U.S. EPA REGION 9, Pacific Southwest

September 1, 2004

APPENDIX I
FINAL REPORT
Data Analysis for Water Quality Monitoring of Traditional Coastal Fishponds on the Island of Moloka'i

The following report analyzes and interprets the available data from water quality analyses performed by a coalition of personnel on Molokai (turbidity, temperature, pH, ammonia, total phosphorus, conductivity, dissolved oxygen), at the University of Hawaii (UH) Agricultural Diagnostic Service Center (ADSC) (total nitrogen, nitrate-nitrite nitrogen), and at the UH Environmental Engineering Lab (chlorophyll-a). Data volume varied for each of the water quality parameters measured as shown in the following table:

Pond	Turbidity, temperature, pH, ammonia, phosphorus, conductivity, dissolved oxygen	Total nitrogen, nitrate-nitrite	Chlorophyll
	No. Sampling Events (Total No. Samples)		
Niaupala	4 (48)	6 (59)	6 (59)
Ualapue	7 (77)	6 (66)	4 (55)
Keawanui	6 (72)	5 (53)	5 (60)
Panahaha	6 (60)	6 (59)	5 (50)
Kahinapohaku	6 (60)	7 (68)	5 (48)

The data are analyzed herein in regard to the applicable regulatory criteria which are contained in Hawaii Administrative Rules (HAR) 11-54. The regulatory criteria are presented in tabular format in the following order: Total nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, chlorophyll-a, turbidity, conductivity, dissolved oxygen, temperature, and pH. The collected data are analyzed and interpreted in the same order in this report.

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I. TOTAL NITROGEN

Criteria:
GeoMean not to exceed –> 150 μg/L (110 dry)
Not to exceed 10% of time –> 250 μg/L (180 dry)
Not to exceed 2% of time –> 350 μg/L (250 dry)
The calculated statistics below are for samples collected inside each pond

Niaupala (CONTROL POND):

GeoMean = 143 μg/L	(MEETS THE CRITERIA)
Exceed 10% value = 350 μg/L	(>250, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 462 μg/L	(>350, DOES NOT MEET THE CRITERIA)

Ualapue (production):

GeoMean = 161 μg/L	(>150, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 264 μg/L	(>250, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 289 μg/L	(MEETS THE CRITERIA)
Calculated criteria = 201 μg/L	(Geometric Mean, based on pond and transect)

Keawanui (production):

GeoMean = 212 μg/L	(>150, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 580 μg/L	(>250, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 661 μg/L	(>350, DOES NOT MEET THE CRITERIA)
Calculated criteria = 248 μg/L	(Geometric Mean, based on pond and transect)

Panahaha (production):

GeoMean = 200 μg/L	(>150, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 448 μg/L	(>250, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 482 μg/L	(>350, DOES NOT MEET THE CRITERIA)
Calculated criteria = 234 μg/L	(Geometric Mean, based on pond and transect)

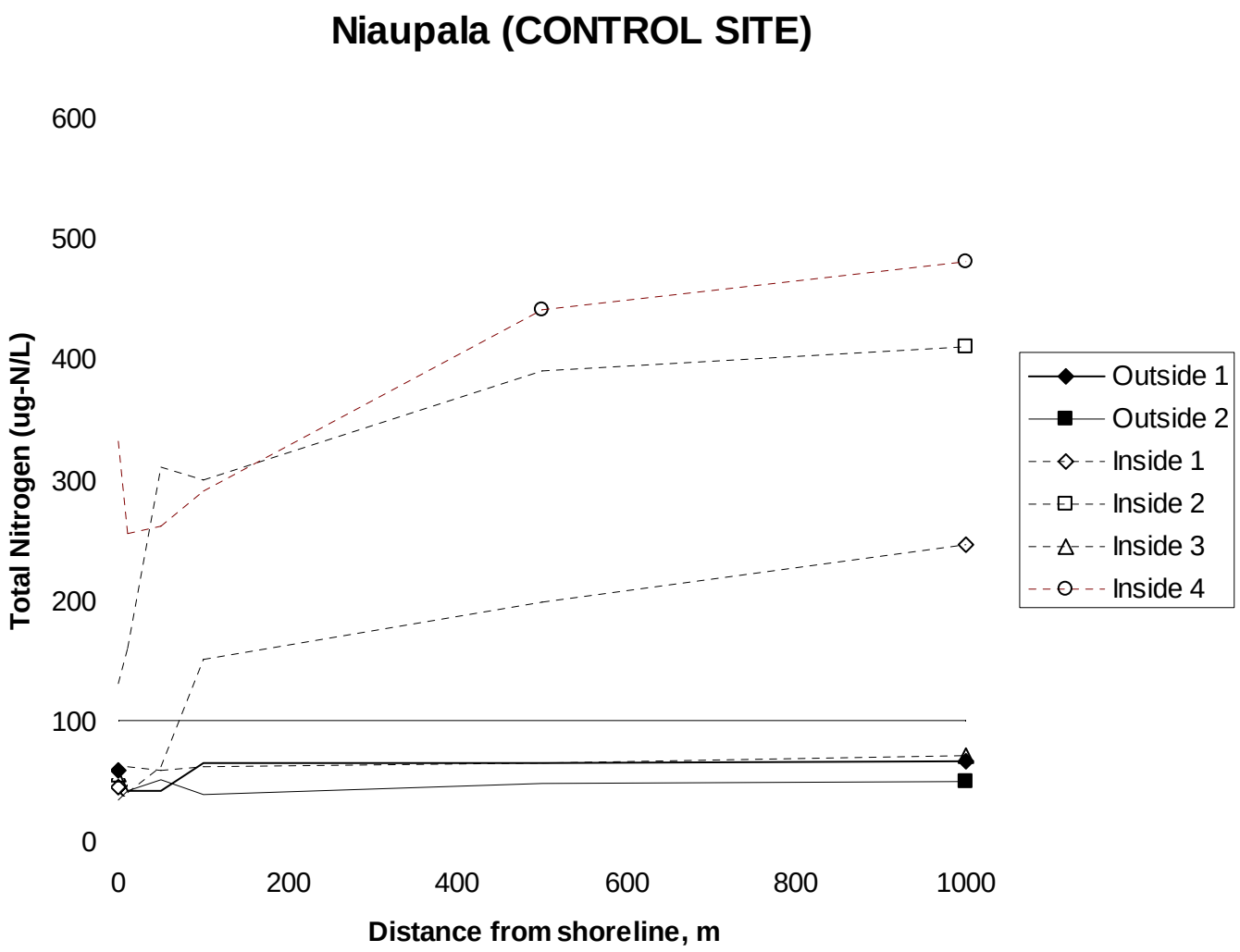
Kahinapohaku (restored but no production):

GeoMean = 171 μg/L	(>150, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 511 μg/L	(>250, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 747 μg/L	(>350, DOES NOT MEET THE CRITERIA)
Calculated criteria = 192 μg/L	(Geometric Mean, based on pond and transect)

Calculated criteria based on all ponds (n=326) = 175 μg/L (Geometric Mean)

Only the control pond and Ualapue each met one of the numeric criteria for total nitrogen in open coastal waters in HAR 11-54 as shown. Criteria were calculated (using a procedure developed for DOH and used to revise HAR 11-54 with specific criteria for the Kona Coast) based upon the data for each pond individually. It could be inferred that production activities in the Ualapue, Keawanui, and Panahaha ponds have caused increases in total nitrogen. However, if there is no reason to believe that any of the ponds have impacted nitrogen concentrations, then

a more appropriate criteria might be: geometric mean not to exceed 200 µg/L. Only Keawanui would not meet this criteria. If all of the nitrogen data from all of the ponds is used (inside and outside), then the recommended criteria would be: geometric mean not to exceed 175 µg/L. Both Keawanui and Panahaha would not meet this criteria.



For the control pond, it is apparent that there is significant variability in total nitrogen concentration profiles along the same transects for different sampling events. In addition, the control transect located outside the pond always had lower and less variable concentrations than the transect through the pond. This would seem to indicate that something occurring within the pond is the cause of the elevated nitrogen. Since Niaupala is the control pond where no human-induced production activities occur, the elevated nitrogen concentrations must be a "natural" condition. For the outside transects, the concentrations do not increase with the distance from the shoreline, instead they are mostly constant indicating a well-mixed background value. We would generally expect to see decreasing concentrations with distance from shore for analytes which are added at or near the shoreline such as in groundwater recharge or due to fishpond activities.

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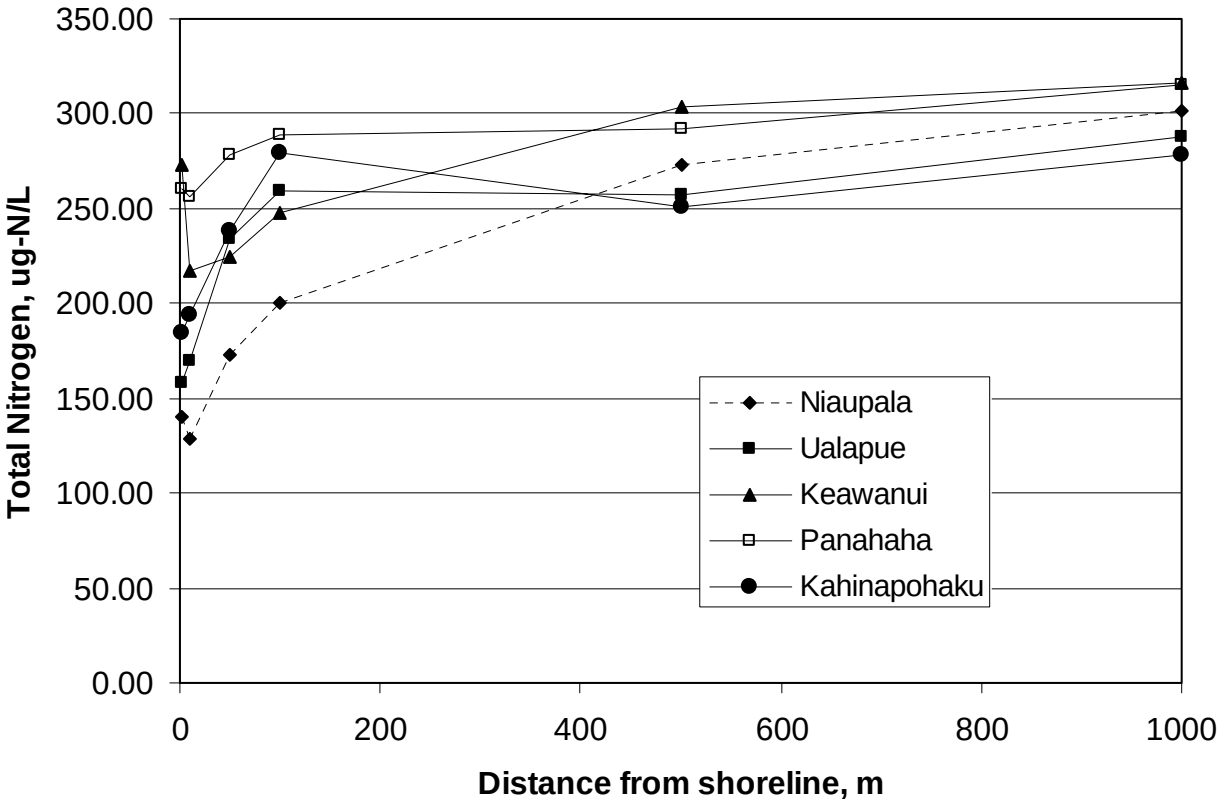

The total nitrogen data for transects through each of the ponds indicates that total nitrogen concentrations increase with distance from the shoreline and that all the ponds have similar profiles in terms of shape and magnitude. The data trend could be interpreted to indicate that nitrogen originating from off-shore is consumed in the nearshore areas. However, this is somewhat counter-intuitive. Generally, the total nitrogen concentrations for Ualapue, Keawanui, Kahinapohaku, and Panahaha ponds are greater than that of the control pond. Table 1 shows additional statistical data for total nitrogen and allows comparisons between inside the ponds and outside of them. It can be observed that nitrogen concentrations inside Niaupala and Kahinapohaku ponds are slightly higher than outside these ponds possibly indicating that processes and/or activities occurring inside the pond are causing increased nitrogen levels. For the other ponds, the concentrations of nitrogen outside the ponds are higher than but similar to the concentrations inside the ponds. Based on these data, it is difficult to infer that the fishponds are of worse water quality than the natural ambient water quality and instead it could be inferred that the existing water quality criteria are not realistic. The most appropriate total nitrogen water quality criteria must consider the ambient water quality outside of the fishponds. Taking this into consideration, the suggested water quality criteria would be: geometric mean not to exceed 230 μg/L. All of the ponds in this study would meet this criteria.

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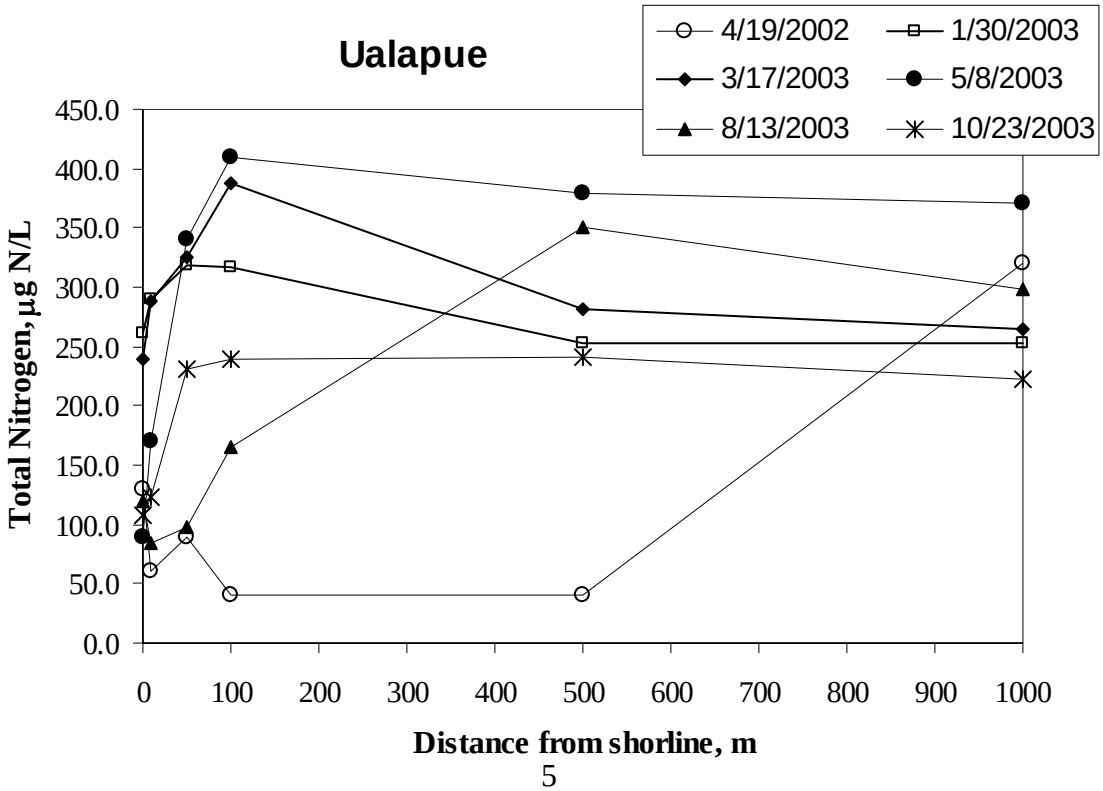
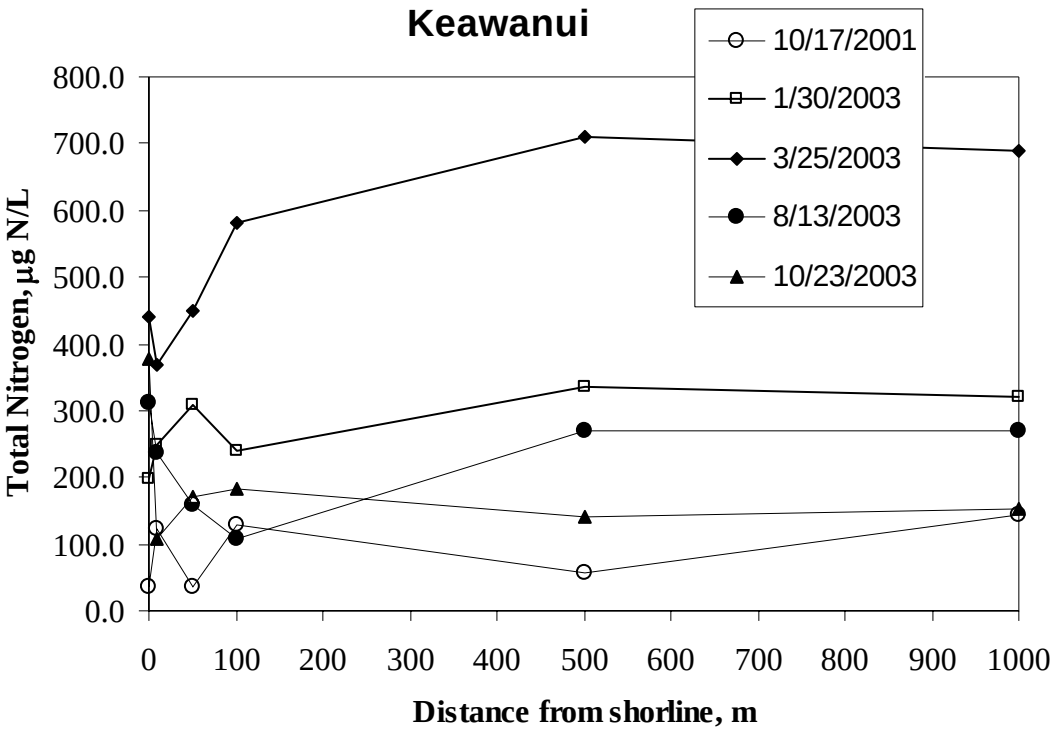
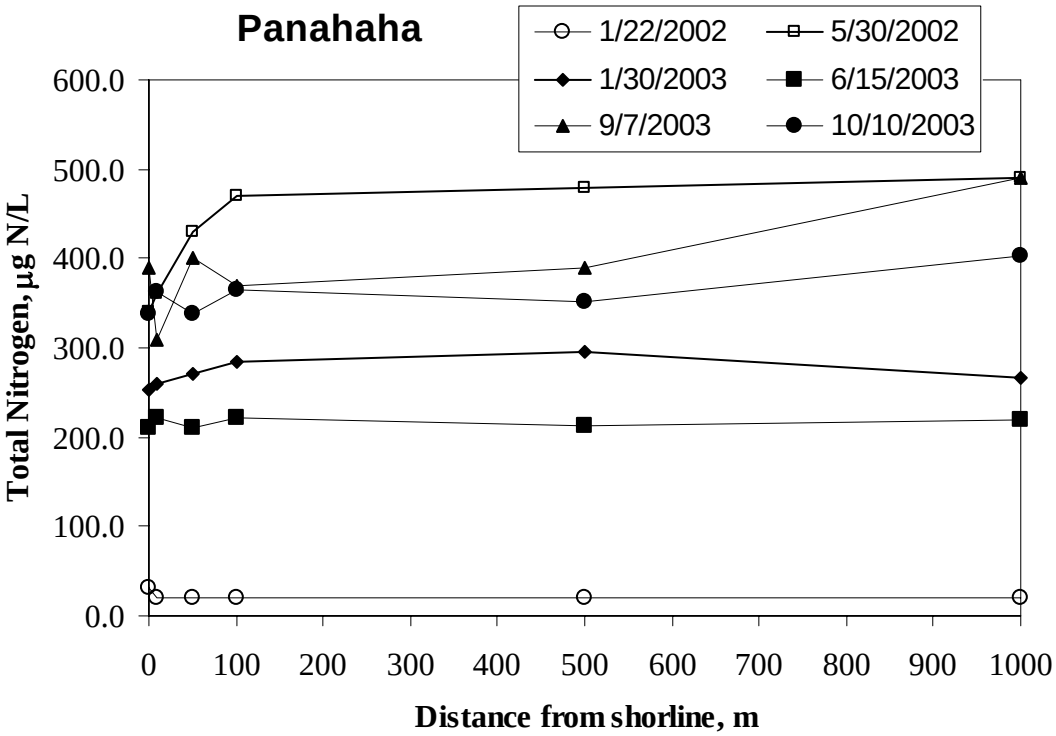
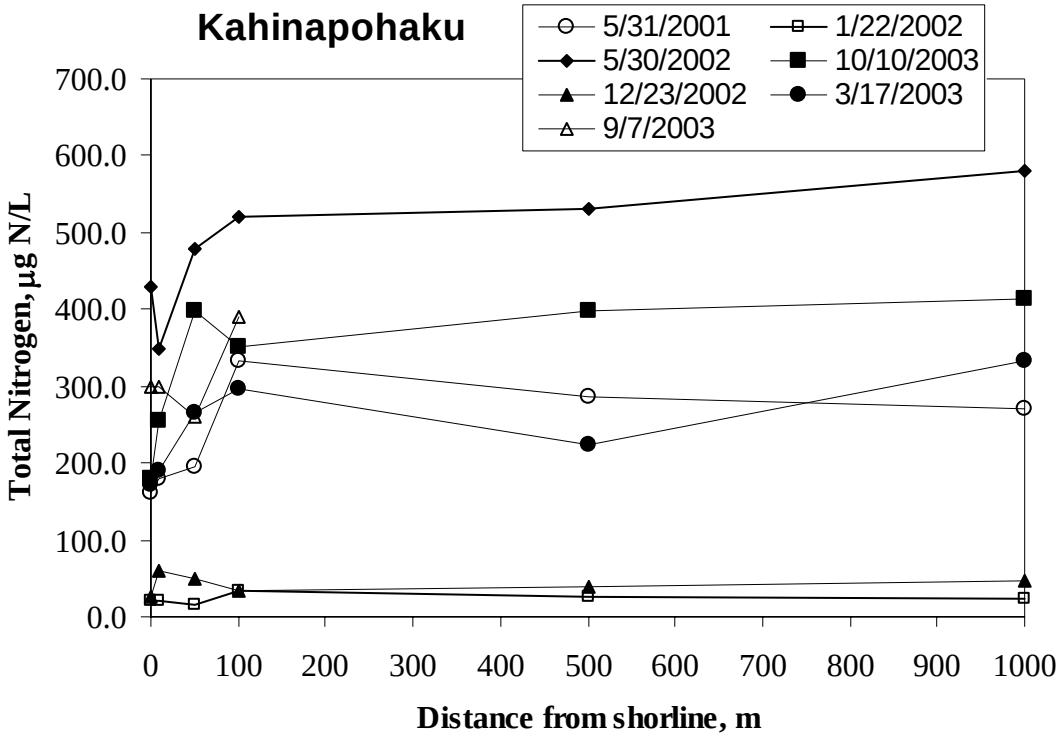
Table 1 Total nitrogen data for Molokai fishponds

	Geometric Mean			10% Exceed		2% Exceed	
Pond	In pond	Outside Pond	All points	In pond	All points	In pond	All points
Niaupala	143.27 (35)	131.95 (18)	123.95 (53)	350.00	374.00	461.60	473.60
Ualapue	161.27 (42)	224.63 (24)	181.92 (66)	263.70	323.00	289.18	385.60
Keawanui	211.97 (45)	229.26 (15)	216.17 (60)	580.00	600.00	661.20	686.40
Panahaha	200.17 (35)	211.04 (24)	203.49 (59)	448.00	460.00	481.92	488.40
Kahinapohaku	171.17 (42)	166.02 (26)	169.18 (68)	511.00	520.00	747.40	580.00




Keawanui
10/17/2001
1/30/2003
3/25/2003
8/13/2003
10/23/2003
Total Nitrogen, µg N/L
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m


Panahaha
1/22/2002
5/30/2002
1/30/2003
6/15/2003
9/7/2003
10/10/2003
Total Nitrogen, µg N/L
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m


Kahinapohaku
5/31/2001
1/22/2002
5/30/2002
10/10/2003
12/23/2002
3/17/2003
9/7/2003
Total Nitrogen, µg N/L
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m

II. AMMONIA NITROGEN

Criteria:
GeoMean not to exceed –> 3.50 μg/L (2.00 dry)
Not to exceed 10% of time –> 8.50 μg/L (5.00 dry)
Not to exceed 2% of time –> 15.00 μg/L (9.00 dry)
The calculated statistics below are for samples collected inside each pond.

Niaupala (CONTROL POND):
GeoMean = 1.05 μg/L (CRITERIA MET)
Exceed 10% value = 2.28 μg/L (CRITERIA MET)
Exceed 2% value = 6.27 μg/L (CRITERIA MET)

Ualapue (production):
GeoMean = 1.64 μg/L (CRITERIA MET)
Exceed 10% value = 2.98 μg/L (CRITERIA MET)
Exceed 2% value = 16.89 μg/L (>15, DOES NOT MEET THE CRITERIA)

Keawanui (production):
GeoMean = 6.28 μg/L (>3.5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 28.8 μg/L (>8.5, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 55.37 μg/L (>15, DOES NOT MEET THE CRITERIA)

Panahaha (production):
GeoMean = 0.75 μg/L (CRITERIA MET)
Exceed 10% value = 2.00 μg/L (CRITERIA MET)
Exceed 2% value = 4.70 μg/L (CRITERIA MET)

Kahinapohaku (restored but no production):
GeoMean = 1.88 μg/L (CRITERIA MET)
Exceed 10% value = 3.31 μg/L (CRITERIA MET)
Exceed 2% value = 8.10 μg/L (CRITERIA MET)

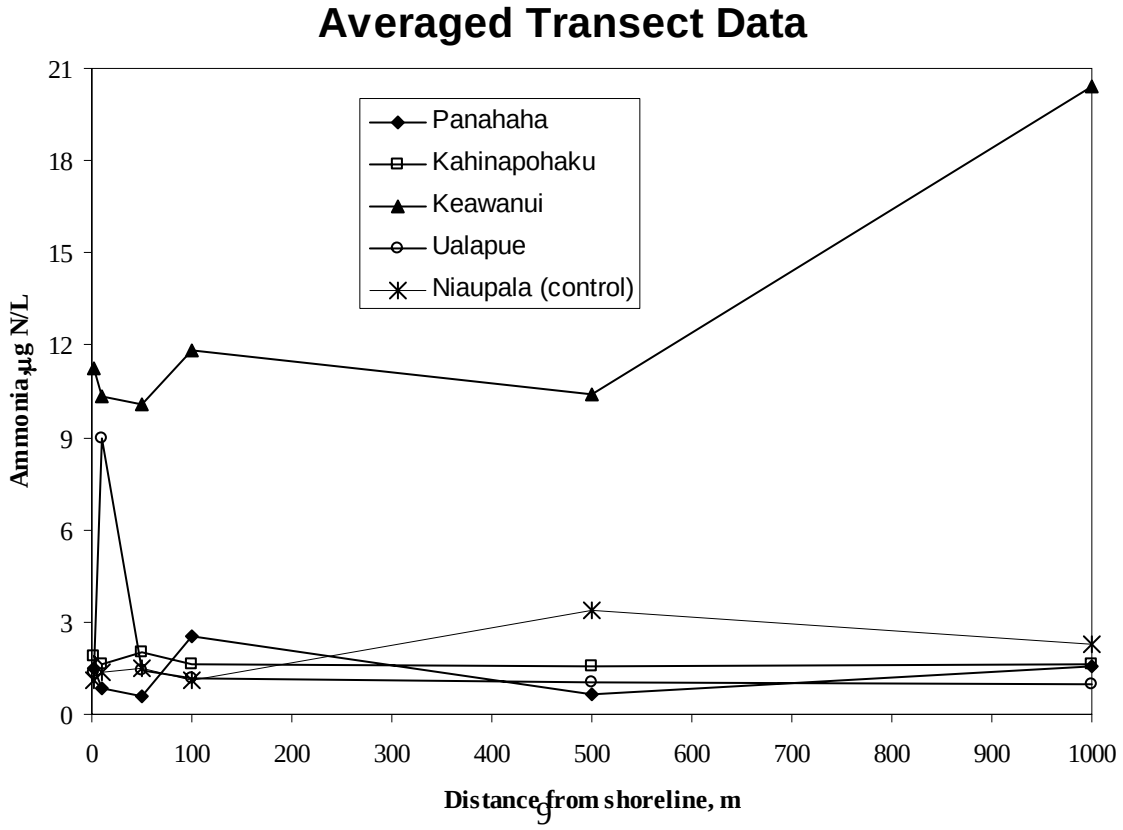
Calculated criteria based on all ponds (n=235) = 2.4 μg/L (Geometric Mean)

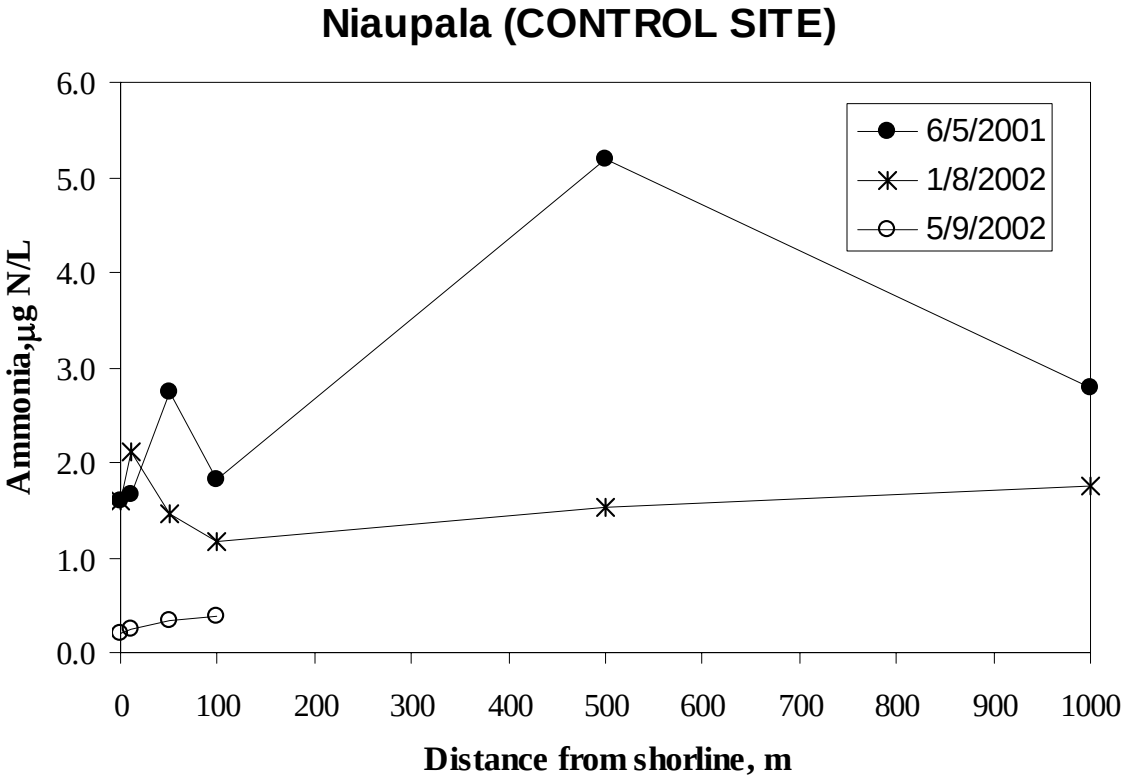
None of the ammonia data met quality control requirements, however, the data were analyzed assuming they are valid. Four of the ponds (Niaupala, Ualaphe, Panahaha, Kahinapohaku) met nearly all of the numeric criteria for ammonia nitrogen in open coastal waters in HAR 11-54 as shown. It could be inferred that production activities in the Keawanui pond have caused increases in ammonia nitrogen above the numeric criteria. A single criteria using all of the data from all of the ponds (inside and outside) was calculated (using a procedure developed for DOH and used to revise HAR 11-54 with specific criteria for the Kona Coast). The calculated criteria is: geometric mean not to exceed 2.4 ug/L. However, this is lower than the existing criteria, and there is no reason to recommend reduction of the existing criteria which is utilized statewide. Table 2 shows additional statistical data for ammonia and allows comparisons between inside the

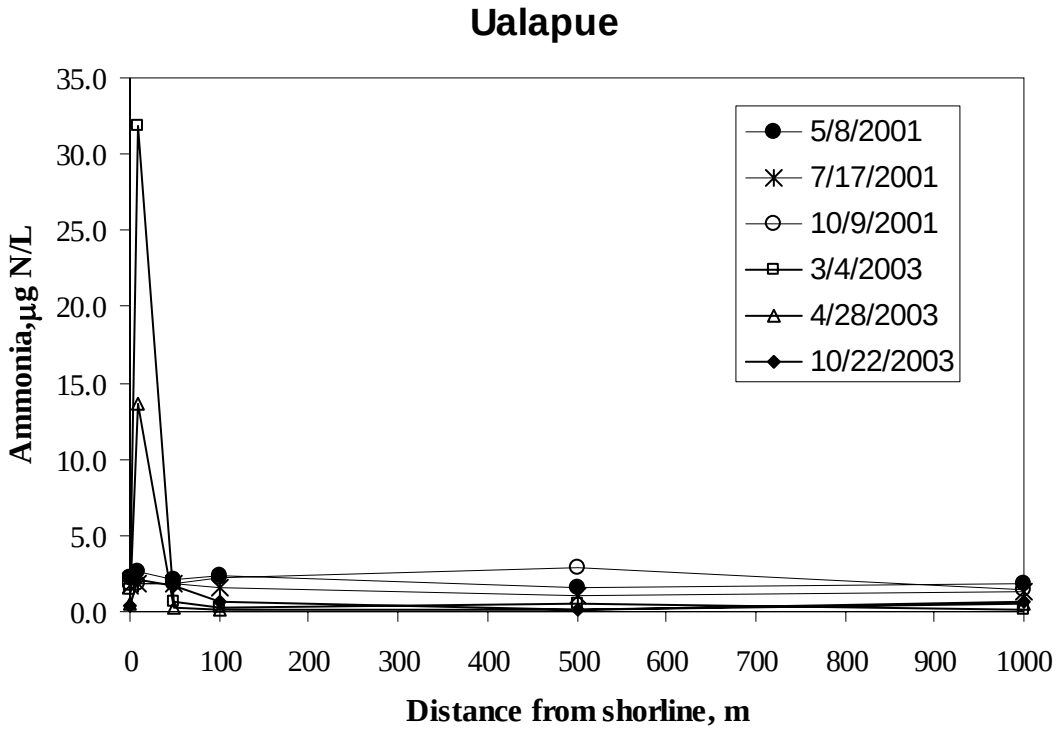
ponds and outside of them. It can be observed that ammonia concentrations inside Ualapue pond are much higher than outside the pond possibly indicating that processes and/or activities occurring inside the pond are causing increased ammonia levels. The same is true but to a lesser extent for both Panahaha and Kahinapohaku. For Keawanui, the opposite case is observed in which the ammonia concentrations outside the pond are slightly greater than the concentrations inside. Keawanui is also the only pond which does not come close to meeting any of the DOH numeric criteria either inside OR outside of the pond. It is not clear why this is, however, it is noted here that this is a relatively small data set (four events, 48 total data points). It would appear that the existing state water quality criteria for ammonia is adequate.

Table 2 Ammonia data for Molokai fishponds

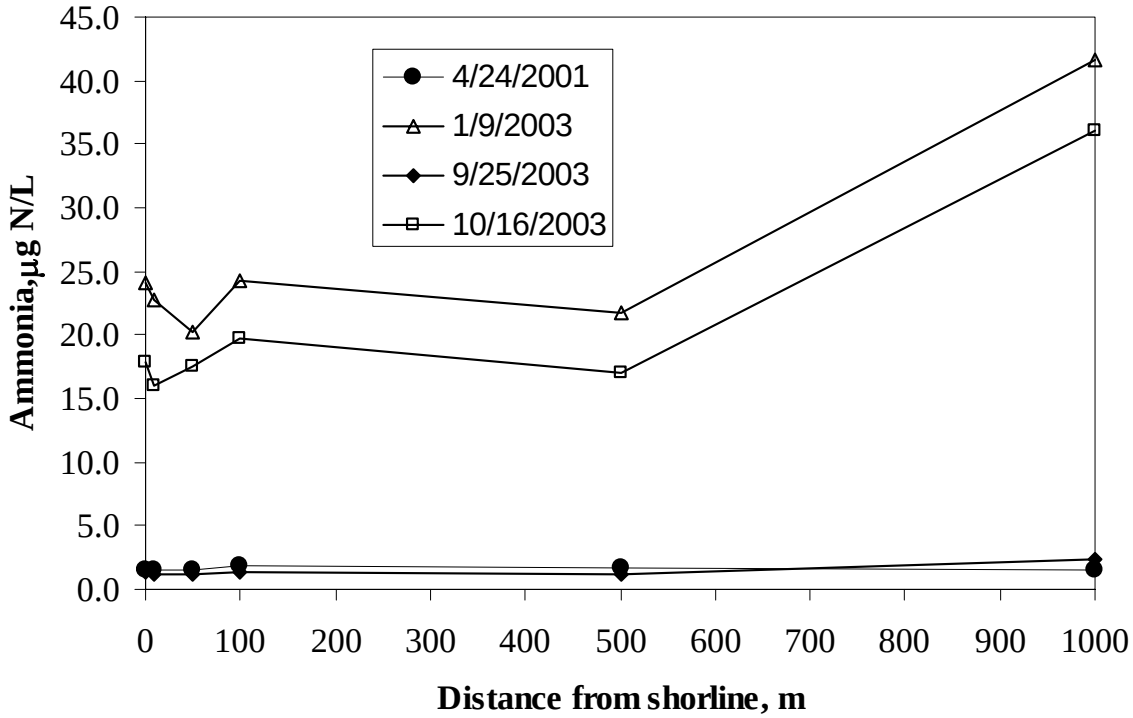
	Geometric Mean			10% Exceed		2% Exceed	
Pond	In pond	Outside Pond	All points	In pond	All points	In pond	All points
Niaupala	1.05 (27)	1.64 (7)	1.15 (34)	2.28	2.62	6.27	6.85
Ualapue	1.64 (42)	0.79 (24)	1.26 (66)	2.98	2.76	16.89	11.21
Keawanui	6.28 (36)	6.48 (12)	6.32 (48)	28.8	34.25	55.37	49.39
Panahaha	0.75 (29)	0.63 (20)	0.70 (49)	2.0	2.0	4.70	5.20
Kahinapohaku	1.88 (30)	1.63 (18)	1.78 (48)	3.31	3.12	8.10	4.50



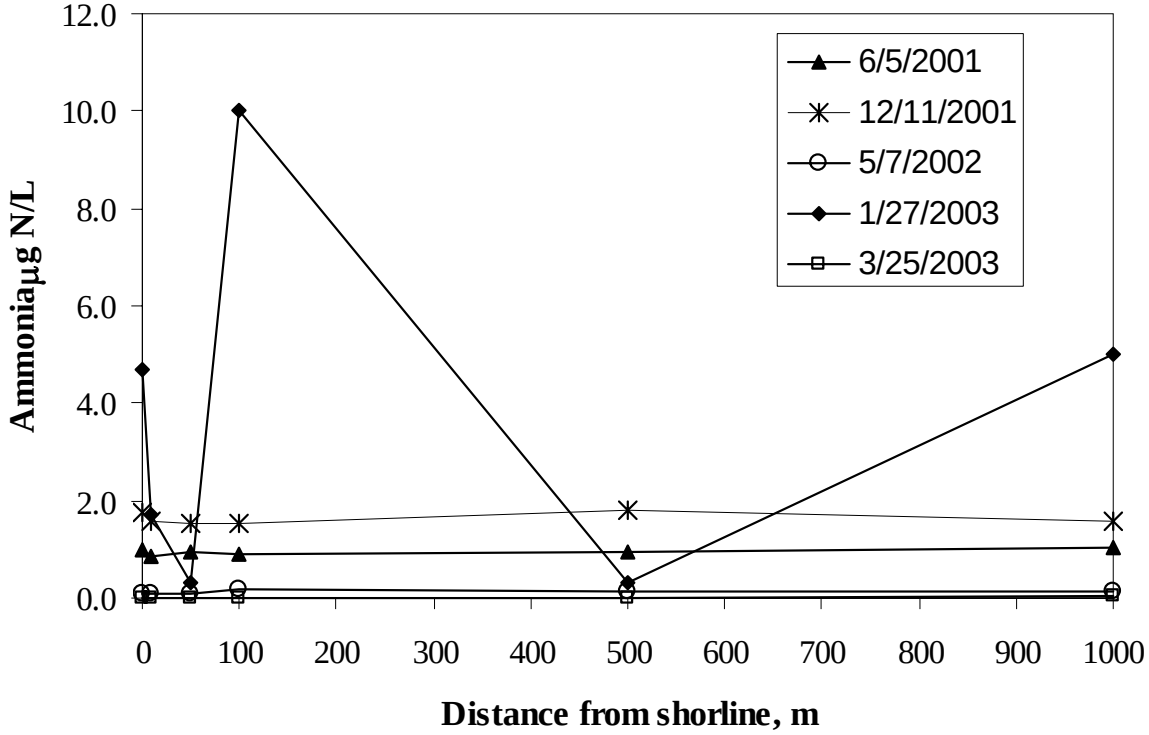

Niaupala (CONTROL SITE)
Ammonia,µg N/L
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m
6/5/2001
1/8/2002
5/9/2002

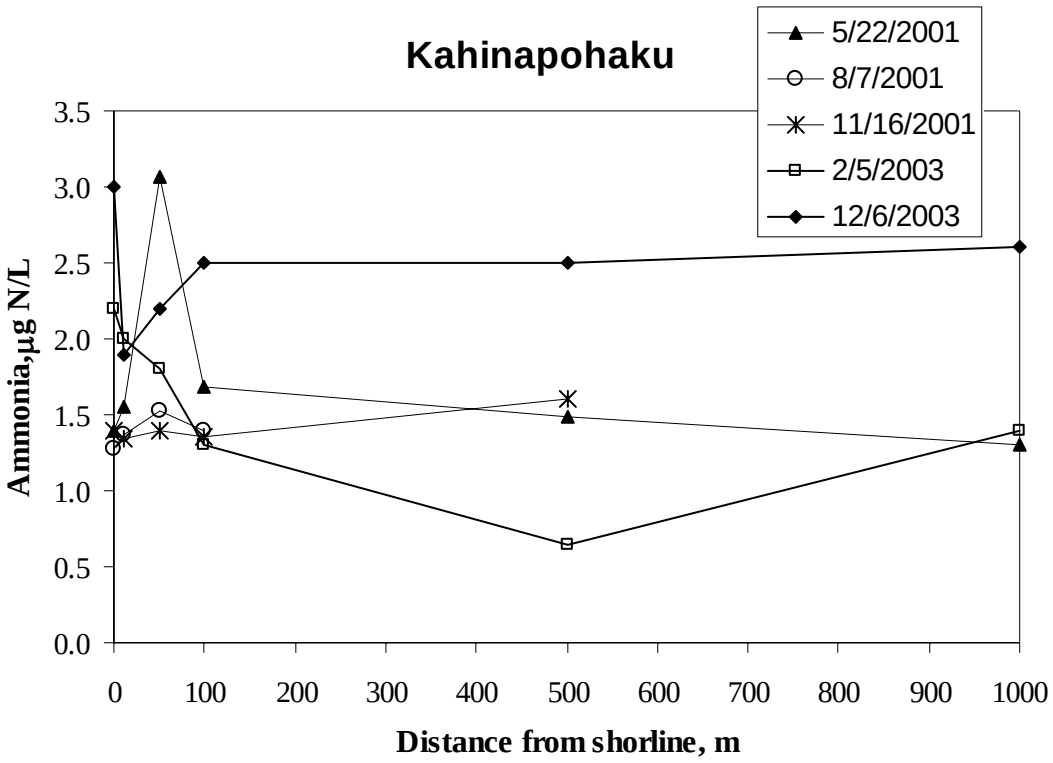

Ualapue
Ammonia,µg N/L
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m
5/8/2001
7/17/2001
10/9/2001
3/4/2003
4/28/2003
10/22/2003

Keawanui



Panahaha




Kahinapohaku
5/22/2001
8/7/2001
11/16/2001
2/5/2003
12/6/2003
Ammonia,µg N/L
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m

III. NITRATE NITROGEN

Criteria:
GeoMean not to exceed –> 5 μg/L (3.5 dry)
Not to exceed 10% of time –> 14 μg/L (10 dry)
Not to exceed 2% of time –> 25 μg/L (20 dry)
The calculated statistics below are for samples collected inside each pond.

Niaupala (CONTROL POND):

GeoMean = 19.6 μg/L	(>5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 71 μg/L	(>14, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 75 μg/L	(>25, DOES NOT MEET THE CRITERIA)
Calculated criteria = 16.9 μg/L	(Geometric Mean, based on pond and transects)

Ualapue (production):

GeoMean = 14.2 μg/L	(>5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 49.7 μg/L	(>14, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 50.0 μg/L	(>25, DOES NOT MEET THE CRITERIA)
Calculated criteria = 19.1 μg/L	(Geometric Mean, based on pond and transect)

Keawanui (production):

GeoMean = 14.8 μg/L	(>5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 48.7 μg/L	(>14, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 150.4 μg/L	(>25, DOES NOT MEET THE CRITERIA)
Calculated criteria = 13.9 μg/L	(Geometric Mean, based on pond and transect)

Panahaha (production):

GeoMean = 17.5 μg/L	(>5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 88.0 μg/L	(>14, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 92.0 μg/L	(>25, DOES NOT MEET THE CRITERIA)
Calculated criteria = 22.0 μg/L	(Geometric Mean, based on pond and transect)

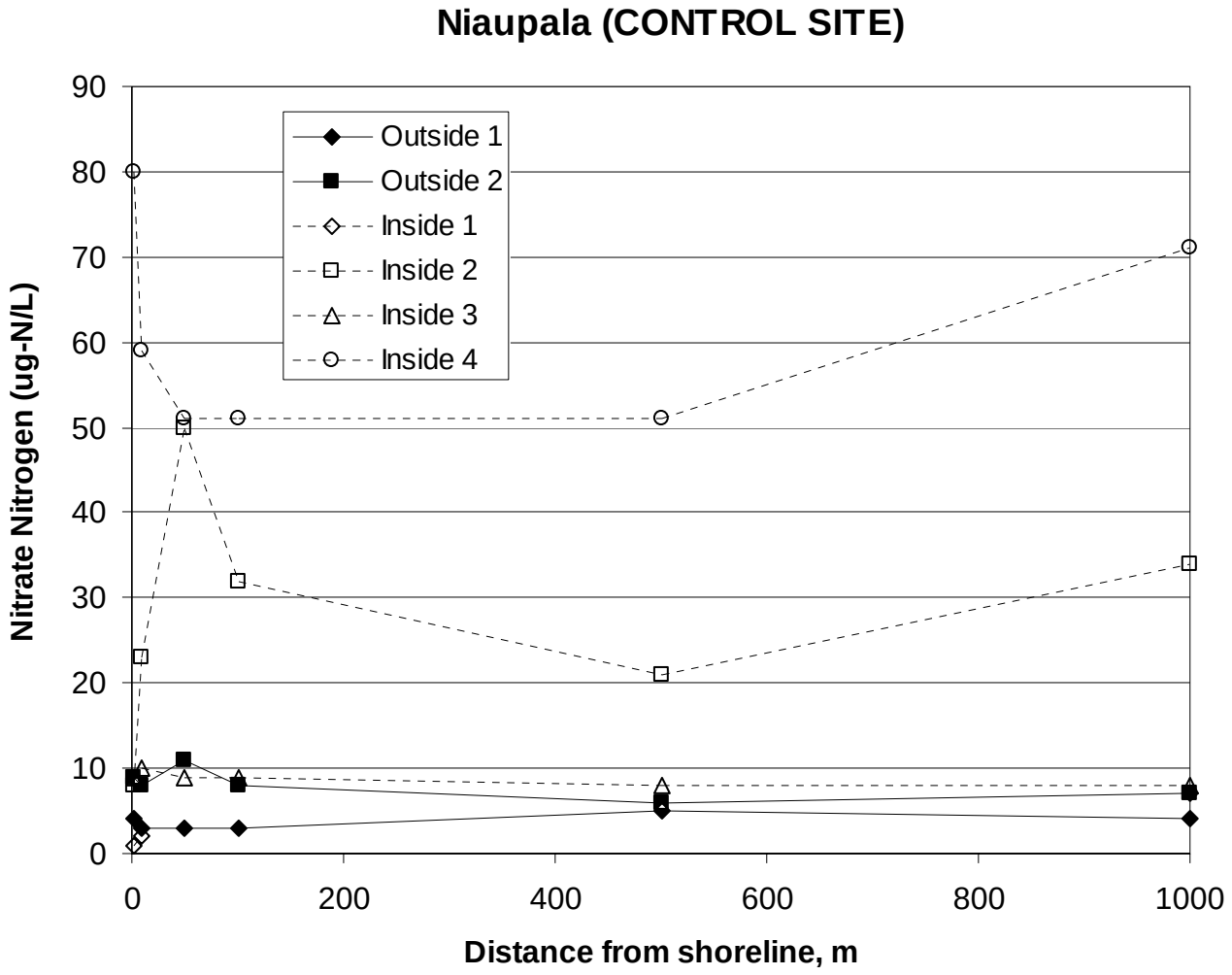
Kahinapohaku (restored but no production):

GeoMean = 27.5 μg/L	(>5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 133.6 μg/L	(>14, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 209.2 μg/L	(>25, DOES NOT MEET THE CRITERIA)
Calculated criteria = 23.2 μg/L	(Geometric Mean, based on pond and transect)

Calculated criteria based on all ponds (n=279) = 16.4 μg/L (Geometric Mean)

None of the ponds meet the numeric criteria for nitrate nitrogen in open coastal waters in HAR 11-54 as shown. All of the ponds exceed the criteria by approximately 300% or more. Criteria were calculated (using a procedure developed for DOH and used to revise HAR 11-54 with specific criteria for the Kona Coast) based upon the data for each pond individually. The criteria calculated for the "control" pond is greater than one of the three "production" ponds. Based on the geometric mean values, it could not be

argued that production activities have caused increases in nitrate concentrations. If all of the nitrate data from all of the ponds are used, then the recommended criteria would be: geometric mean not to exceed 16.4 μg/L. However, the derived criteria is somewhat problematic since the control pond itself does not meet the criteria even without active production systems in place (Panahaha and Kahinapohaku also would not meet this criteria). A more appropriate criteria might be: geometric mean not to exceed 20 μg/L. Only Kahinapohaku would not meet this criteria. A criteria which all of the ponds could meet would be: geometric mean not to exceed 30 μg/L.



For inside the control pond, it is apparent that there is significant variability in nitrate nitrogen concentration profiles along the same transects for different sampling events. In addition, the control transect located outside the pond always had lower and less variable concentrations than the transect through the pond. This would seem to indicate that something occurring within the pond is the cause of the elevated nitrate nitrogen. Since Niaupala is the control pond where no human-induced production activities occur, the elevated nitrate concentrations must be a "natural" condition.

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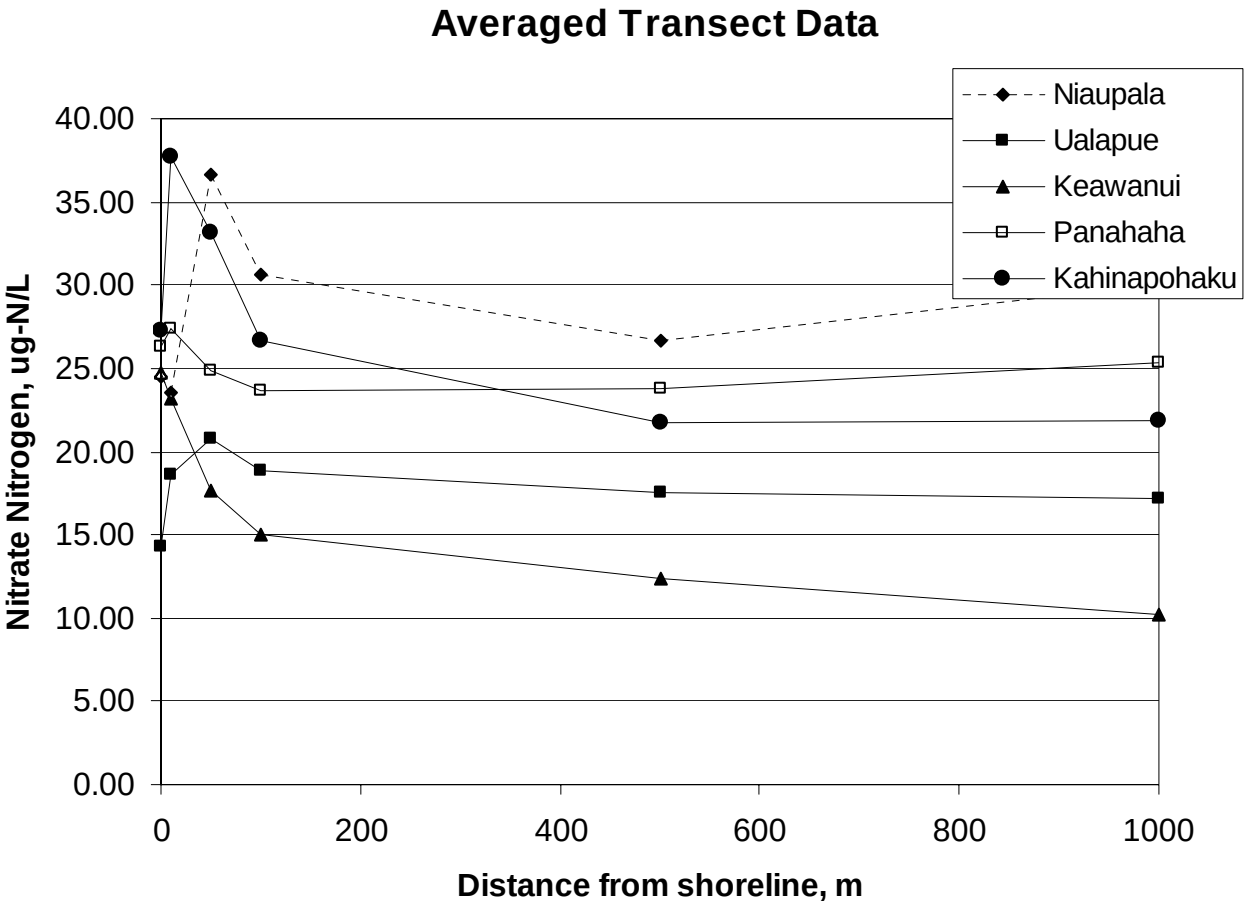

The nitrate nitrogen data for transects through each of the ponds indicate that nitrate concentrations mostly decrease somewhat with distance from the shoreline as expected. Also, the nitrate concentrations in nearly all of the ponds have lower values than the "control" pond. This later finding is not expected and may just indicate the natural variability of nitrate concentrations within these types of fishponds. Table 3 shows additional statistical data for nitrate and allows comparisons between inside the ponds and outside of them. It can be observed that nitrate concentrations inside all of the ponds are higher than outside the ponds possibly indicating that processes and/or activities occurring inside the pond are causing increased nitrate levels.

Table 3 Nitrate data for Molokai fishponds

	Geometric Mean			10% Exceed		2% Exceed	
Pond	In pond	Outside Pond	All points	In pond	All points	In pond	All points
Niaupala	19.57 (29)	12.47 (16)	14.64 (45)	71.00	71.00	74.96	71.00
Ualapue	14.23 (38)	13.92 (19)	14.13 (57)	49.70	47.00	50.00	50.00
Keawanui	14.76 (40)	8.08 (13)	12.73 (53)	48.70	48.10	150.40	145.94
Panahaha	17.52 (27)	10.82 (23)	14.04 (50)	88.00	84.00	92.00	92.00
Kahinapohaku	27.48 (38)	16.18 (24)	22.38 (62)	133.60	113.10	209.16	172.40

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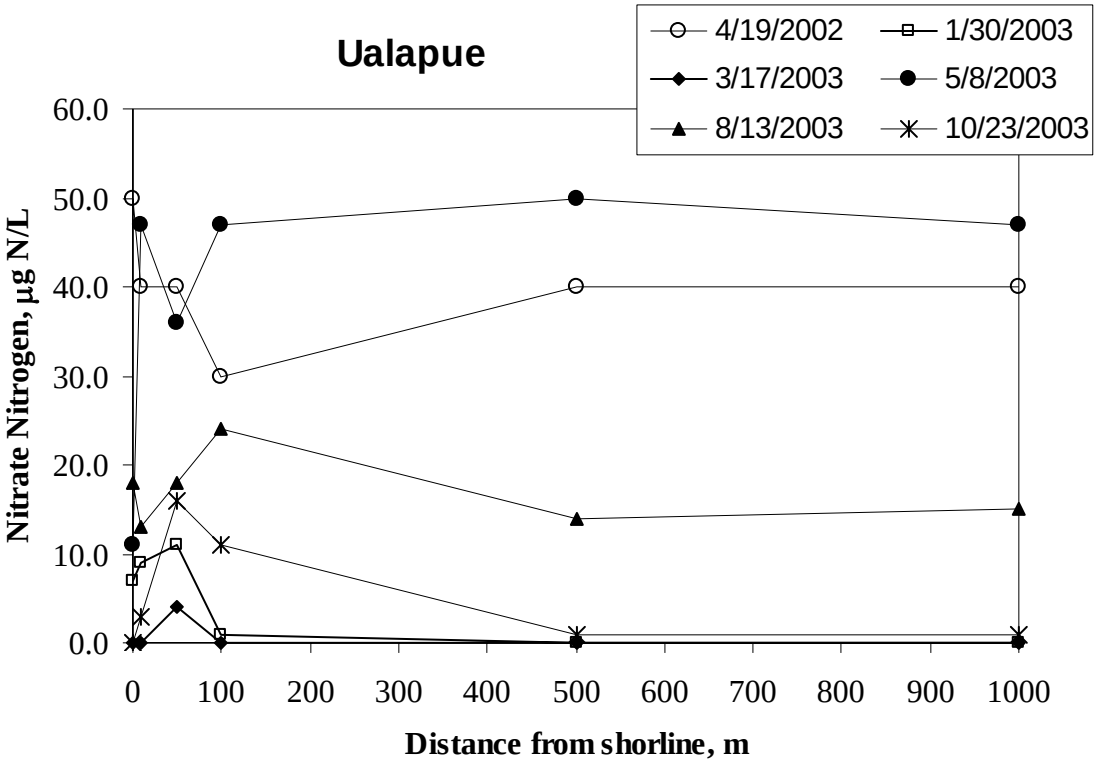
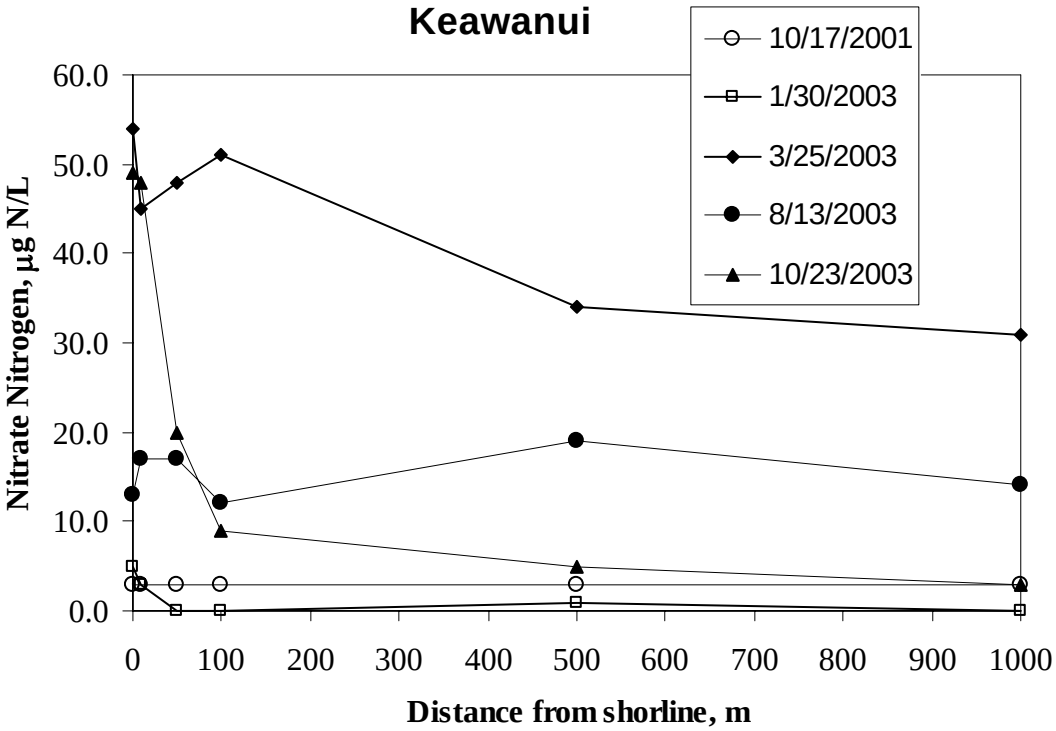
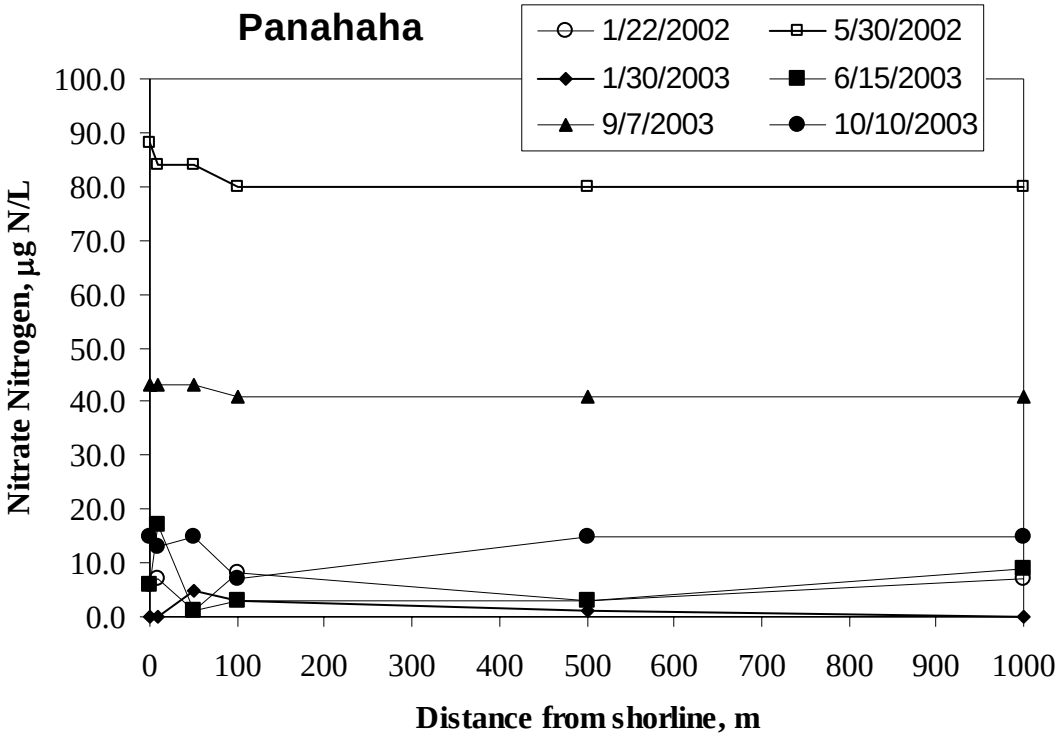
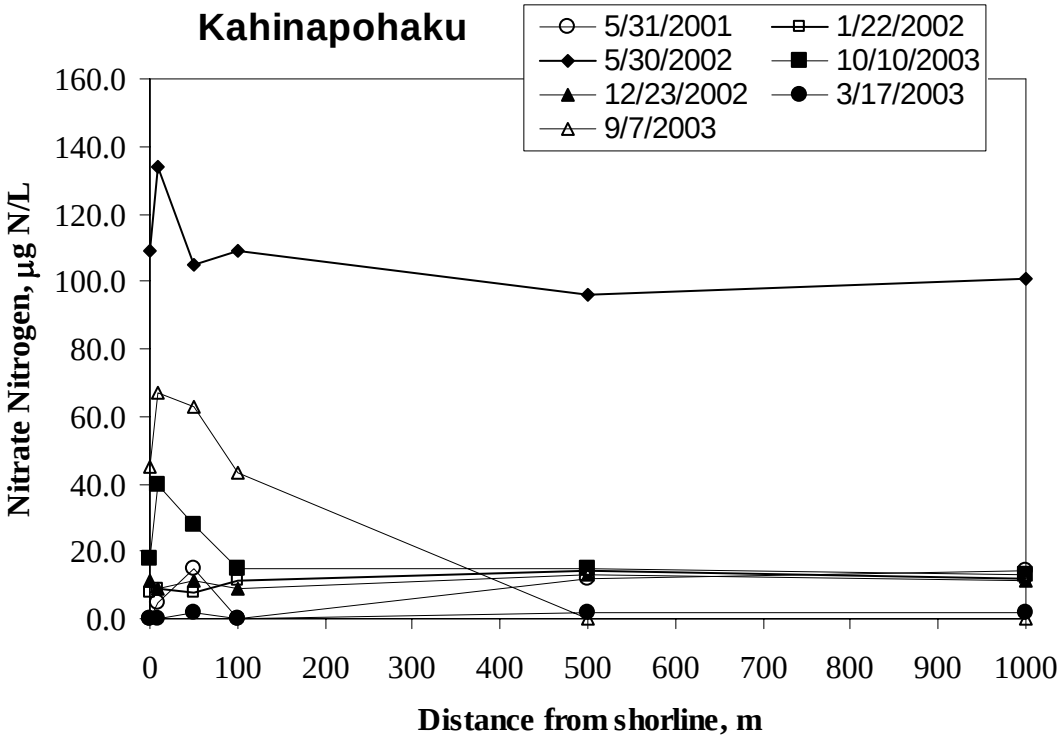

Ualapue
4/19/2002
1/30/2003
3/17/2003
5/8/2003
8/13/2003
10/23/2003
Nitrate Nitrogen, µg N/L
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m


Keawanui
10/17/2001
1/30/2003
3/25/2003
8/13/2003
10/23/2003
Nitrate Nitrogen, µg N/L
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m


Panahaha
1/22/2002
5/30/2002
1/30/2003
6/15/2003
9/7/2003
10/10/2003
Nitrate Nitrogen, µg N/L
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m


Kahinapohaku
5/31/2001
1/22/2002
5/30/2002
10/10/2003
12/23/2002
3/17/2003
9/7/2003
Nitrate Nitrogen, µg N/L
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m

`

IV. TOTAL PHOSPHORUS

Criteria:
GeoMean not to exceed –> 20 μg/L (16 dry)
Not to exceed 10% of time –> 40 μg/L (30 dry)
Not to exceed 2% of time –> 60 μg/L (45 dry)
The calculated statistics below are for samples collected inside each pond.

Niaupala (CONTROL POND):

GeoMean = 47.51 μg/L	(>20, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 66.4 μg/L	(>40, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 74.08 μg/L	(>60, DOES NOT MEET THE CRITERIA)
Calculated criteria = 45.1 μg/L	(Geometric Mean, based on pond and transects)

Ualapue (production):

GeoMean = 68.39 μg/L	(>20, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 221.64 μg/L	(>40, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 515.75 μg/L	(>60, DOES NOT MEET THE CRITERIA)
Calculated criteria = 56.1 μg/L	(Geometric Mean, based on pond and transect)

Keawanui (production):

GeoMean = 41.08 μg/L	(>20, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 67.72 μg/L	(>40, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 92.88 μg/L	(>60, DOES NOT MEET THE CRITERIA)
Calculated criteria = 44.5 μg/L	(Geometric Mean, based on pond and transect)

Panahaha (production):

GeoMean = 16.71 μg/L	(CRITERIA MET)
Exceed 10% value = 44.02 μg/L	(>40, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 61.3 μg/L	(>60, DOES NOT MEET THE CRITERIA)

Kahinapohaku (restored but no production):

GeoMean = 66.75 μg/L	(>20, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 205.68 μg/L	(>40, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 222.24 μg/L	(>60, DOES NOT MEET THE CRITERIA)
Calculated criteria = 81.1 μg/L	(Geometric Mean, based on pond and transect)

Calculated criteria based on all ponds (n=263) = 40 μg/L (Geometric Mean)

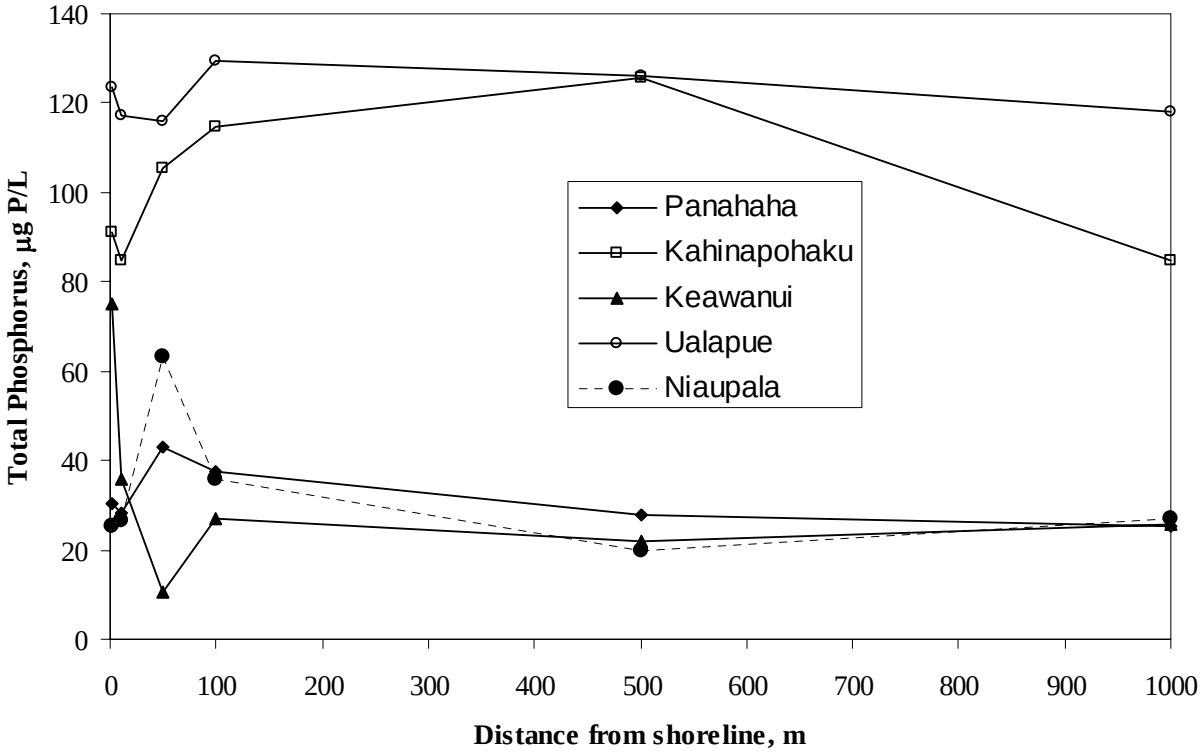
None of the phosphorus data met quality control requirements, however, the data were analyzed assuming they are valid. Four of the ponds including the control pond (Niaupala, Ualaphe, Keawanui, Kahinapohaku) met none of the numeric criteria for total phosphorus in open coastal waters in HAR 11-54 as shown. Panahaha pond only met the geometric mean criteria. A single criteria using all of the data from all of the ponds was calculated (using a procedure developed for DOH and used to revise HAR 11-54 with specific criteria for the Kona Coast). The

calculated criteria is: geometric mean not to exceed 40 ug/L. However, only Panahaha would meet this criteria. A more appropriate criteria might be: geometric mean not to exceed 50 ug/L. At least the control pond (as well as Panahaha and Keawanui) would meet this criteria. However, Kahinapohaku (which does not have production activities) would not meet this criteria and thus, the most appropriate criteria might be: geometric mean not to exceed 70 ug/L. All of the ponds would meet this later criteria. Table 4 shows additional statistical data for total phosphorus and allows comparisons between inside the ponds and outside of them. It can be observed that phosphorus concentrations inside Niaupala (control), Ualapue, and Keawanui are much higher than outside these ponds possibly indicating that processes and/or activities occurring inside the pond are causing increased phosphorus levels. For Kahinapohaku and Panahaha, the opposite case is observed in which the phosphorus concentrations outside the pond are slightly greater (10%) and significantly greater (100%), respectively than the concentrations inside. Because of the fact that phosphorus levels are nearly two times greater inside the control pond than outside, it could be inferred that this is a "natural" condition, not caused by human-influenced production activities, that cannot be avoided. However, it is notable that the mean values outside of the control pond are lower than all of the other ponds and significantly lower than Kahinapohaku. It is also notable that none of the "outside the ponds" mean data meets the existing State criteria (20 ug/L), however, all but Kahinapohaku would meet the "calculated" criteria (40 ug/L).

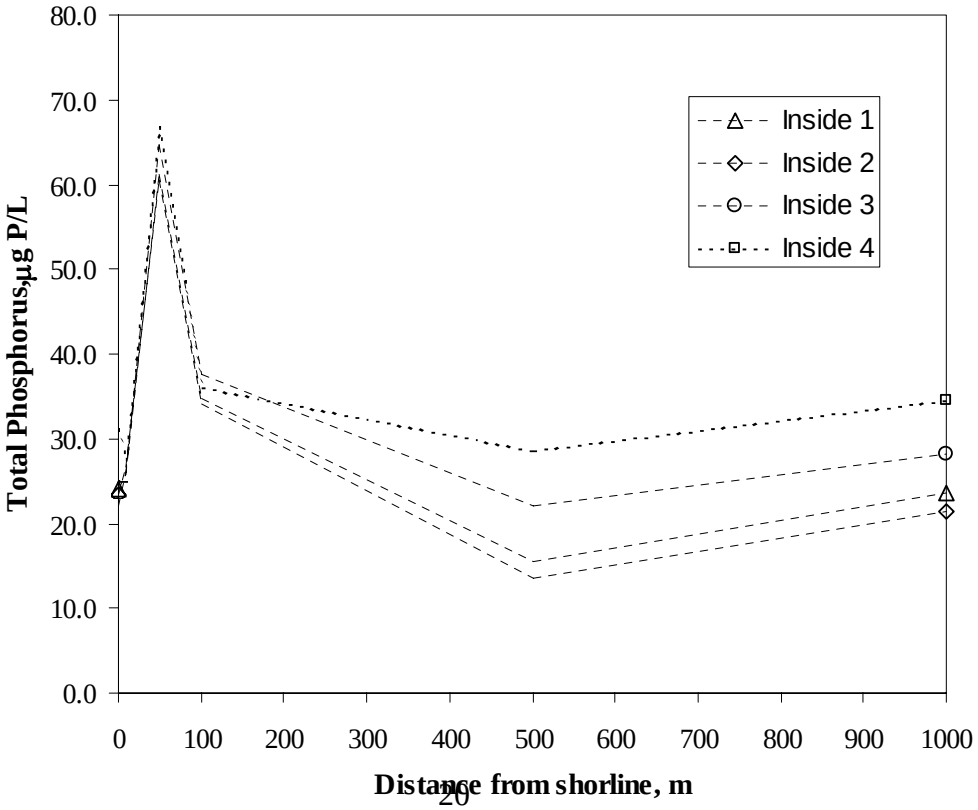
Table 4 Phosphorus data for Molokai fishponds

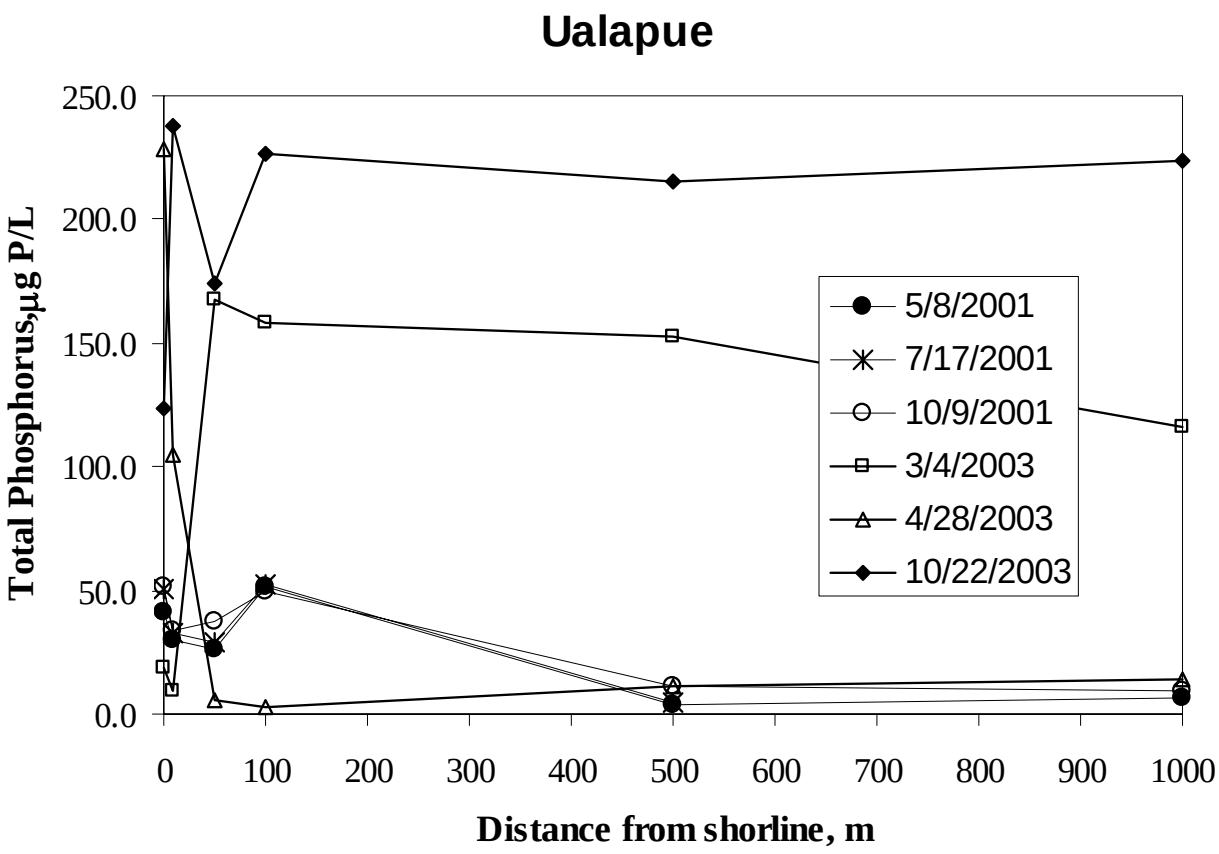
	Geometric Mean			10% Exceed		2% Exceed	
Pond	In pond	Outside Pond	All points	In pond	All points	In pond	All points
Niaupala	47.51 (36)	26.23 (12)	40.95 (48)	66.40	65.89	74.08	72.50
Ualapue	68.39 (42)	33.41 (23)	52.28 (65)	221.64	220.16	515.75	423.04
Keawanui	41.08 (45)	33.12 (15)	39.28 (60)	67.72	70.34	92.88	91.08
Panahaha	16.71 (35)	30.21 (24)	20.95 (59)	44.02	53.32	61.28	61.53
Kahinapohaku	66.75 (30)	73.83 (20)	69.50 (50)	205.68	226.14	222.24	250.64

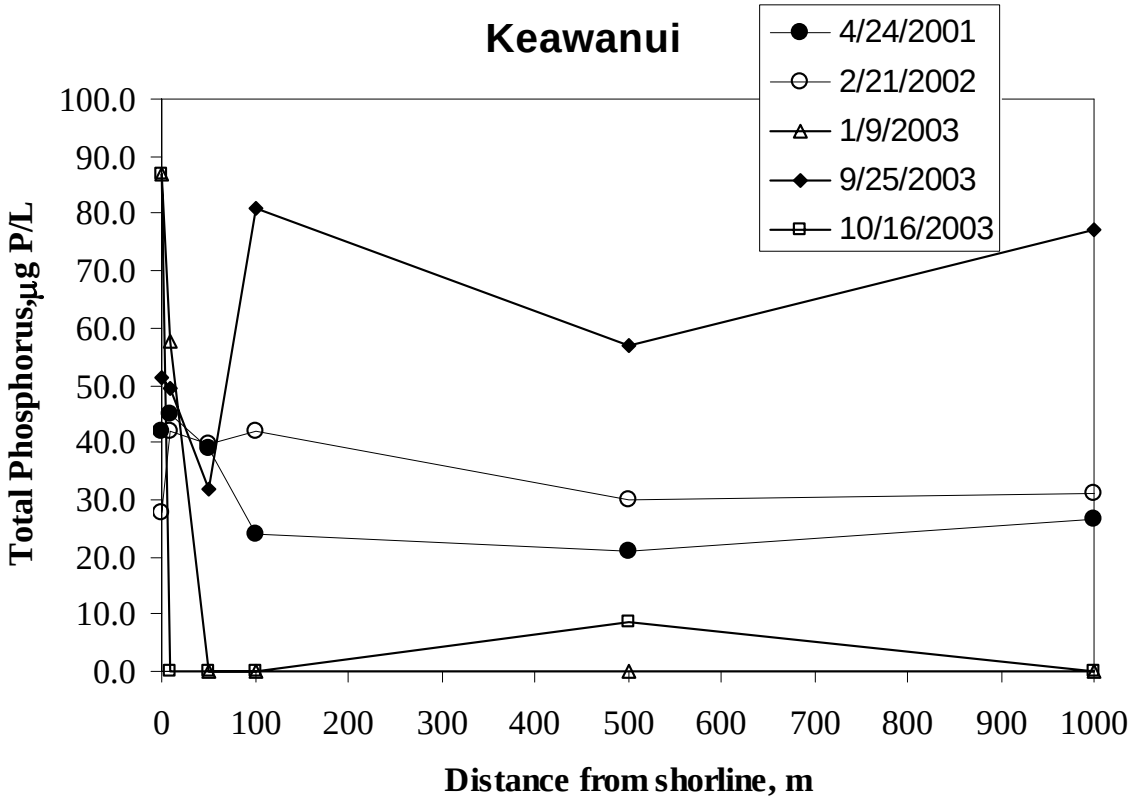
Averaged Transect Data

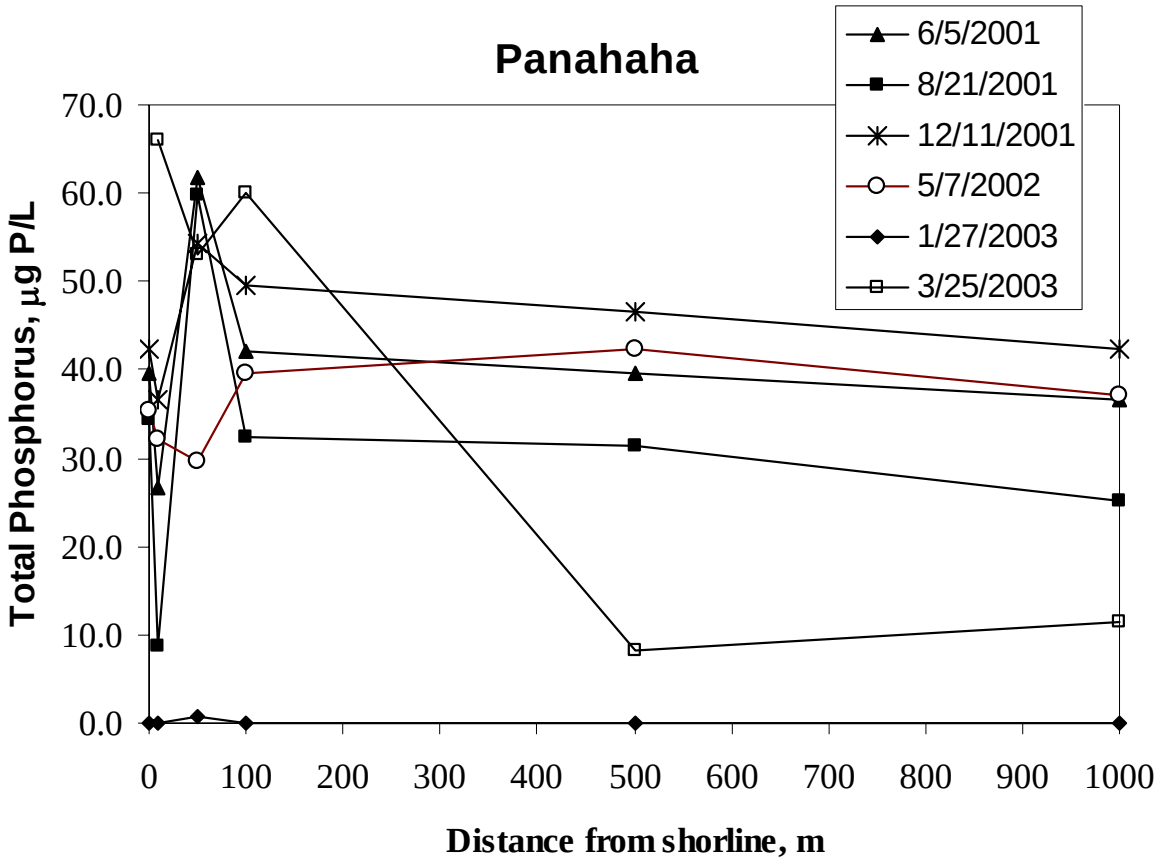


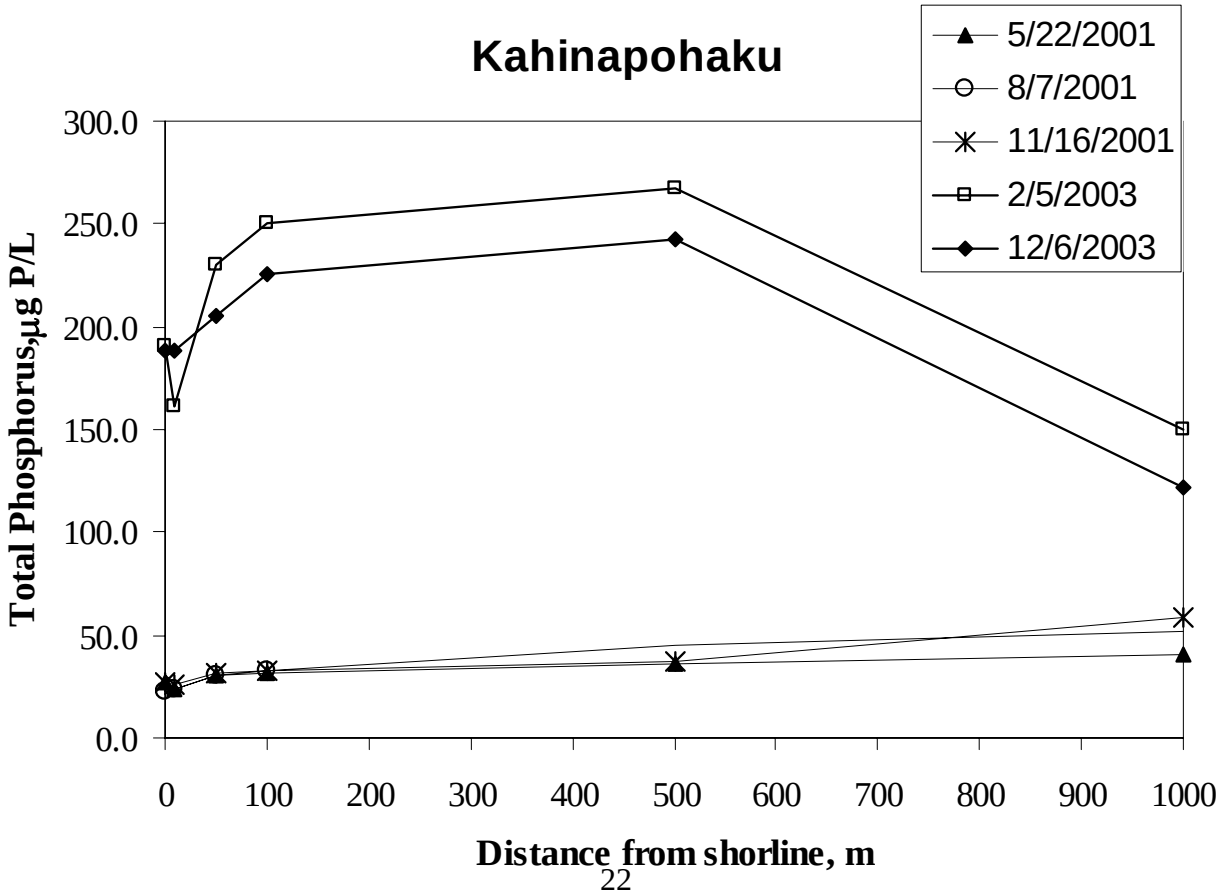
Niaupala (CONTROL SITE)




Ualapue
250.0
200.0
150.0
100.0
50.0
0.0
Total Phosphorus,µg P/L
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m
5/8/2001
7/17/2001
10/9/2001
3/4/2003
4/28/2003
10/22/2003


Keawanui
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Total Phosphorus,µg P/L
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m
4/24/2001
2/21/2002
1/9/2003
9/25/2003
10/16/2003


Panahaha
6/5/2001
8/21/2001
12/11/2001
5/7/2002
1/27/2003
3/25/2003
Total Phosphorus, µg P/L
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m


Kahinapohaku
5/22/2001
8/7/2001
11/16/2001
2/5/2003
12/6/2003
Total Phosphorus,µg P/L
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m

V. CHLOROPHYLL-A

Criteria:
GeoMean not to exceed –> 0.30 μg/L (0.15 dry)
Not to exceed 10% of time –> 0.90 ug/L (0.50 dry)
Not to exceed 2% of time –> 1.75 mg/L (1.00 dry)
The calculated statistics below are for samples collected inside each pond.

Niaupala (CONTROL POND):

GeoMean = 4.27 μg/L	(>0.3, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 12.44 μg/L	(>0.9, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 13.86 μg/L	(>1.75, DOES NOT MEET THE CRITERIA)
Calculated criteria = 3.04 μg/L	(Geometric Mean, based on pond and transects)

Ualapue (production):

GeoMean = 5.57 μg/L	(>0.3, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 9.04 μg/L	(>0.9, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 11.20 μg/L	(>1.75, DOES NOT MEET THE CRITERIA)
Calculated criteria = 5.96 μg/L	(Geometric Mean, based on pond and transect)

Keawanui (production):

GeoMean = 1.72 μg/L	(>0.3, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 4.92 μg/L	(>0.9, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 8.49 μg/L	(>1.75, DOES NOT MEET THE CRITERIA)
Calculated criteria = 1.80 μg/L	(Geometric Mean, based on pond and transect)

Panahaha (production):

GeoMean = 0.92 μg/L	(>0.3, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 1.73 μg/L	(>0.9, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 2.60 μg/L	(>1.75, DOES NOT MEET THE CRITERIA)
Calculated criteria = 1.54 μg/L	(Geometric Mean, based on pond and transect)

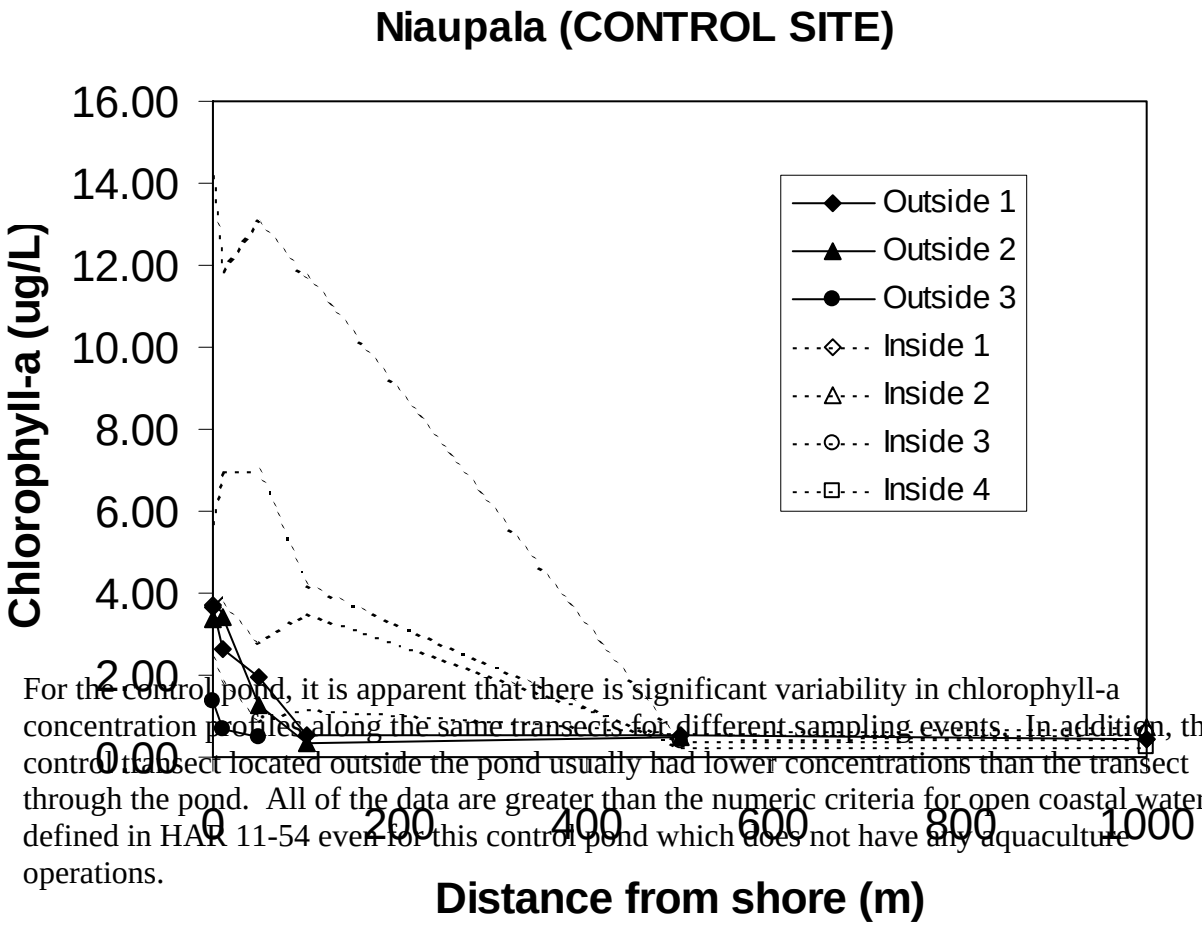
Kahinapohaku (restored but no production):

GeoMean = 1.22 μg/L	(>0.3, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 2.76 μg/L	(>0.9, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 3.84 μg/L	(>1.75, DOES NOT MEET THE CRITERIA)
Calculated criteria = 1.83 μg/L	(Geometric Mean, based on pond and transect)

Calculated criteria based on all ponds (n=267) = 1.9 μg/L (Geometric Mean)

None of the ponds meet the numeric criteria for open coastal waters in HAR 11-54 as shown. Criteria were calculated (using a procedure developed for DOH and used to revise HAR 11-54 with specific criteria for the Kona Coast) based upon the data for each pond individually. The criteria calculated for the "control" pond is greater than that for two of the three "production" ponds. It could be inferred that production activities in the Ualapue pond have caused increases

in Chlorophyll-a concentrations. If all of the chlorophyll-a data from all of the ponds are used, then the calculated criteria would be: geometric mean not to exceed 2 μg/L. Both Niaupala and Ualalpue would not meet this criteria. This criteria is somewhat problematic since the control pond does not meet the criteria even without active production systems in place. A more appropriate criteria might be: geometric mean not to exceed 6 μg/L. All the ponds would meet this criteria. The chlorophyll-a data for the transects through the control pond show how the concentrations are generally much higher inside the pond than outside, that there is quite a lot of variability between sampling events, and that far from shore (500 to 1000 m) concentrations are consistently low.



For the control pond, it is apparent that there is significant variability in chlorophyll-a concentration profiles along the same transects for different sampling events. In addition, the control transect located outside the pond usually had lower concentrations than the transect through the pond. All of the data are greater than the numeric criteria for open coastal waters as defined in HAR 11-54 even for this control pond which does not have any aquaculture operations.

The chlorophyll-a data for transects through each of the ponds indicates that some ponds have less activity than others. It is likely that the differences observed have something to due with the nature of the circulation in and around these fishponds. Since Kahinapohaku and Pananhaha both have good circulation, the chlorophyll-a profile is flat and the samples near the shoreline have low concentrations. The other three ponds are more protected from waves and circulation

and thus have higher concentrations of algae inside the pond compared to out beyond the walls (500 m) and beyond the reef (1000 m). Table 4 shows additional statistical data for chlorophyll-a and allows comparisons between inside the ponds and outside of them. It can be observed that concentrations of chlorophyll-a are much higher inside all of the ponds than outside. Reduced circulation and availability of nutrients stimulate algae growth in the ponds.

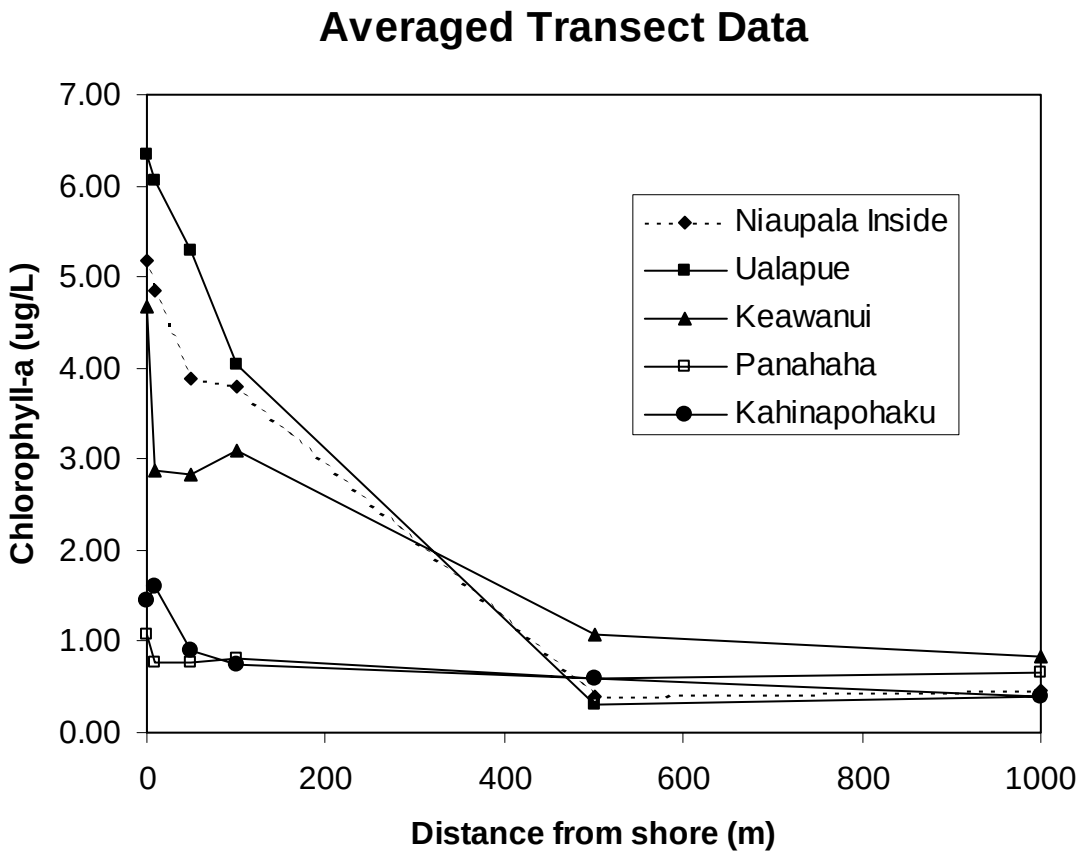
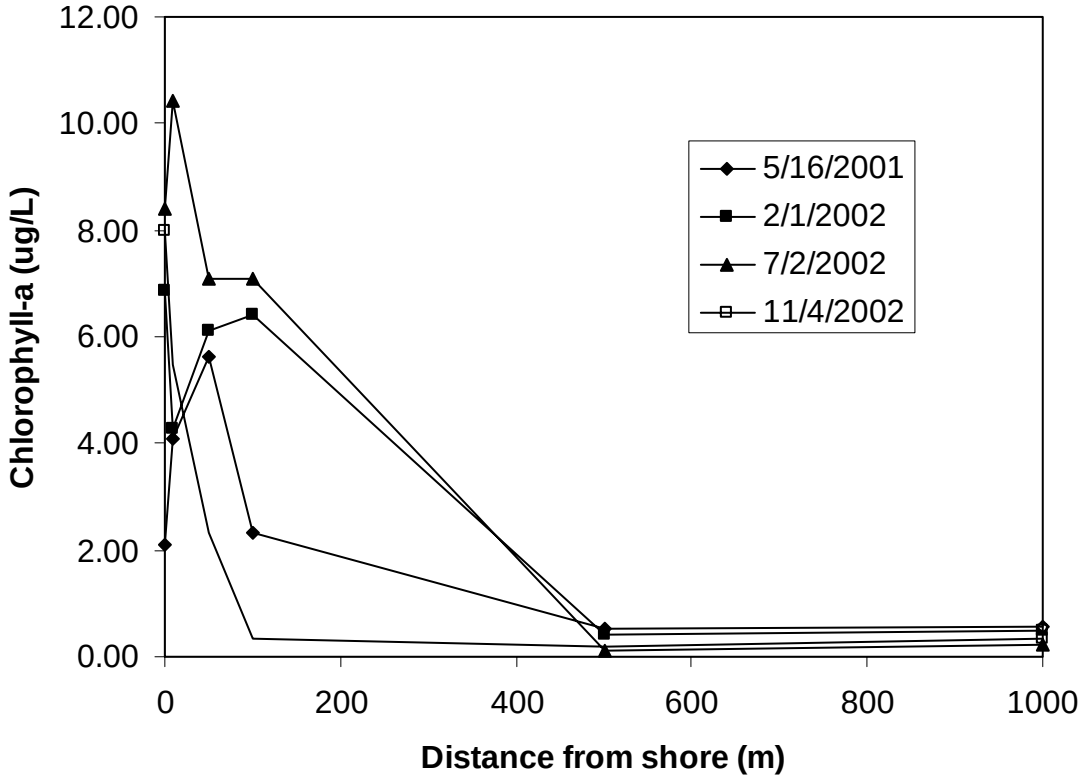


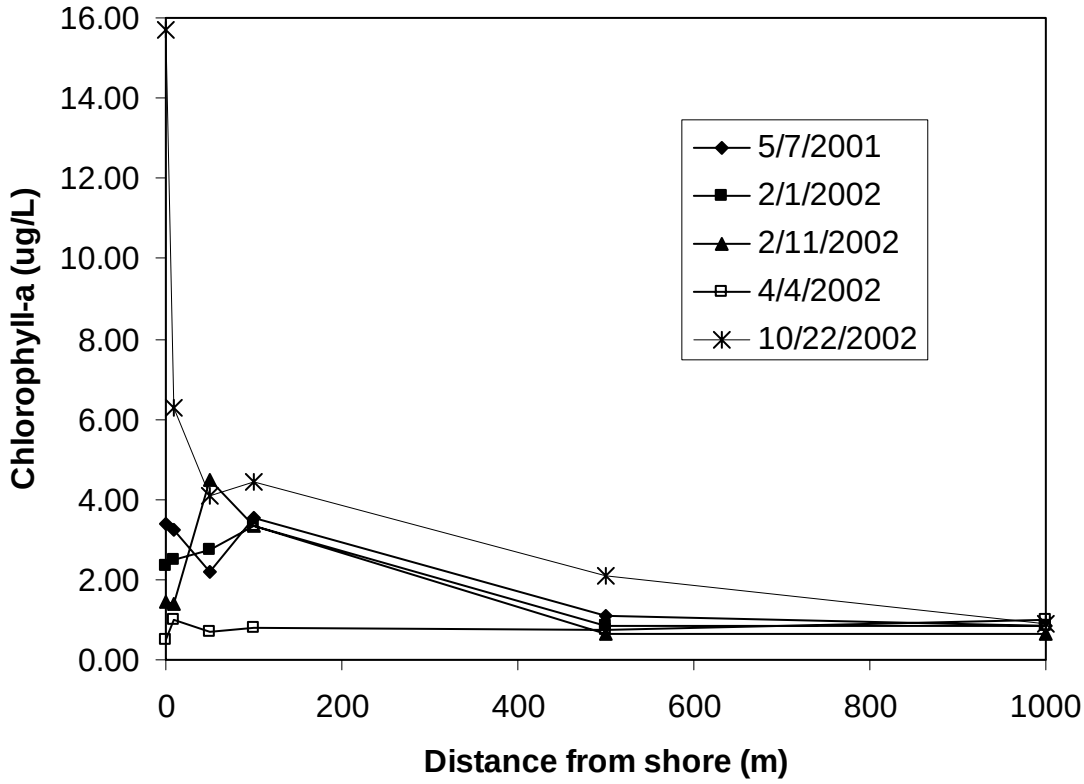
Table 5 Chlorophyll-a data for Molokai fishponds

	Geometric Mean			10% Exceed		2% Exceed	
Pond	In pond	Outside Pond	All points	In pond	All points	In pond	All points
Niaupala	4.27 (36)	0.88 (12)	2.25 (48)	12.44	10.52	13.86	13.59
Ualapue	5.57 (28)	1.05 (16)	3.03 (44)	9.04	8.29	11.20	10.66
Keawanui	1.72 (45)	1.30 (15)	1.60 (60)	4.92	4.44	8.49	7.33
Panahaha	0.92 (30)	0.66 (20)	0.80 (50)	1.73	1.56	2.60	2.58
Kahinapohaku	1.22 (30)	0.52 (18)	0.89 (48)	2.76	2.35	3.84	3.42

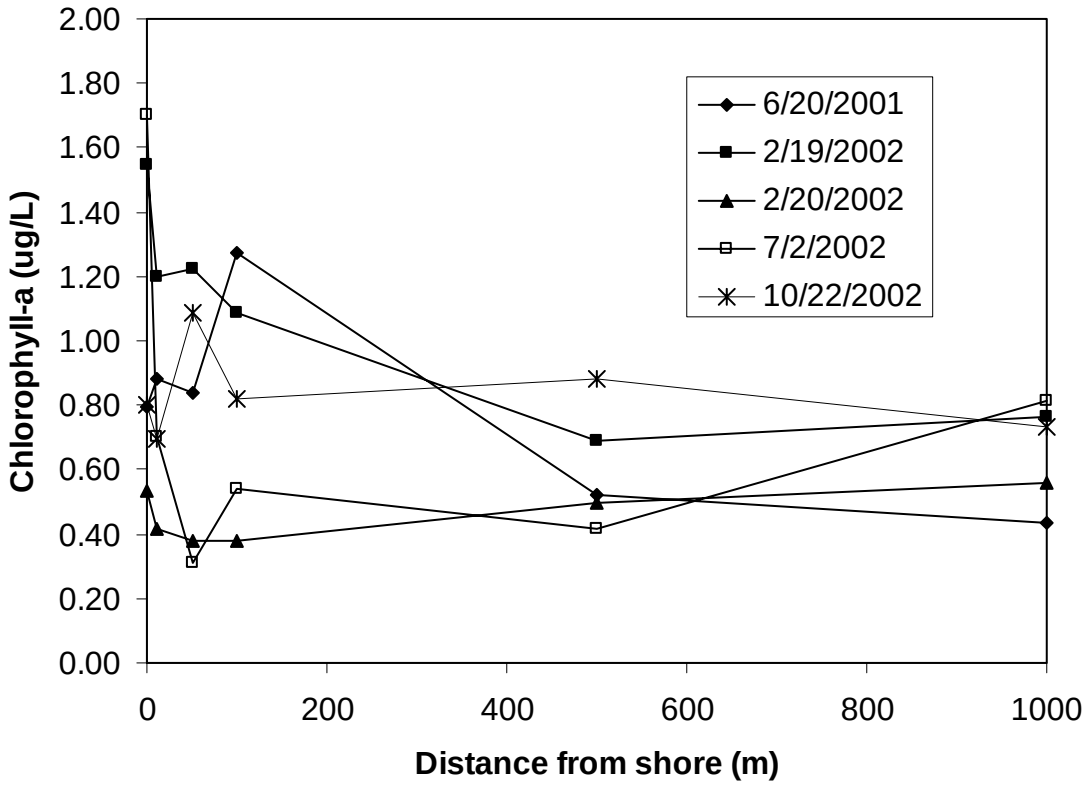
Ualapue



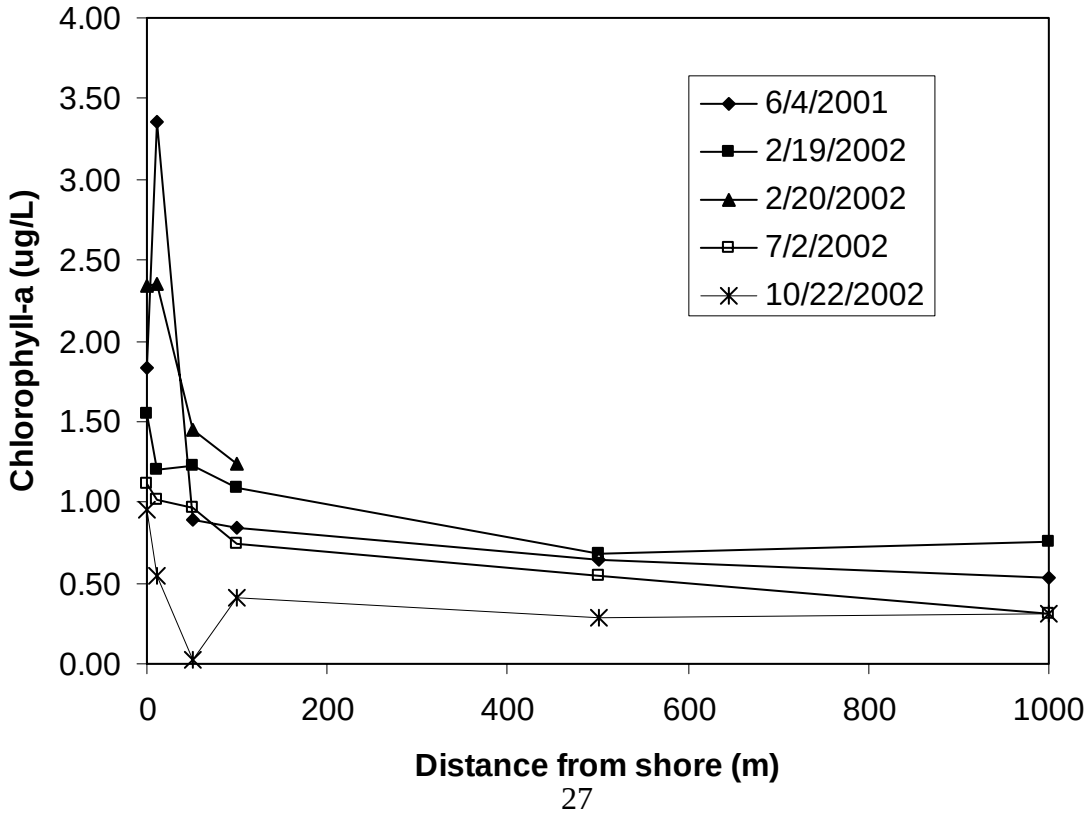
Keawanui



Panahaha



Kahinapohaku



VI. TURBIDITY

Criteria:
GeoMean not to exceed –> 0.50 NTU (0.20 dry)
Not to exceed 10% of time –> 1.25 NTU (0.50 dry)
Not to exceed 2% of time –> 2.00 NTU (1.00 dry)
The calculated statistics below are for samples collected inside each pond.

Niaupala (CONTROL POND):
GeoMean = 12.38 NTU (>0.5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 18.02 NTU (>1.25, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 27.08 NTU (>2.00, DOES NOT MEET THE CRITERIA)
Calculated criteria = 6.87 NTU (Geometric Mean, based on pond and transects)

Ualapue (production):
GeoMean = 6.51 NTU (>0.5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 13.14 NTU (>1.25, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 21.58 NTU (>2.00, DOES NOT MEET THE CRITERIA)
Calculated criteria = 4.08 NTU (Geometric Mean, based on pond and transects)

Keawanui (production):
GeoMean = 4.46 NTU (>0.5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 8.42 NTU (>1.25, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 9.46 NTU (>2.00, DOES NOT MEET THE CRITERIA)
Calculated criteria = 3.82 NTU (Geometric Mean, based on pond and transects)

Panahaha (production):
GeoMean = 3.45 NTU (>0.5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 11.40 NTU (>1.25, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 16.66 NTU (>2.00, DOES NOT MEET THE CRITERIA)
Calculated criteria = 2.69 NTU (Geometric Mean, based on pond and transects)

Kahinapohaku (restored but no production):
GeoMean = 4.01 NTU (>0.5, DOES NOT MEET THE CRITERIA)
Exceed 10% value = 11.90 NTU (>1.25, DOES NOT MEET THE CRITERIA)
Exceed 2% value = 13.34 NTU (>2.00, DOES NOT MEET THE CRITERIA)
Calculated criteria = 3.37 NTU (Geometric Mean, based on pond and transects)

Calculated criteria based on all ponds (n=353) = 3.4 NTU (Geometric Mean)

None of the four ponds met any of the numeric criteria for turbidity in open coastal waters in HAR 11-54 as shown. A single criteria using all of the data from all of the ponds was calculated (using a procedure developed for DOH and used to revise HAR 11-54 with specific criteria for the Kona Coast). The calculated criteria is: geometric mean not to exceed 3.4 NTU. However, only Panahaha and Kahinapohaku would meet this criteria. The control pond had the highest turbidity levels of all and a more appropriate criteria that the control pond can meet could be:

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geometric mean not to exceed 12.5 NTU. Table 6 shows additional statistical data for turbidity and allows comparisons between inside and outside of the ponds. It can be observed that turbidity values inside all four ponds are much higher than outside the same ponds possibly indicating that processes and/or activities occurring inside the pond are causing increased turbidity. This can be explained by the fact that the source of the turbidity is stirred-up sediment (from erosion of watershed lands) which accumulates in great quantity inside the fishponds but does not accumulate nearly as much outside the ponds. In addition, currents outside the ponds tend to carry away and dilute the suspended sediments.

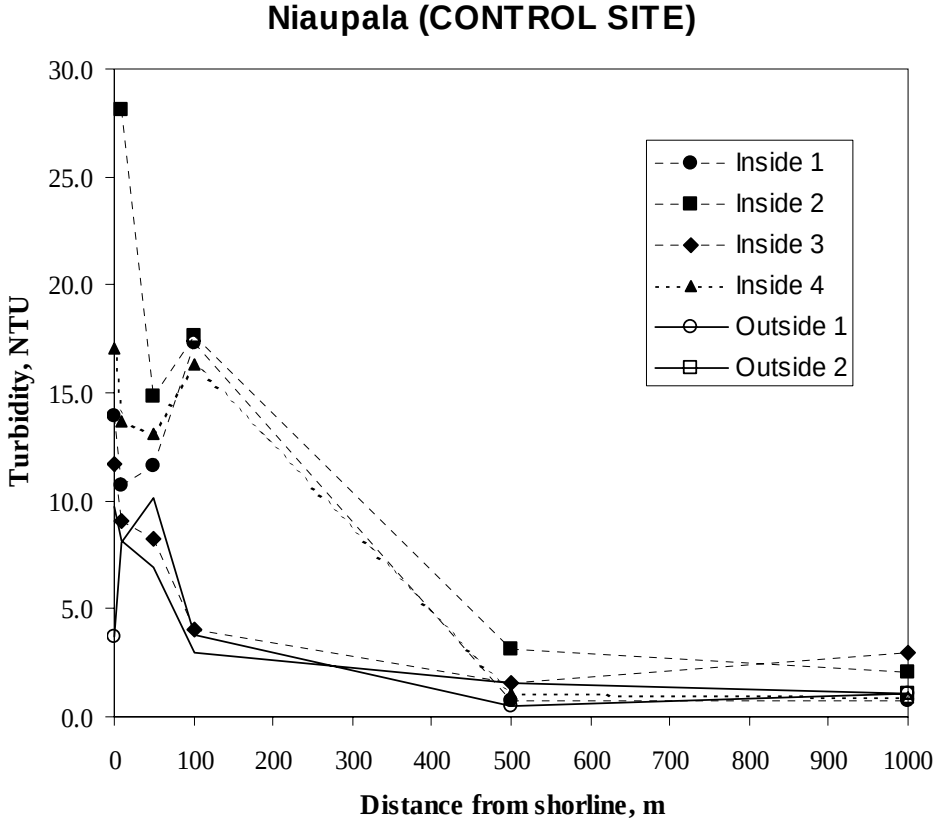
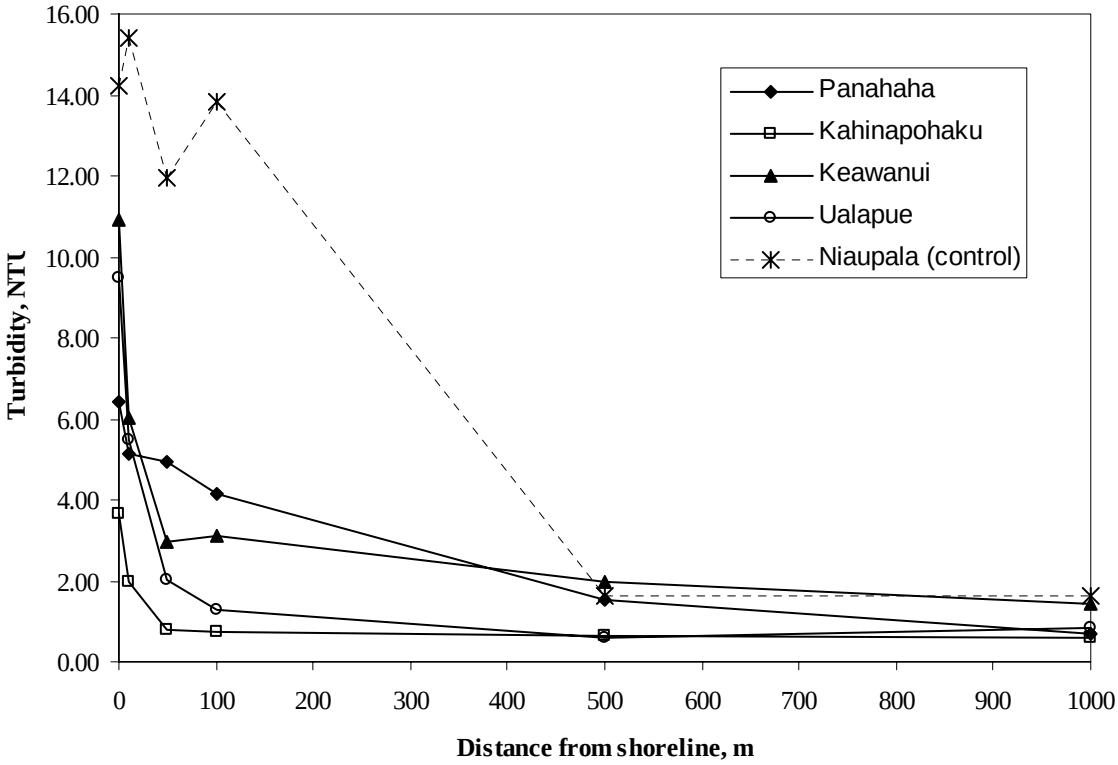


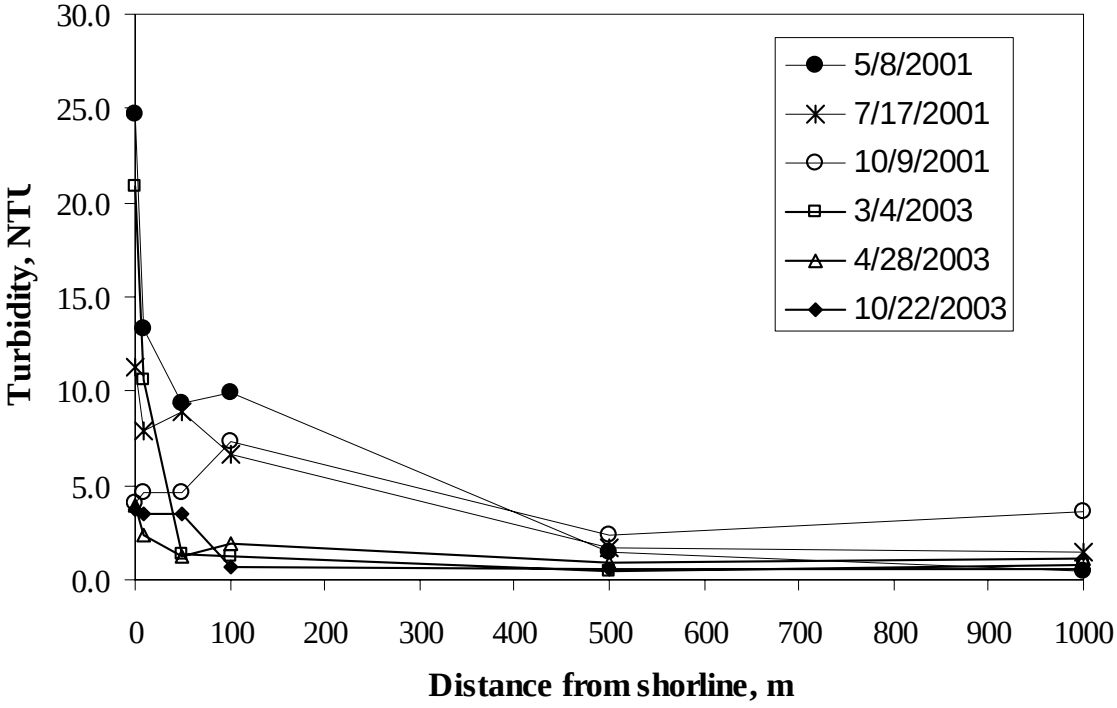
Table 6 Turbidity data for Molokai fishponds

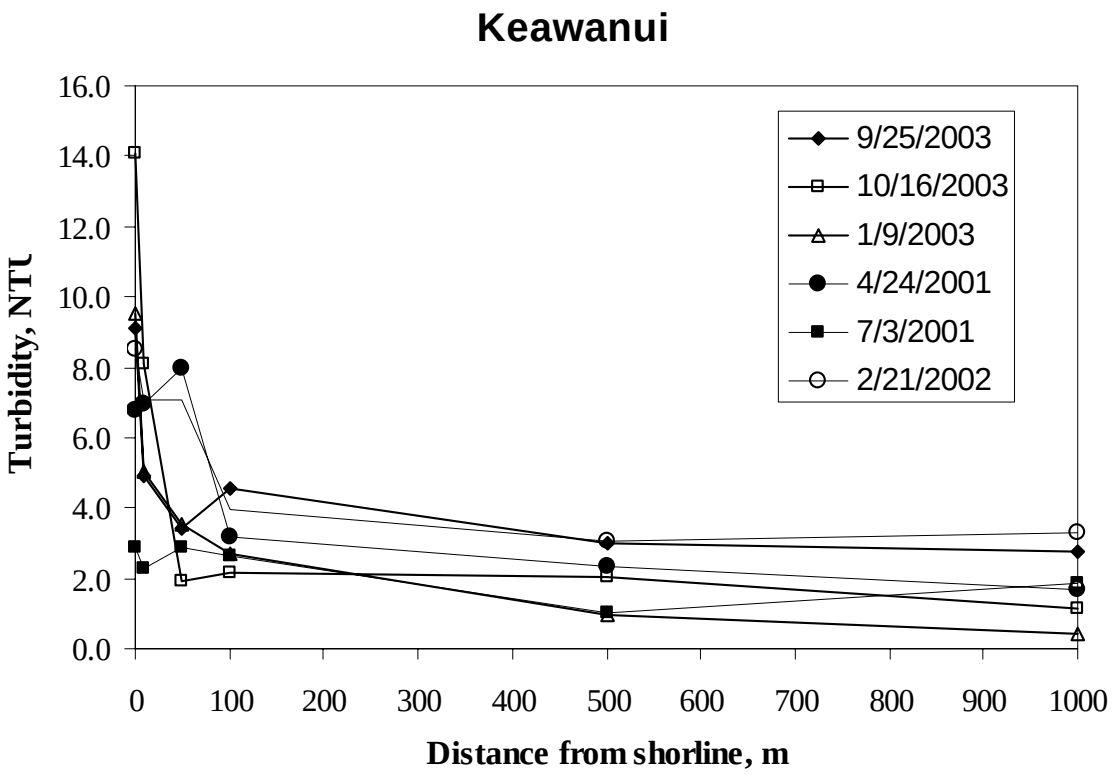
	Geometric Mean			10% Exceed		2% Exceed	
Pond	In pond	Outside Pond	All points	In pond	All points	In pond	All points
Niaupala	12.38 (35)	6.09 (48)	7.03 (83)	18.02	17.60	27.08	25.38
Ualapue	6.51 (42)	1.84 (24)	4.11 (66)	13.14	11.40	21.58	20.18
Keawanui	5.13 (63)	1.79 (18)	3.94 (81)	8.93	8.48	11.71	10.88
Panahaha	3.45 (36)	1.52 (24)	2.48 (60)	11.40	11.40	16.66	14.99
Kahinapohaku	4.01 (36)	1.17 (24)	2.89 (60)	11.90	11.74	13.34	13.76

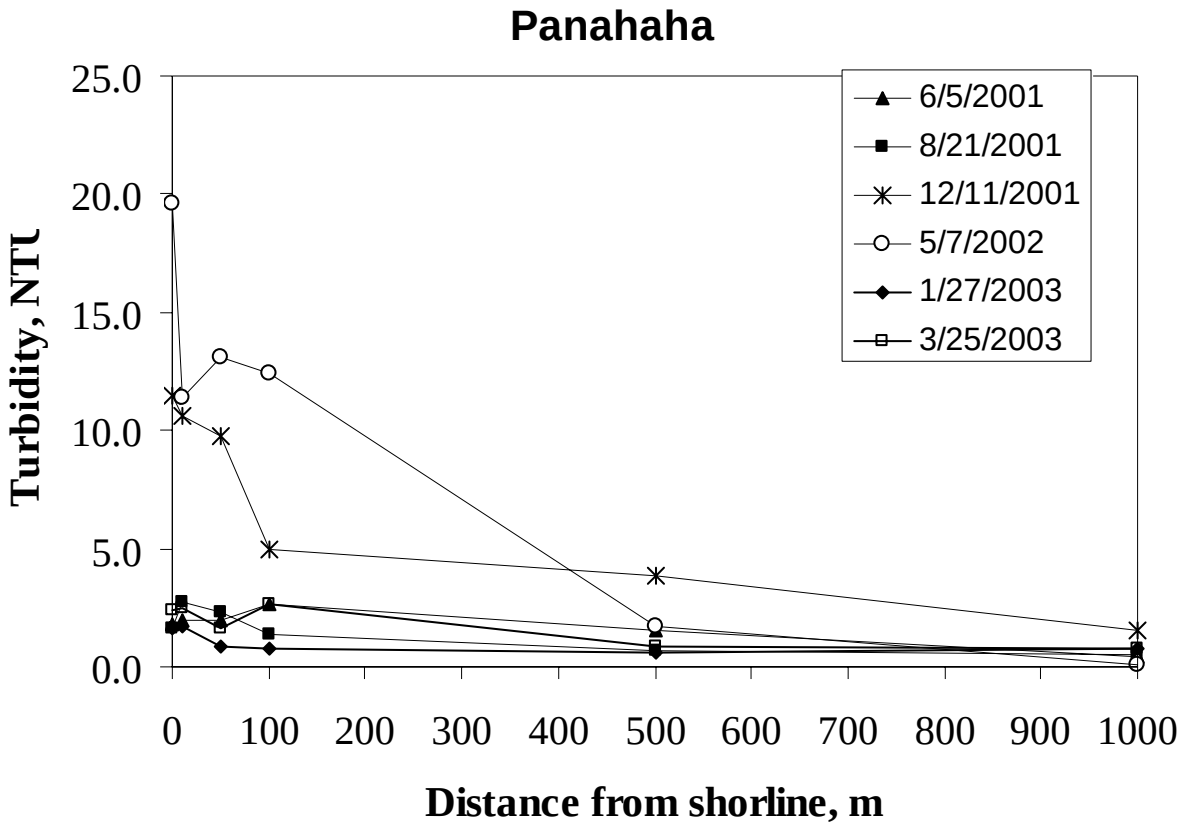
Averaged Transect Data



Ualapue




Keawanui
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Turbidity, NTU
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m
9/25/2003
10/16/2003
1/9/2003
4/24/2001
7/3/2001
2/21/2002


Panahaha
25.0
20.0
15.0
10.0
5.0
0.0
Turbidity, NTU
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m
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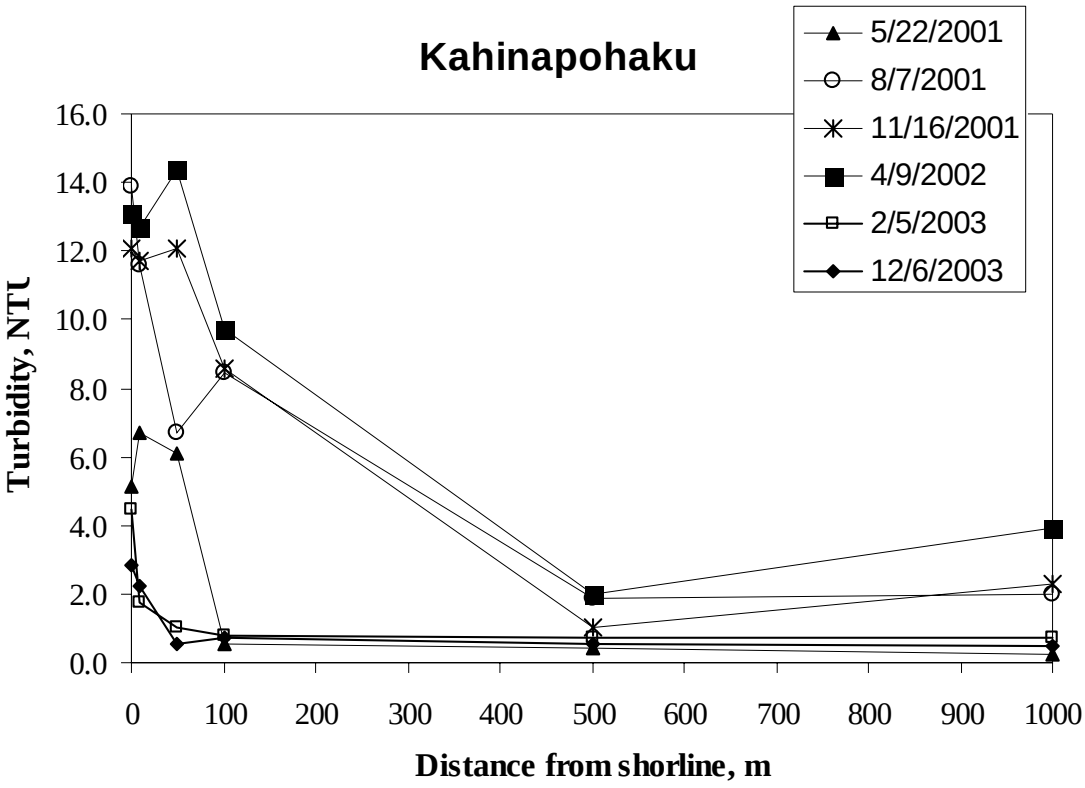
8/21/2001
12/11/2001
5/7/2002
1/27/2003
3/25/2003


Kahinapohaku
5/22/2001
8/7/2001
11/16/2001
4/9/2002
2/5/2003
12/6/2003
Turbidity, NTU
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
Distance from shorline, m

VII. CONDUCTIVITY

Criteria:
Shall not vary more than 10% from natural or seasonal changes considering hydrologic input and oceanographic factors.

For conductivity, the natural conditions were calculated as the average of the values for sampling stations outside each pond. Then each in-pond value was compared to the outside average.

Ualapue (production):

Dist.	10/22/2002	Meet?	3/4/2003	Meet?	4/28/2003	Meet?
1	44.9	No	48.3	Y	44.7	No
10	46.4	No	49.7	Y	48.6	Y
50	53	-	51.1	-	55	-
100	57	-	52.4	-	55.7	-
500	57.7	-	52.8	-	54.8	-
1000	57.5	-	53.7	-	59.6	-
	49.4	Y	53.1	Y	48.7	Y
	49.2	Y	53.7	Y	49.5	Y
	47.9	Y	53.2	Y	48.6	Y
	49.9	Y	53.1	Y	49.7	Y
	50.5	Y	52.6	Y	48.6	Y
Avg	52.46	47.2-57.6	52.86	47.5-58.1	52.24	47-57.4

Keawanui (production):

Dist.	9/25/2001	Meet?	10/16/2002	Meet?	1/9/2003	Meet?
1	49	Y	43.2	Y	52.1	Y
10	47.3	No	44.8	Y	53.1	Y
50	46.6	No	50.7	Y	54.5	Y
100	46.9	-	50.1	-	54	-
500	58.2	-	50.7	-	57.9	-
1000	58.7	-	49.8	-	58.3	-
	50.5	Y	44.3	Y	52.3	Y
	49.7	Y	46.3	Y	53.6	Y
	52.3	Y	48.8	Y	52.2	Y
	57.3	Y	46.8	Y	51.7	Y
	55.1	Y	46.7	Y	51.2	Y
	59.2	Y	48.2	Y	50.5	Y
Avg	54.21	48.8-59.6	47.97	42-53	53.52	48-59

Panahaha (production):

Dist.	1/27/2003	Meet?	3/25/2003	Meet?
1	56.1	Y	55.3	Y
10	55.8	Y	55.9	Y
50	57.1	-	55.1	-
100	56.9	-	55.9	-
500	56.4	-	55.6	-
1000	56.8	-	56.2	-
	54.8	Y	54.2	Y
	53.8	Y	53.7	Y
	54.3	Y	54.6	Y
	51.7	Y	53.1	Y
Avg.	55.37	50-60	54.96	50-60

Kahinapohaku (restored but no production):

Dist.	12/6/2002	Meet?	2/5/2003	Meet?
1	49.6	Y	47.7	Y
10	51.3	Y	53	Y
50	54.8	-	52	-
100	54.7	-	52.5	-
500	54.9	-	53.1	-
1000	56	-	52.4	-
	53.1	Y	51.7	Y
	53.9	Y	55.1	Y
	54.4	Y	52.2	Y
	54.8	Y	54.3	Y
Avg.	53.75	46-58	52.4	47.2-57.6

The criteria for conductivity was met at for nearly every sample taken in the study. The five samples that did not meet the criteria were for sampling locations inside the ponds near to the shoreline where conductivity was more than 10% lower than the ambient (outside) value presumably due to dilution with fresh groundwater discharges. The existing State criteria appears to be achievable and appropriate.

VIII. DISSOLVED OXYGEN

Criteria:
Not less than 75% saturation, determined as a function of ambient water temperature and salinity.

Ualapue (production):

Dist.	10/22/2002	temp	salinity	saturation	75% Sat	Meet?
1	4.2	24.9	31	6.92	5.19	No
10	4.3	25.5	30	6.88	5.16	No
50	3.9	25.6	33	6.76	5.07	No
100	4.1	25.6	34	6.72	5.04	No
500	4.1	25.7	34	6.71	5.03	No
1000	3.8	25.3	34	6.75	5.06	No
	3.7	25	30	6.94	5.21	No
	4	24.9	30	6.95	5.22	No
	3.8	24.8	30	6.97	5.22	No
	3.5	24.7	30	6.98	5.23	No
	3.4	24.8	29	7.01	5.25	No
Dist.	3/4/2003	temp	salinity	saturation	75% Sat	Meet?
1	4.9	25.1	28	7.01	5.26	No
10	5.1	25.2	28	7.00	5.25	No
50	5.4	24.8	33	6.85	5.14	Y
100	5.5	24.7	33	6.86	5.15	Y
500	5.5	24.5	33	6.88	5.16	Y
1000	5.6	24.5	33	6.88	5.16	Y
	4.9	25.4	29	6.93	5.20	No
	4.7	25.3	27	7.03	5.27	No
	4.5	25.7	27	6.98	5.23	No
	4.8	25.2	28	7.00	5.25	No
	4.6	25.3	28	6.99	5.24	No
Dist.	4/28/2003	temp	salinity	saturation	75% Sat	Meet?
1	4.5	24.9	26	7.11	5.34	No
10	4.5	25.1	27	7.05	5.29	No
50	4.3	25.7	33	6.74	5.06	No
100	4.7	25.3	33	6.79	5.09	No
500	4.7	25.3	33	6.79	5.09	No
1000	4.8	25.2	33	6.80	5.10	No
	4.1	25.3	31	6.87	5.15	No
	4.6	25.7	32	6.78	5.09	No
	4.5	25.1	25	7.13	5.35	No
	4.1	25.3	26	7.07	5.30	No
	4.5	25.6	30	6.87	5.15	No

Keawanui (production):

Dist.	10/16/2002	temp	salinity	saturation	75% Sat	Meet?
1	4.04	27.2	30	6.69	5.02	No
10	3.94	27.1	35	6.51	4.89	No
50	3.4	26.6	30	6.76	5.07	No
100	3.47	26.4	33	6.66	5.00	No
500	3.58	26.3	33	6.68	5.01	No
1000	3.22	26.4	33	6.66	5.00	No
	4.09	26.7	25	6.94	5.20	No
	4.01	26.9	26	6.87	5.16	No
	3.58	27	29	6.75	5.06	No
	3.6	27	27	6.82	5.12	No
	3.81	27.1	28	6.77	5.08	No
	3.75	27.1	30	6.70	5.02	No
Dist.	1/9/2003	temp	salinity	saturation	75% Sat	Meet?
1	5.2	24.5	33	6.88	5.16	Y
10	5.2	24.4	32	6.94	5.20	Y
50	5.4	24.3	34	6.87	5.15	Y
100	5.3	24.6	34	6.83	5.12	Y
500	5.4	24.2	34	6.88	5.16	Y
1000	5.1	24.1	34	6.89	5.17	No
	5.3	24.3	32	6.95	5.21	Y
	5.3	24.4	31	6.98	5.23	Y
	4.6	24.5	30	7.00	5.25	No
	5.1	24.1	30	7.05	5.29	No
	5.2	24.2	30	7.04	5.28	No
	5.1	24.1	27	7.17	5.38	No

Panahaha (production):

Dist.	1/27/2003	temp	salinity	saturation	75% Sat	Meet?
1	4.7	26.1	32	6.74	5.05	No
10	4.5	26.3	32	6.71	5.04	No
50	5.1	26.1	33	6.70	5.02	Y
100	5.3	25.9	33	6.72	5.04	Y
500	5.1	26.1	33	6.70	5.02	Y
1000	5.4	26.2	33	6.69	5.02	Y
	4.6	26.1	32	6.74	5.05	No
	4.6	26.3	31	6.75	5.06	No
	4.8	26.4	33	6.66	5.00	No
	4.7	27.6	33	6.53	4.90	No
Dist.	3/25/2003	temp	salinity	saturation	75% Sat	Meet?
1	5.01	25.1	29	6.97	5.23	No
10	5.25	25.2	31	6.88	5.16	Y
50	5.86	25.4	34	6.74	5.06	Y
100	6.74	24.9	34	6.80	5.10	Y
500	5.94	25.1	34	6.77	5.08	Y
1000	5.99	25.3	34	6.75	5.06	Y
	5.23	25.3	29	6.95	5.21	Y
	5.89	25.6	30	6.87	5.15	Y
	5.77	25.1	31	6.89	5.17	Y
	5.67	25.2	29	6.96	5.22	Y

Kahinapohaku (restored but no production):

Dist.	12/6/2002	temp	salinity	saturation	75% Sat	Meet?
1	5.3	23.6	33	6.99	5.24	Y
10	5.9	23.4	33	7.02	5.26	Y
50	6.8	25.7	34	6.71	5.03	Y
100	6.6	25.4	33	6.78	5.08	Y
500	6.6	25.4	33	6.78	5.08	Y
1000	6.8	25.6	33	6.76	5.07	Y
	5.6	23.5	32	7.05	5.28	Y
	5.6	23.6	32	7.03	5.27	Y
	5.9	23.4	34	6.98	5.23	Y
	5.9	23.4	33	7.02	5.26	Y
Dist.	2/5/2003	temp	salinity	saturation	75% Sat	Meet?
1	5.01	24.5	30	7.00	5.25	No
10	4.9	24.6	32	6.91	5.18	No
50	4.4	24.3	33	6.91	5.18	No
100	4.57	24.4	33	6.90	5.17	No
500	4.96	24.6	33	6.87	5.15	No
1000	5.17	24.2	33	6.92	5.19	No
	5.03	24.6	33	6.87	5.15	No
	4.98	24.7	33	6.86	5.15	No
	5.16	24.5	32	6.92	5.19	No
	5.08	24.3	33	6.91	5.18	No

Niaupala (CONTROL SITE)

Data for dissolved oxygen were recorded for the control pond. However, unfortunately, no corresponding salinity data are available and thus it is not possible to determine compliance with the water quality criteria. The recorded DO data are as follows:

Outside the pond:

Dist.	6/19/2001	9/13/2001	1/31/2002
1	6.43	7.15	3.76
10	5.81	4.56	4.45
50	5.61	3.37	5.23
100	5.80	3.53	7.23
500	8.86	6.49	5.00
1000	9.36		5.34

Inside the pond:

Dist.	6/5/2001	8/22/2001	1/8/2002	5/9/2002
1	4.39	5.09	8.21	5.25
10	4.25	6.47	5.28	5.2
50	4.7	5.26	6.19	4.92
100	4.25	5.75	4.83	4.52
500	3.85	4.4	4.43	4.7
1000	3.64	5.29	5.52	4.69
	4.57	4.91	5.56	4.79
	4.36	4.59	5.29	4.08
	4.13	4.6	5.23	4.05
	4.32	5.26	6.69	3.97
	4.43	6.12	7.56	3.9
	4.24	6.26	5.44	3.91

The criteria for dissolved oxygen (DO) was met for less than one-third of the samples taken in the study (35 of 97). DO concentration is an indirect measure of biological activity in the ponds. When there is high activity and poor circulation, then dissolved oxygen concentrations will decrease. The DO data for Ualapue pond indicate that there is significant biological activity and poor circulation since 29 of 33 samples showed DO less than 75% of saturation. Also, most of the samples that did meet the criteria were from outside of the pond. Keawanui pond also seems to have high activity and poor circulation since 17 of 24 samples were less than 75% of saturation. For Panahaha pond, 7 of 20 samples did not meet the criteria which may be indicative of better circulation since all of the samples from outside the pond were in compliance with the criteria. The data for Kahinapohaku show how temporal or seasonal variations can affect the DO. In one event all the samples met the criteria, and during another sampling event none of the samples met the criteria.

Calculations were made to determine what modified criteria would allow a larger percentage of the data to be in compliance. If the criteria were reduced to a minimum saturation of 70% then over one-half of the samples would be OK (52/97). If the criteria were reduced further to a minimum saturation of 65% then about two-thirds of the samples would be OK (66/97). If the criteria were reduced even further to a minimum saturation of 60% then a few more of the samples would be OK (72/97). In order to have all the samples meet a single criteria, the minimum saturation would have to be reduced to 50%. It is not clear whether or not there are problems associated with having reduced DO concentrations in these fishponds. Clearly, if they are reduced due to active fish production efforts which are optimized to maximize production rates, then the reduced DO relative to saturation is likely acceptable perhaps unless it is at the expense to other fauna in the ponds. If there are no serious side effects of reduced DO in this setting and in fact it is a natural result of actively growing fish for beneficial use, then a more appropriate criteria would be: not less than 50% saturation based upon ambient temperature and salinity.

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IX. TEMPERATURE

Criteria:
Shall not vary more than one degree Celsius from ambient conditions.

For temperature, ambient conditions were calculated as the average of the values for sampling stations outside each pond. Then each in-pond value was compared to the outside average.

Ualapue (production):

Dist.	10/22/2002	Meet?	3/4/2003	Meet?	4/28/2003	Meet?
1	24.9	Y	25.1	Y	24.9	Y
10	25.5	Y	25.2	Y	25.1	Y
50	25.6	-	24.8	-	25.7	-
100	25.6	-	24.7	-	25.3	-
500	25.7	-	24.5	-	25.3	-
1000	25.3	-	24.5	-	25.2	-
	25	Y	25.4	Y	25.3	Y
	24.9	Y	25.3	Y	25.7	Y
	24.8	Y	25.7	No	25.1	Y
	24.7	Y	25.2	Y	25.3	Y
	24.8	Y	25.3	Y	25.6	Y
Avg.	25.55	24.6-26.6	24.63	23.6-25.6	25.38	24.4-26.4

Keawanui (production):

Dist.	10/16/2002	Meet?	1/9/2003	Meet?
1	27.2	Y	24.5	Y
10	27.1	Y	24.4	Y
50	26.6	Y	24.3	Y
100	26.4	-	24.6	-
500	26.3	-	24.2	-
1000	26.4	-	24.1	-
	26.7	Y	24.3	Y
	26.9	Y	24.4	Y
	27	Y	24.5	Y
	27	Y	24.1	Y
	27.1	Y	24.2	Y
	27.1	Y	24.1	Y
Avg.	26.37	25.4-27.4	24.30	23.3-25.3

Panahaha (production):

Dist.	1/27/2003	Meet?	3/25/2003	Meet?
1	26.1	Y	25.1	Y
10	26.3	Y	25.2	Y
50	26.1	-	25.4	-
100	25.9	-	24.9	-
500	26.1	-	25.1	-
1000	26.2	-	25.3	-
	26.1	Y	25.3	Y
	26.3	Y	25.6	Y
	26.4	Y	25.1	Y
	27.6	No	25.2	Y
Avg.	26.08	25-27	25.18	24-26

Kahinapohaku (restored but no production):

Dist.	12/6/2002	Meet?	2/5/2003	Meet?
1	23.6	No	24.5	Y
10	23.4	No	24.6	Y
50	25.7	-	24.3	-
100	25.4	-	24.4	-
500	25.4	-	24.6	-
1000	25.6	-	24.2	-
	23.5	No	24.6	Y
	23.6	No	24.7	Y
	23.4	No	24.5	Y
	23.4	No	24.3	Y
Avg.	25.53	24.5-26.5	24.38	23.4-25.4

The criteria for temperature was met for most of the samples taken in the study. It is not known why eight samples (out of 56) did not meet the criteria. For the two samples which were higher than allowed, it could be due to localized warming within the pond due to a lack of good circulation. The existing State criteria appears to be achievable and appropriate.

X. pH

Criteria:
Shall not deviate more than 0.5 units from a value of 8.1, except at coastal locations where and when freshwater from stream, storm drain or groundwater discharge may depress the pH to a minimum level of 7.0.

Keawanui (production):

Dist.	9/25/2001	7.6<pH<8.6
1	8.2	Y
10	8.21	Y
50	8.22	Y
100	8.23	Y
500	8.18	Y
1000	8.16	Y
	8.2	Y
	8.2	Y
	8.19	Y
	8.16	Y
	8.18	Y
	8.16	Y

There was only one set of pH data collected. The data for Keawanui pond indicate that pH was in compliance with the DOH criteria.

In summary, it is apparent that water quality in the Molokai fishponds examined herein did not generally meet a significant proportion of the existing regulatory criteria (HAR 11-54). Most notably; compliance with turbidity, chlorphyll-a, nitrate-nitrogen, total nitrogen, total phosphorus, and dissolved oxygen was poor; compliance with ammonia-nitrogen and temperature was fairly good, and compliance with conductivity, and pH was very good. For those parameters where there was poor compliance, it may be that the existing numeric criteria are not appropriate for Southern Molokai fishpond areas. For those parameters, new criteria that might be more appropriate were calculated using a procedure developed for DOH for the Kona Coast. In some cases, the control pond would not meet these calculated criteria and other criteria may be more appropriate. Suggested criteria for Southern Molokai fishpond areas are given in Table 7 below.

Table 7. Suggested water quality criteria for southern Molokai fishpond areas

Parameter	Geometric mean not to exceed the given value
Total Nitrogen (µg N/L)	230.00
Ammonia Nitrogen (µg N/L)	3.50 (existing)
Nitrate + Nitrite Nitrogen (µg N/L)	30.00
Total Phosphorus (µg P/L)	70.00
Chlorophyll-a (µg/L)	6.0
Turbidity (NTU)	6.0
Conductivity (salinity)	Shall not vary more than 10% from natural or seasonal changes considering hydrologic input and oceanographic factors (existing)
Dissolved Oxygen (% saturation)	Not less than 50% saturation, determined as a function of ambient water temperature and salinity
Temperature (degrees Celsius)	Shall not vary more than one degree Celsius from ambient conditions (existing)
pH	Shall not deviate more than 0.5 units from a value of 8.1, except at coastal locations where and when freshwater from stream, storm drain or groundwater discharge may depress the pH to a minimum level of 7.0 (existing)

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