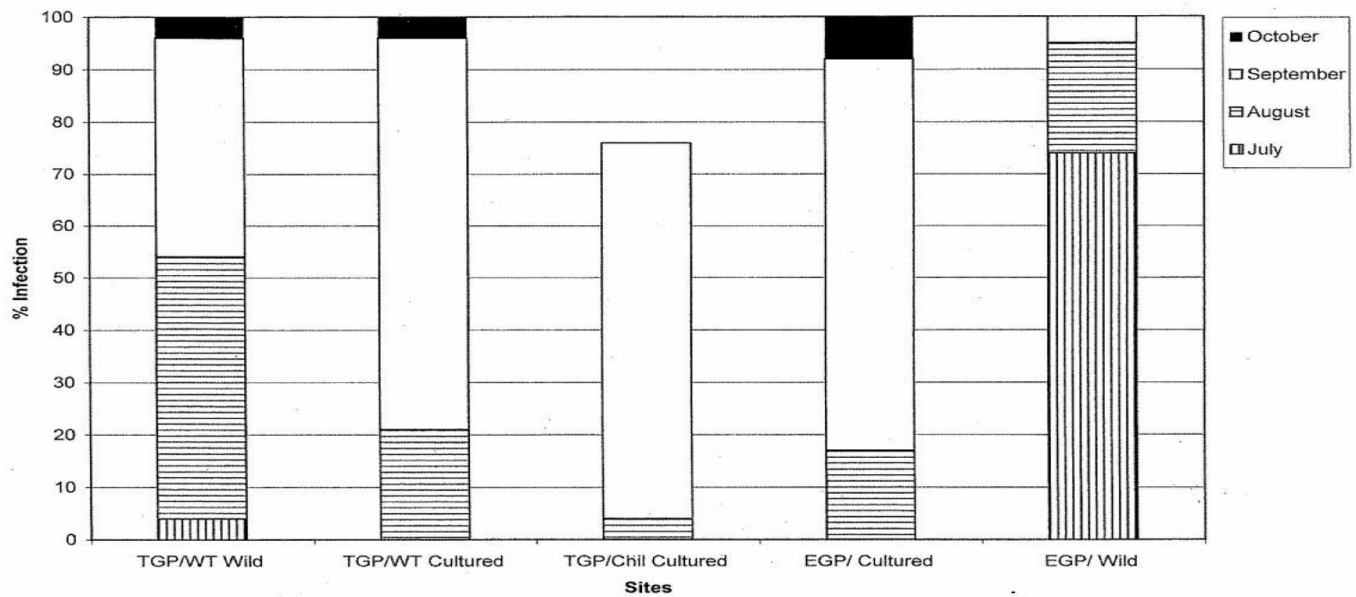
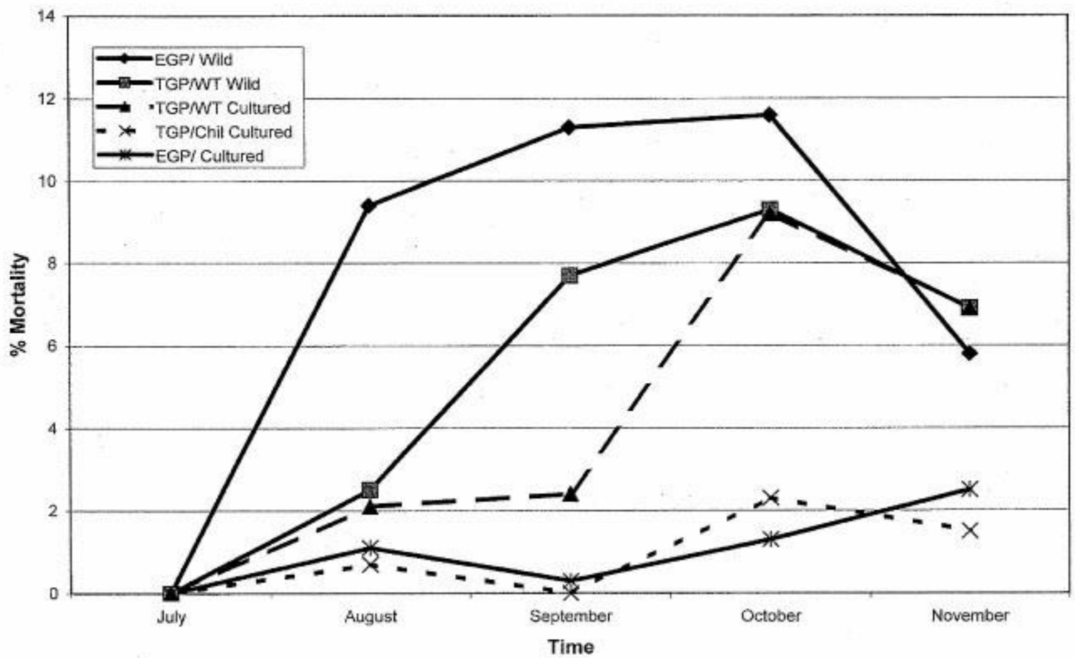


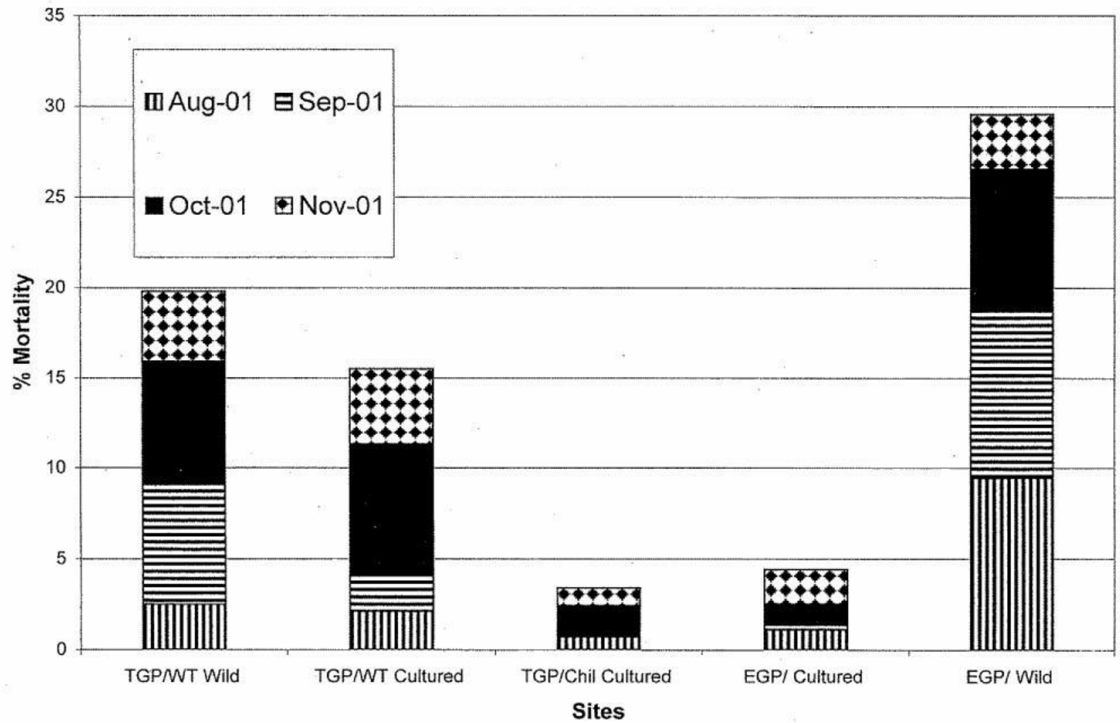
Figure 8 Monthly Mortality of Wild and Cultured *Crassostrea virginica* in Edgartown and Tisbury Great ponds



The cumulative mortality is also shown in Table 4 and in Figure 9. It eliminated 19.8% of the animals in the wild sample in Tisbury Great Pond and 29.5% of the Edgartown Great Pond wild sample by November. The rate of mortality was slower in the disease-free animals in Tisbury Great Pond but still reached 15.5% of the population on the West Tisbury side of the pond by November. The cultured, disease-free, specimens on the Chilmark side died off at a much slower rate, reaching 3.4% of the initial population by November. A similar, slow mortality rate was observed in the Edgartown Great Pond cultured sample, which totaled 4.4%, by November.

Table 4 Tisbury Great Pond Salinity Management Study							
Percent Dermo Infection of Crassostrea virginica							
		July	August	Sept.	October		
TGP/WT wild		4	50	42	4		
TGP/WT cult		0	21	75	4		
TGP/CH cult		0	4	72	0		
EGP/cult		0	17	75	8		
EGP/wild		74	21	5	0		
Cumulative mortality						Total Mortality	
TGP/WT wild		2.5	6.7	6.7	3.9	19.8	
TGP/WT cult		2.1	2.1	7.1	4.2	15.5	
TGP/CH cult		0.7	0	1.7	1.0	3.4	
EGP/cult		1.11	0.3	1.1	1.9	4.41	
EGP/wild		9.44	9.4	7.7	3.0	29.54	
Monthly mortality							
TGP/WT wild		0	2.5	7.7	9.3	6.9	
TGP/WT cult		0	2.1	2.4	9.2	6.9	
TGP/CH cult		0	0.7	0	2.3	1.5	
EGP/cult		0	1.1	0.3	1.3	2.5	
EGP/wild		0	9.4	11.3	11.6	5.8	

Figure 9: Cumulative Mortality of Wild and Cultured *Crassostrea virginica* in Tisbury and Edgartown Great Ponds



The higher cumulative mortality rate in the wild sample in Edgartown Great Pond is a reflection of the higher initial infection rate in the animals. We believe that the comparatively high rate of mortality in the cultured sample on the West Tisbury side of Tisbury Great Pond may result from these animals being in close proximity to a wild, infected, oyster population that is not found on the Chilmark side. This lead to earlier onset of infection (21% on the West Tisbury side by August compared to 4% on the Chilmark side). The Chilmark bags were placed in an area with no wild animals and there were no wild population samples placed in that area.

The decline in the infection rate at all sites in the October sample is a result of cooling water temperatures. The mortality rate follows this trend in November.

Conclusions:

It is difficult but possible for pond managers to adjust the timing and duration of the cut through the barrier beach and, thereby, lower the salinity to 10 PPT in the Pond over the course of several months. However, natural variables such as wind direction and speed that cannot be accurately predicted more than a few days in advance may have great influence over the inlet lifetime.

During the course of the study, phytoplankton populations were not increased beyond those levels found during 1995 when no attempt was made to manipulate the salinity. This is indicated by chlorophyll *a,* particulate nitrogen and particulate carbon.

Water quality in the pond in general was not different than during the 1995 season. A scoring system indicates that water quality was reasonably good during the experiment. More frequent sampling is desirable to identify short-term lower quality events.

The infection rate for initially disease-free oysters is strongly affected by the proximity of an infected resident population. In both Great Ponds, the parasite had reached nearly all disease-free animals in proximity to infected, wild animals by the end of the summer.

Although in the first year, the infection-rate of the disease-free oysters introduced into the contaminated portion of the ponds was nearly 100%, the mortality rate of these animals was lower when compared to the resident, wild-oyster population. From the data this season, it appears that the infection will reach well over half of disease-free animals placed where there is a source of infection nearby.   It appears likely that disease-free animals infected the first year will die the following year roughly in proportion to the die out found in Edgartown Great Pond (29.5%). Mortality is a function of the intensity of the infection, which builds over time, rather than the presence of the *dermo* parasite.

Over time, the infection rate of wild populations in Tisbury Great Pond at the beginning of the growing season may rise until it is well in excess of half the total resident population based on the historical progression and observation of the disease in Edgartown Great Pond.

TABLE 1

Field Data

Lab Data

Abbreviations used:

PPT parts per thousand a concentration measurement
Sp. Cond. Specific conductivity a measure of dissolved chemicals in the water, similar to salinity
µm micromoles a concentration
PO4 orthophosphate
NH4 ammonium
NOX nitrate and nitrite combined
POC particulate organic carbon- a measure of biomass
PON particulate organic nitrogen- "" ""
DIN dissolved inorganic nitrogen- the sum of NH4 and NOX
ChLa Chlorophyll a- one of the chlorophyll molecules

TISBURY
GREAT POND
FIELD DATA 2001

					SURFACE				**0.5 METER**			
Date	**Sta #**	**Total D.**	**Secchi**	**DO %**	**Sp. Cond**	**Temp**	**Sal**	**DO %**	**Sp. Cond.**	**Temp**	**Sal**	**DO %**
		Meters	Meters	%	kuS	Cent.	PPT	%	KuS	Cent.	PPT	
04/23/01	1	0.8	0.8	102.3	19.2	13.8	11.4	112.6	27.9	14.2	17.9	
04/23/01	2	0.75	0.75	85.1	17.7	14.3	10.4	113.8	30.2	14.1	18.5	
04/23/01	4	2.1	2.1	127.3	18.6	13.2	10.3					122.5
04/23/01	7	2.6	2.6	128.1	16.5	12.7	12.1		30.3	13.1	18.8	128.8
04/23/01	6	2.8	2.8	129.4	24.2	13.6	14.7					122.5
			2.5	***114.44***	***19.24***	***13.52***	***11.78***	***113.2***	***29.47***	***13.8***	***18.4***	***124.6***
05/18/01	1											
05/18/01	2											
05/18/01	4	2.3	1.5	96.3	21.9	15.9	13.1					91.3
05/18/01	7	3.2	2.05	96.4	22.3	14.6	13.4					96.3
05/18/01	6											
			1.78	***96.35***	***22.1***	***15.25***						***93.8***
06/13/01	1	0.5	0.5	61.5	3.02	18.5	1.1					
06/13/01	2	0.5	0.5	55	0.7	20.3	0.25					
06/13/01	4	1.6	1.15	100.6	31.81	22.8	21.1					95.2
06/13/01	7	2.5	1.35	121.7	26.31	22.7	16.2					106.9
06/13/01	6	2.4	1.5	99.8	16.79	23.2	9.7					97.5
			1.33	***87.72***	***15.73***	***21.5***	***9.67***					***99.87***
07/11/01	1	0.7	0.7	44.3	34.39	25.5	21.6	48.8	35.81	25.7	22.6	
07/11/01	2	0.5	0.5	56	25.25	25.3	15.4	66	35.18	26.6	22	
07/11/01	4	1.85	1.7	99.3	34.89	26.4	21.6					99
07/11/01	7	2.6	2.1	104.7	36.75	24.2	19.9					104.1
07/11/01	6	2.6	2.25	99.5	25.26	25.3	15.7					92.6
			2.02	***80.76***	***31.31***	***25.34***	***18.84***	***57.4***	***35.495***	***26.15***	***22.3***	***98.57***
08/07/01	1	1	0.9	80.4	1.61	22.1	0.9	55.3	28.63	26.1	17.4	
08/07/01	2	0.9	0.9	83	14.92	24.1	11.4	81.3	29.61	26.7	17.8	
08/07/01	4	2.1	1.65	99.3	13.01	24.3	7.6					95.4
08/07/01	7	3	1.6	94.1	29.93	24.7	18.5					92.3
08/07/01	6	2.9	1.9	97.8	26.61	25.3	16.3					94.8

			1.72	***90.92***	***17.22***	***24.1***	***10.94***	***68.3***	***29.12***	***26.4***	***17.6***	***94.17***
08/28/01	1	0.7	0.6	72.8	0.943	21.2	0	38.6	18.9	23.9	11.5	
08/28/01	2	1.1	1	87.4	6.95	24.2	3.9	70.6	22.4	25.6	12.9	97.4
08/28/01	4	2.4	1.15	97.2	20.95	25.1	13.7					87.7
08/28/01	7	3.1	1.55	97.7	24.26	24.1	14.9					96.8
08/28/01	6	3.2	1.65	90.7	23.33	24.5	14.2					89.7
			1.45	***89.16***	***15.29***	***23.82***	***9.34***	***54.6***	***20.65***	***24.75***	***12.2***	***92.9***
09/18/01	1	1.2	1.2	62.4	15.42	19.6	9.5	66.3	19.65	20.1	10	73.1
09/18/01	2	1.1	1.1	65.5	17.85	20.3	10.3	77.7	20.31	21	12.2	69.2
09/18/01	4	2.5	1.7	84.6	20.5	20.4	12.3					84.1
09/18/01	7	3.15	2.1	89.6	21.31	19.7	12.8					87.9
09/18/01	6	3.2	2.25	85.4	20.45	19.7	12.3					84.4
			2.02	***77.5***	***19.11***	***19.94***	***11.44***	***72***	***19.98***	***20.55***	***11.1***	***79.74***

		1METERS				**1.5 METERS**				**2.0 METERS**			
Date	**Sta #**	**Sp. Cond.**	**Temp**	**Sal**	**DO %**	**Sp. Cond**	**Temp**	**Sal**	**DO %**	**Sp. Cond.**	**Temp**	**Sal**	**DO %**
		KuS	Cent.	PPT		KuS	Cent.	PPT	%	KuS	Cent.	PPT	
04/23/01	1												
04/23/01	2												
04/23/01	4	31.4	13.7	19.4		31.8	13.3	19.7	118.3	31.9	13.3		
04/23/01	7	30	13.3	18.6					128.2	31.2	13	19.3	
04/23/01	6	28.2	14	17.3					117.5	28.8	13.7	17.6	113.6
		29.87	***13.67***	***18.43***		***31.8***	***13.3***		***121.33***	***30.63***	***13.33***	***18.45***	***113.6***
05/18/01	1												
05/18/01	2												
05/18/01	4	21.9	15.9	13.1					90.6	22.8	15.1	13.7	
05/18/01	7	22.4	14.5	13.4					93.1	22.7	14.3	13.7	
05/18/01	6												
		22.15	***15.2***	***13.25***					***91.85***	***22.75***	***14.7***	***13.7***	
06/13/01	1												
06/13/01	2												
06/13/01	4	40.02	21.7	25.5	72.9	41.65	20.8	26.8					
06/13/01	7	40.61	20.8	25.9					79.6	42.98	19.7	27.7	68.7
06/13/01	6	25.72	22.9	16.4					85.5	33.3	21.8	21.1	
		35.45	***21.8***	***22.6***	***72.9***	***41.65***	***20.8***		***82.55***	***38.14***	***20.75***	***24.4***	***68.7***
07/11/01	1												
07/11/01	2												
07/11/01	4	37.88	25.3	24.1	103.7	39.51	25.3	25.2					
07/11/01	7	37.69	24.7	23.9					100.2	39.72	24.8	25.3	
07/11/01	6	34.66	25.9	21.8					94.4	37.63	24.9	23.9	69
		36.74	***25.30***	***23.27***	***103.7***	***39.51***	***25.3***		***97.3***	***38.68***	***24.85***	***24.6***	***69***
08/07/01	1												
08/07/01	2												
08/07/01	4	30.44	26.1	18.8	95.4	30.38	25.5	18.8	90	30.33	25.1	18.8	
08/07/01	7	29.95	24.7	18.5					93.2	29.98	24.7	18.6	94.9
08/07/01	6	27.6	25.2	16.8					88.9	28.18	25	17.3	55.3
		29.33	***25.33***	***18.03***	***95.4***	***30.38***	***25.5***		***90.7***	***29.50***	***24.93***	***18.23***	***75.10***

08/28/01	1								
08/28/01	2	23.5	25.3	14.2					
08/28/01	4	24.35	24.5	14.9	80.9	24.39	24.3	14.9	76.5
08/28/01	7	24.28	24	14.9	97.7	24.33	24	14.9	96.7
08/28/01	6	23.34	24.5	14.2	77.8	23.56	24.4	14.4	71.6
		23.87	***24.58***	***14.55***	***85.47***	***24.09***	***24.23***	***14.73***	***81.60***
09/18/01	1	20.94	20.9	12.6					
09/18/01	2	21.43	21.3	12.9					
09/18/01	4	21.15	20.3	12.7	74.4	21.72	20.4	13.1	74.7
09/18/01	7	21.44	19.7	12.9	85.5	21.78	19.7	13.1	
09/18/01	6	20.69	19.7	12.8	76.5	21.26	19.8	12.8	
		21.13	***20.38***	***12.78***	***78.8***	***21.59***	***19.97***	***13***	***74.7***

Great Ponds Data Summary													
Coastal Systems Group, CMAST, B.Howes					**on bottom**	**PPM**							
Marine Chem Lab, UWash, K. Krogslund													
	Values in Italics are for parameters usually done in lab but as shown were recorded in field.												
	NOx includes NO3 & NO2												
		SALINITY	SILICATES	PO4	NH4	NOX	POC	PON	DIN	DIN/PO4	DSi/PO4	Secchi	Chl A
DATE	STA	(ppt)	(uM)	(uM)	(uM)	(uM)	uM	uM/L	uM/L			M	uG/L
4/23/01	1	11.40	47.17	0.03	0.01	0.14	0.00	0.00	10.93	13.01	56.15		0.00
6/13/01	1	1.1	144.02	1.36	4.56	10.82	73.49	6.53	15.58	11.45	105.83		1.71
7/11/01	1	21.6	116.91	0.42	0.00	1.58	93.07	14.05	1.70	4.02	277.04		1.33
8/7/01	1	0.9	56.01	0.52	0.00	0.00	94.98	13.23	0.11	0.20	108.26		1.63
8/28/01	1	0	129.89	0.89	1.48	8.71	0.00	0.00	10.28	11.56	146.11		0.63
9/18/01	1	8	151.76	0.95	0.04	0.69	95.99	14.46	0.78	0.82	160.00		7.64
10/31/01	1	0	91.14	0.64	0.03	7.01	382.50	39.29	7.15	11.18	142.50		
4/23/01	2	10.40	47.17	0.33	0.38	8.96	47.98	5.93	9.34	28.00	141.44		0.22
	2												
6/13/01	2	0.25	131.95	1.68	4.87	23.29	96.67	8.68	28.43	16.87	78.31		1.78
7/11/01	2	15.4	126.41	0.37	0.00	1.92	96.68	13.92	2.00	5.45	343.82		1.12
8/7/01	2	11.4	92.99	0.41	0.00	0.00	244.62	32.72	0.04	0.10	226.82		6.26
8/28/01	2	3.9	126.12	0.33	0.00	0.00	0.00	0.00	0.04	0.13	382.58		2.53
9/18/01	2	10.3	153.08	1.10	0.13	0.01	68.97	10.24	0.18	0.16	138.83		6.29
10/31/01	2	23.9	104.52	0.44	0.00	6.13	224.17	21.43	6.21	14.07	236.60		
4/23/01	4	10.3	58.60	0.27	0.29	3.19	53.10	7.07	3.52	12.89	214.81	2.10	0.14
5/18/01	4	13.1	46.72	0.08	0.01	0.38	51.35	7.77	0.43	5.29	575.83	1.50	3.34
6/13/01	4	21.1	107.63	0.17	1.81	5.10	114.25	15.47	7.04	41.72	637.50	1.15	9.76
7/11/01	4	21.6	83.90	0.47	0.00	0.14	63.32	9.80	0.21	0.44	179.01	1.70	0.95
8/7/01	4	7.6	98.07	0.21	0.00	0.00	88.05	11.77	0.03	0.13	477.82	1.65	0.91
8/28/01	4	13.2	122.35	0.17	0.01	0.00			0.04	0.23	704.75	1.15	3.03
9/18/01	4	12.3	154.53	0.90	0.04	0.00	85.06	16.47	0.07	0.08	171.82	1.70	6.04
10/31/01	4	23.9	80.71	0.65	0.10	0.52	130.83	12.14	0.69	1.05	123.89	1.75	
4/23/01	7	11.5	35.48	0.15	0.13	0.70	54.11	7.93	0.89	5.96	238.34	2.60	0.36
5/18/01	7	13.4	42.54	0.08	0.00	0.43	46.23	6.86	0.48	6.18	547.04	2.05	2.48
6/13/01	7	16.2	73.96	0.11	0.00	0.16	123.37	18.07	0.19	1.77	684.52	1.35	11.08
7/11/01	7	19.9	88.95	0.40	0.00	0.05	56.61	9.25	0.09	0.23	220.05	2.10	0.62
8/7/01	7	18.5	76.78	0.81	0.00	0.00	100.13	14.79	0.05	0.06	94.73	1.60	1.59

4/23/01	7	11.5	35.48	0.15	0.13	0.70	54.11	7.93	0.89	5.96	238.34	2.60	0.36
5/18/01	7	13.4	42.54	0.08	0.00	0.43	46.23	6.86	0.48	6.18	547.04	2.05	2.48
6/13/01	7	16.2	73.96	0.11	0.00	0.16	123.37	18.07	0.19	1.77	684.52	1.35	11.08
7/11/01	7	19.9	88.95	0.40	0.00	0.05	56.61	9.25	0.09	0.23	220.05	2.10	0.62
8/7/01	7	18.5	76.78	0.81	0.00	0.00	100.13	14.79	0.05	0.06	94.73	1.60	1.59
8/28/01	7	14.9	115.59	0.83	0.00	0.00			0.03	0.04	139.08	1.55	1.55
9/18/01	7	12.8	151.59	0.94	0.04	0.00	72.17	11.51	0.08	0.08	161.83	2.10	3.12
10/31/01	7	25.4	52.79	0.97	1.02	0.70	26.67	3.57	1.79	1.85	54.44	2.40	
4/23/01	6	14.7		0.19	0.63	0.67	50.97	7.64	1.35	7.20		2.80	0.14
	6												
6/13/01	6	9.7	109.67	0.07	0.08	0.19	56.86	8.10	0.30	4.39	1623.97	1.50	3.29
7/11/01	6	15.7	122.19	0.31	0.00	0.00	59.65	9.57	0.03	0.09	394.93	2.25	0.63
8/7/01	6	16.3	87.53	0.58	0.00	0.00	98.15	14.44	0.04	0.07	150.52	1.90	1.08
8/28/01	6	14.2	116.94	0.96	0.00	0.00			0.03	0.03	121.80	1.65	1.45
9/18/01	6	12.3	132.31	0.72	0.09	0.00	59.58	9.42	0.13	0.18	184.72	2.25	4.77
10/31/01	6	21.9	63.19	0.73	0.00	0.72	36.67	5.00	0.78	1.07	86.28	2.30	