Appendix 1

SAS® Routines to determine

MAXIMS curves for milkfish

October 1996

```
data a ;
   input X Y ;
   cards ;
6.00    0.685958  6.00    1.355671  6.00    1.545187  6.00    0.448360
6.00    0.723689  7.00    0.790480  7.00    0.817858  7.00    0.853679
7.00    1.520441  7.00    0.941053  8.00    0.664794  8.00    1.048153
8.00    0.318375  8.00    0.962518  8.00    0.677836  9.00    1.411580
9.00    0.413058  9.00    0.000000  9.00    1.497342  9.00    1.914338
10.00   0.000000  10.00   2.914340  10.00   2.934162  10.00   0.633297
10.00   0.899247  11.00   0.823592  11.00   0.981562  11.00   1.091192
11.00   1.451481  11.00   1.441534  12.00   1.736222  12.00   1.525285
12.00   1.492565  12.00   1.569260  12.00   1.166655  13.00   0.893953
13.00   1.013550  13.00   1.268239  13.00   0.994737  13.00   1.302000
14.00   0.967995  14.00   0.997912  14.00   0.918285  14.00   1.793440
14.00   0.714691  15.00   0.329568  15.00   1.023475  15.00   0.921878
15.00   1.412936  15.00   1.369661  16.00   1.108429  16.00   1.138862
16.00   0.631014  16.00   1.013094  16.00   0.645469  17.00   0.750655
17.00   1.193676  17.00   1.099498  17.00   1.600568  17.00   0.858612
18.00   1.406837  18.00   1.025892  18.00   2.133550  18.00   1.308159
18.00   0.653525  19.00   0.245606  19.00   2.157529  19.00   0.918344
19.00   0.736479  19.00   0.528271  20.00   1.827478  20.00   1.483064
20.00   0.753057  20.00   1.095328  20.00   1.046202  21.00   1.949515
21.00   0.812212  21.00   0.000000  21.00   1.254972  21.00   0.921993
22.00   0.000000  22.00   0.879599  22.00   1.406837  22.00   0.853679
22.00   0.659699  23.00   1.631399  23.00   0.000000  23.00   0.812212
23.00   1.456078  23.00   2.286525  24.00   0.769544  24.00   0.315984
24.00   1.640008  24.00   0.000000  24.00   0.000000  1.00    0.000000
1.00    0.680519  1.00    0.193755  1.00    0.249872  1.00    0.000000
2.00    0.000000  2.00    0.543877  2.00    0.000000  2.00    0.000000
2.00    0.322734  3.00    0.000000  3.00    0.000000  3.00    0.000000
3.00    0.000000  3.00    0.000000  4.00    0.586997  4.00    0.000000
4.00    0.000000  4.00    1.059331  4.00    1.409633  5.00    0.000000
5.00    0.486735  5.00    0.883574  5.00    0.672540  5.00    0.000000
;
proc nlin method=dud ;
   parms  J=0.705  E=0.645  T1=3.33  T2=23 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

February 1997

```
data a ;
   input X Y ;
   cards ;
7.00    0.775288  7.00    0.625545  7.00    0.000000  7.00    0.672540
8.00    1.299466  8.00    0.600292  8.00    0.849281  8.00    1.416489
8.00    0.623301  9.00    1.301542  9.00    0.000000  9.00    0.886358
10.00   0.938094  10.00   1.226351  10.00   0.903781  10.00   0.685101
10.00   0.978446  11.50   1.203738  11.50   1.002761  11.50   1.227465
11.50   0.664619  11.50   1.263958  12.50   0.980566  12.50   0.942752
12.50   0.454012  12.50   0.635843  12.50   0.682155  13.75   1.564232
13.75   1.413077  13.75   0.884892  13.75   0.789263  13.75   0.889179
14.75   0.577391  14.75   0.691425  14.75   0.776455  14.75   0.865035
14.75   0.793125  16.00   0.843188  16.00   0.447770  16.00   0.604037
17.00   0.940834  17.00   1.098561  17.00   0.878848  18.00   0.662378
18.00   1.160236  18.00   0.413093  18.00   2.483404  18.00   1.876566
19.00   1.832273  19.00   0.669876  19.00   1.008323  19.00   1.281623
20.50   0.000000  20.50   0.466321  20.50   1.118223  20.50   1.056906
20.50   1.499713  21.50   0.847204  21.50   0.396251  21.50   0.926811
21.50   0.462896  21.50   1.414795  23.50   0.617037  23.50   1.426132
23.50   0.386254  0.75    0.000000  0.75    0.000000  0.75    0.330623
0.75    0.387787  0.75    0.438396  1.75    0.220565  1.75    0.000000
1.75    1.116545  3.50    0.000000  3.50    0.000000  3.50    0.000000
3.50    0.215799  4.50    0.000000  4.50    0.378898  4.50    0.000000
4.50    0.301003  4.50    0.000000  5.50    0.250690  5.50    0.592860
5.50    0.000000  5.50    0.243370
;
proc nlin method=dud ;
   parms  J=0.6  E=0.6  T1=4.5  T2=23 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

April 1997

```
data a ;
   input X Y ;
   cards ;
6.50    0.926417  6.50    0.656632  6.50    0.796928  6.50    0.431506
7.50    0.505391  7.50    0.437101  7.50    0.829418  7.50    0.000000
7.50    0.581863  8.50    0.755378  8.50    0.991856  8.50    0.912142
8.50    0.961122  8.50    1.215903  9.50    0.407884  9.50    0.998099
9.50    0.862795  9.50    0.925556  9.50    0.971715  10.50   0.968892
10.50   0.972455  10.50   0.593370  10.50   0.643788  11.50   0.789896
11.50   0.715830  11.50   0.351690  11.50   0.354457  12.50   0.271372
12.50   0.853996  12.50   1.216189  12.50   0.337346  12.50   0.525306
13.50   0.725688  13.50   1.104476  13.50   0.865997  13.50   0.961231
13.50   0.405370  14.50   1.610551  14.50   0.798515  14.50   1.050611
14.50   0.637633  15.50   0.970219  15.50   0.865035  15.50   0.848864
15.50   0.242489  15.50   0.223309  16.50   0.785559  16.50   1.025375
16.50   0.787958  16.50   0.593630  16.50   0.368409  17.50   0.538992
17.50   0.646748  17.50   0.971641  17.50   1.107263  18.50   0.375327
18.50   1.951077  18.50   0.627223  18.50   1.004657  20.00   0.915445
```

```
20.00   0.997647  20.00   1.365925  20.00   0.611812  21.00   1.042664
21.00   0.000000  21.00   0.871880  22.00   0.433118  22.00   0.925736
22.00   1.673849  22.00   0.000000  1.00    0.128507  1.00    0.000000
1.00    0.000000  1.00    0.000000  3.00    0.000000  3.00    0.000000
3.00    0.389314  3.00    0.000000  4.00    0.000000  4.00    0.188636
4.00    0.000000  4.00    0.000000  4.00    0.000000  5.00    0.000000
5.00    1.261915
;
proc nlin method=dud ;
   parms  J=0.6  E=0.75  T1=4  T2=22 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

June 1997

```
/* ALL DATA POINTS PUT 1.5 HOURS EARLIER (X'=X-1.5) TO */
/* ALLOW FOR LONGER FEEDING PERIOD PAST MIDNIGHT       */
/* RECALCULATE TIMES (X-VALUES) AFTER ANALYSIS         */|

data a ;
   input X Y ;
   cards ;
4.5     0.384520  4.5   0.489895    4.5   0.546357    4.5   0.000000
4.5     1.004588  5.5   0.757261    5.5   0.897840    5.5   0.486543
5.5     0.907937  6.5   0.756127    6.5   0.777309    6.5   0.000000
6.5     0.518304  7.5   0.616551    7.5   0.555162    7.5   0.420788
8.5     0.707842  8.5   0.722233    8.5   0.671571    8.5   0.546625
8.5     0.940757  9.5   0.565292    9.5   0.315323    9.5   0.388910
9.5     0.657953  10.5  0.468671    10.5  0.374434    10.5  0.756931
10.5    0.740074  10.5  0.591129    11.5  0.820425    11.5  0.782086
11.5    0.532449  12.75 0.647658    12.75 0.244148    12.75 0.408103
13.75   0.498608  13.75 1.098548    13.75 0.528803    13.75 0.460710
13.75   0.547105  14.5  0.380536    14.5  0.628089    14.5  0.550868
14.5    0.304117  14.5  0.427779    15.5  0.610620    15.5  0.765863
15.5    0.746770  15.5  0.624051    15.5  0.373995    16.5  1.046625
16.5    0.771423  16.5  0.950588    17.5  0.542391    17.5  0.458889
17.5    0.522856  17.5  0.613761    17.5  0.835582    18.5  0.444360
18.5    0.561063  18.5  0.498590    18.5  0.934349    18.5  0.193274
19.5    0.822573  19.5  0.926251    19.5  0.875761    20.5  0.607269
20.5    0.631683  20.5  0.188388    20.5  0.598043    20.5  0.000000
21.5    0.000000  21.5  0.090368    21.5  0.209110    22.5  0.848751
22.5    2.251614  22.5  0.000000    23.5  0.270301    23.5  1.782448
23.5    0.000000  23.5  0.000000    23.5  0.000000    0.5   0.224253
0.5     0.000000  0.5   0.624832    0.5   1.207979    1.5   0.000000
1.5     0.000000  1.5   0.000000    2.5   0.201838    2.5   0.000000
2.5     0.000000  2.5   0.155022    3.5   0.000000    3.5   0.712605
3.5     0.841286  3.5   0.447255    3.5   0.400683
;
proc nlin method=dud ;
   parms  J=0.7  E=0.8  T1=2.2  T2=22.5 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
```

```
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

August 1997

```
data a ;
   input X Y ;
   cards ;
7.75    0.04818   7.75  0.06357     9.00  0.07079     9.00  0.06501
9.00    0.05599   9.00  0.05273     10.00 0.06096     10.00 0.07577
10.00   0.03341   10.00 0.07241     10.00 0.06130     11.00 0.04384
11.00   0.05788   11.00 0.06657     11.00 0.04002     12.00 0.04976
12.00   0.07273   12.00 0.04132     12.00 0.04690     13.00 0.04429
13.00   0.07582   13.00 0.05425     13.00 0.05941     14.00 0.08191
14.00   0.03368   14.00 0.05386     15.00 0.05428     15.00 0.03083
15.00   0.04014   15.00 0.04917     16.00 0.03833     16.00 0.04850
16.00   0.05434   17.25 0.03351     17.25 0.04524     17.25 0.07555
17.25   0.03125   18.75 0.03846     18.75 0.05281     19.75 0.05830
19.75   0.07932   19.75 0.04342     19.75 0.02029     19.75 0.02018
20.75   0.02691   20.75 0.05328     20.75 0.02545     20.75 0.02402
20.75   0.02842   21.75 0.02943     21.75 0.03540     21.75 0.01002
21.75   0.00431   23.00 0.00000     23.00 0.00000     23.00 0.00000
23.00   0.00000   23.00 0.00000     24.00 0.00000     24.00 0.00000
24.00   0.00000   24.00 0.00000     24.00 0.00000     1.00  0.01534
1.00    0.00000   1.00  0.00000     2.00  0.00000     2.00  0.00000
2.00    0.00000   2.00  0.00000     3.00  0.01196     3.00  0.00500
3.00    0.00931   4.00  0.01633     4.00  0.03457     4.00  0.03296
4.00    0.02177   5.00  0.00000     5.00  0.03527     5.00  0.02273
5.00    0.03080   5.00  0.02899     6.00  0.03393     6.00  0.02372
6.00    0.01320   6.00  0.02182     6.00  0.02924
;
proc nlin method=dud ;
   parms  J=0.05  E=0.5  T1=3.25  T2=19.4 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

Appendix 2

SAS® Routines to determine

MAXIMS curves for Nile tilapia

May 1995 - large fish

```
data a ;
   input X Y ;
   cards ;
    9.5     3.027719        9.5     1.449664        9.5     1.279772
    9.5     0.566667        9.5     2.205882       12.5     1.275343
   12.5     2.116402       12.5     2.340892       12.5     2.876481
   12.5     3.559436       15.5     1.662313       15.5     3.613726
   15.5     3.471553       15.5     1.078626       15.5     3.010552
   18.5     2.571861       18.5     3.024417       18.5     2.328373
   18.5     2.066487       18.5     1.330724       21.5     0.853298
   21.5     1.305622       21.5     1.898734       21.5     1.222494
   21.5     1.794872        0.5     1.913394        0.5     0.528402
    0.5     1.308615        0.5     2.119527        0.5     0.000000
    3.5     0.665509        3.5     1.290323        3.5     1.581990
    3.5     0.000000        3.5     1.225667        6.5     0.000000
    6.5     0.904977        6.5     0.000000        6.5     0.000000
    6.5     0.000000
;
proc nlin method=dud ;
   parms  J=0.5  E=0.15  T1=6  T2=17 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

May 1995 - small fish

```
data a;
   input X Y ;
   cards ;
    9.5     2.356021        9.5     1.823154        9.5     0.837989
    9.5     3.275862        9.5     4.000000       12.5     1.229896
   12.5     1.277683       12.5     0.956522       12.5     0.595238
   12.5     0.655022       15.5     0.311526       15.5     1.434978
   15.5     0.865052       15.5     1.688312       15.5     0.000000
   18.5     2.308961       18.5     2.560000       18.5     2.748626
   18.5     2.147577       18.5     3.488372       21.5     2.500000
   21.5     1.622248       21.5     0.000000       21.5     0.794702
   21.5     0.000000        0.5     0.400000        0.5     0.000000
    0.5     0.000000        0.5     0.318134        0.5     0.000000
    3.5     0.000000        3.5     0.000000        3.5     0.000000
    3.5     0.000000        3.5     0.000000        6.5     0.469484
```

```
    6.5     0.000000        6.5     1.564537        6.5     0.000000
    6.5     0.515464
;
proc nlin method=dud ;
   parms  J=1.5  E=0.5  T1=6  T2=10.5  T3=15  T4=19.5 ;
   file print ;
   Sra=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T4))*(1-exp(-E*(T4-T3))*
        (1-exp(-E*(T3-T2))*(1-exp(-E*(T2-T1))))) ;
   Sfa=Sra*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   Srb=Sfa*exp(-E*(T3-T2)) ;
   Sfb=Srb*exp(-E*(T4-T3))+(J/E)*(1-exp(-E*(T4-T3))) ;
   So=Sfb*exp(-E*(24-T4)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sra*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=T3 then do ;
      model Y=Sfa*exp(-E*(X-T2)) ;
   end ;
   else if T3<X<=T4 then do ;
      model Y=Srb*exp(-E*(X-T3))+(J/E)*(1-exp(-E*(X-T3))) ;
   end ;
   else if T4<X<=24 then do ;
      model Y=Sfb*exp(-E*(X-T4)) ;
   end ;
   run ;
```

August 1995

```
data a ;
   input X Y ;
   cards ;
10.5    1.779399  10.5    3.253549  10.5    1.320132  10.5    1.385189
10.5    3.062803  10.5    2.210229  10.5    2.880000  10.5    1.799763
10.5    3.537432  10.5    0.000000  13.5    2.927928  13.5    1.035570
13.5    1.669471  13.5    1.538462  13.5    1.564572  13.5    0.733272
13.5    1.063516  13.5    1.514387  13.5    1.213172  13.5    1.450610
16.5    0.878416  16.5    0.525977  16.5    1.794669  16.5    0.805902
16.5    1.205396  16.5    0.236904  16.5    0.647634  16.5    1.195730
16.5    0.278094  19.5    0.836623  19.5    0.680052  19.5    0.909720
19.5    1.237191  19.5    0.784626  19.5    0.827690  19.5    0.628931
19.5    0.682109  19.5    1.254657  19.5    0.939387  22.5    1.178034
22.5    1.314060  22.5    1.583873  22.5    0.558914  22.5    0.799087
22.5    0.800500  22.5    0.984081  22.5    1.444992  22.5    1.754109
22.5    1.157184  1.5     0.000000  1.5     0.000000  1.5     0.000000
1.5     0.000000  1.5     0.751295  1.5     0.000000  1.5     0.000000
1.5     1.275964  1.5     0.000000  1.5     0.000000  4.5     0.000000
4.5     0.000000  4.5     0.000000  4.5     0.000000  4.5     0.000000
4.5     0.000000  4.5     0.000000  4.5     0.000000  4.5     0.000000
4.5     0.000000  7.5     0.847336  7.5     0.610842  7.5     0.838619
7.5     0.607287  7.5     0.000000  7.5     0.606469  7.5     1.689189
7.5     0.142399  7.5     0.991543  7.5     1.116838
;
proc nlin method=dud ;
   parms  J1=1.25  J2=0.48  E=0.48  T1=7.1  T2=11.75  T3=12.6  T4=22.5  ;
   file print ;
   Sr1=(J1/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1)))+
((J2/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T3-T4))*(1-exp(-E*(T4-T3)))*
exp(-E*(T4-T3))+(J2/E)*(1-exp(-E*(T4-T3))))*exp(-E*(24+T1-T4))  ;
   Sf1=Sr1*exp(-E*(T2-T1))+(J1/E)*(1-exp(-E*(T2-T1))) ;
   Sr2=Sf1*exp(-E*(T3-T2)) ;
   Sf2=Sr2*exp(-E*(T4-T3))+(J2/E)*(1-exp(-E*(T4-T3))) ;
   So=Sf2*exp(-E*(24-T4)) ;
   if 0<=X<=T1 then do ;
```

```
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr1*exp(-E*(X-T1))+(J1/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=T3 then do ;
      model Y=Sf1*exp(-E*(X-T2)) ;
   end ;
   else if T3<X<=T4 then do ;
      model Y=Sr2*exp(-E*(X-T3))+(J2/E)*(1-exp(-E*(X-T3))) ;
   end ;
   else if T4<X<=24 then do ;
      model Y=Sf2*exp(-E*(X-T4)) ;
   end ;
   run ;
```

March 1996

```
data a ;
   input X Y ;
   cards ;
6       0.267329  6       0.302656  6       0.041824  6       0.213010
6       0.002711  7       0.130405  7       0.313127  7       0.076235
7       0.107379  7       0.230957  8       0.032713  8       0.039068
8       0.282034  8       0.216609  8       0.000000  9       0.379533
9       0.111829  9       0.270133  9       0.181444  10      0.000000
10      0.178507  10      0.000000  10      0.324228  10      0.196466
11      0.060309  11      0.257378  11      0.311226  11      0.109436
12      0.279141  12      0.202338  12      0.131572  12      0.404315
12      0.195076  13      0.372037  13      0.318499  13      0.392267
13      0.465272  13      0.449927  14      0.186073  14      0.322776
14      0.421281  14      0.068202  14      0.109160  15      0.309221
15      0.574899  15      0.384615  15      0.276701  16      0.384570
16      0.281215  16      0.285598  16      0.623575  17      1.139122
17      0.062758  17      0.316504  17      0.453619  17      0.562117
18      0.337086  18      0.577953  18      0.164175  18      1.140608
19      0.209903  19      0.151960  19      0.000000  19      0.276890
20      0.583897  20      0.524094  20      0.575222  20      0.156686
21      0.000000  21      0.385249  21      0.000000  21      0.000000
21      0.223450  22      0.000000  22      0.057794  22      0.000000
22      0.000000  22      0.000000  23      0.000000  23      0.000000
23      0.000000  23      0.227348  24      0.000000  24      0.000000
24      0.000000  24      0.000000  24      0.122577  1       0.000000
1       0.000000  1       0.000000  1       0.000000  1       0.000000
2       0.000000  2       0.000000  2       0.000000  2       0.000000
2       0.000000  3       0.000000  3       0.000000  3       0.000000
4       0.000000  4       0.066462  4       0.000000  4       0.000000
4       0.000000  5       0.000000  5       0.000000  5       0.000000
5       0.000000  5       0.000000
;
proc nlin method=dud ;
   parms  J=0.1  E=0.3  T1=5  T2=18.2 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run  ;
```

May 1996

```
data a ;
   input X Y ;
   cards ;
6     0.075815    6     0.069396    6     0.172340    6     0.107488
6     0.091033    7     0.045725    7     0.069735    7     0.127226
7     0.000000    7     0.098232    8     0.000000    8     0.133038
8     0.067249    8     0.086580    8     0.214500    9     0.336875
9     0.188561    9     0.360082    9     0.000000    9     0.180126
10    0.090212    10    0.073314    10    0.352645    10    0.279525
10    0.141343    11    0.302480    11    0.303951    11    0.448430
11    0.369276    11    0.327225    12    0.361882    12    0.287632
12    0.166945    12    0.107296    12    0.328330    13    0.061162
13    0.311333    13    0.385604    13    0.376176    13    0.321932
14    0.085763    14    0.522193    14    0.545171    14    0.397614
14    0.338696    15    0.735294    15    0.532351    15    0.131148
15    0.383772    15    0.436999    16    0.109981    16    0.362450
16    0.455005    16    0.031878    16    0.165563    17    0.259628
17    0.168527    17    0.458872    17    0.000000    17    0.453515
18    0.782949    18    0.278834    18    0.046937    18    0.338066
18    0.308166    19    0.048065    19    0.450362    19    0.062637
19    0.111607    20    0.064837    21    0.565327    21    0.000000
21    0.208623    21    0.062344    21    0.059207    22    0.000000
22    0.000000    22    0.000000    22    0.000000    22    0.094162
23    0.185014    23    0.000000    23    0.088355    23    0.045579
23    0.071582    24    0.142891    24    0.041929    24    0.043113
24    0.000000    24    0.000000    1     0.000000    1     0.104676
1     0.000000    1     0.112676    1     0.000000    2     0.074553
2     0.000000    2     0.038730    3     0.000000    3     0.044222
3     0.118427    3     0.048638    3     0.130492    4     0.049546
4     0.054555    4     0.031447    4     0.000000    5     0.046168
5     0.054805    5     0.043917    5     0.048008    5     0.000000
;
proc nlin method=dud ;
   parms  J=0.1  E=0.2  T1=5  T2=16.5 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

July 1996

```
data a ;
   input X Y ;
   cards ;
6     0.026110    6     0.146056    6     0.000000    6     0.076687
6     0.000000    7     0.088810    7     0.148258    7     0.121581
7     0.258131    7     0.000000    8     0.081588    8     0.181406
8     0.117096    8     0.265675    8     0.053619    9     0.168549
9     0.207156    9     0.178359    9     0.167616    10    0.118378
10    0.220629    10    0.150565    10    0.187793    10    0.217746
11    0.219386    11    0.742532    11    0.409218    11    0.351351
11    0.371471    12    0.173581    12    0.376851    12    0.405954
12    0.510687    12    0.216732    13    0.200240    13    0.552196
```

```
13    0.550122    13    0.425254    14    0.455032    14    0.414869
14    0.308642    14    0.196323    14    0.210600    15    0.471563
15    0.256279    15    0.284669    15    0.246548    16    0.294811
16    0.294166    16    0.414610    16    0.289169    16    0.210526
17    0.134202    17    0.164054    17    0.589910    17    0.134641
17    0.069767    18    0.202293    18    0.000000    18    0.407166
18    0.155763    18    0.397141    20    0.000000    20    0.000000
20    0.045496    20    0.109469    20    0.000000    21    0.038329
21    0.000000    21    0.123916    21    0.000000    21    0.000000
22    0.000000    22    0.088378    22    0.000000    22    0.000000
22    0.000000    23.5  0.000000    23.5  0.000000    23.5  0.000000
1.5   0.000000    1.5   0.000000    1.5   0.000000    1.5   0.000000
1.5   0.000000
;
proc nlin method=dud ;
   parms  J1=0.05  J2=0.3  E=0.3  T1=5.5  T2=10  T3=13  T4=16.5  ;
   file print ;
   Sr1=(J1/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T4))*(1-exp(-E*(T4-T1)))+
(((J2-J1)/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T2-T3))*(1-exp(-E*(T3-T2)))*
exp(-E*(T3-T2))+((J2-J1)/E)*(1-exp(-E*(T3-T2))))*exp(-E*(24+T1-T3))  ;
   Sr2=Sr1*exp(-E*(T2-T1))+(J1/E)*(1-exp(-E*(T2-T1))) ;
   Sf1=Sr2*exp(-E*(T3-T2))+(J2/E)*(1-exp(-E*(T3-T2))) ;
   Sf2=Sf1*exp(-E*(T4-T3))+(J1/E)*(1-exp(-E*(T4-T3))) ;
   So=Sf2*exp(-E*(24-T4)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr1*exp(-E*(X-T1))+(J1/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=T3 then do ;
      model Y=Sr2*exp(-E*(X-T2))+(J2/E)*(1-exp(-E*(X-T2))) ;
   end ;
   else if T3<X<=T4 then do ;
      model Y=Sf1*exp(-E*(X-T3))+(J1/E)*(1-exp(-E*(X-T3))) ;
   end ;
   else if T4<X<=24 then do ;
      model Y=Sf2*exp(-E*(X-T4)) ;
   end ;
   run ;
```

September 1996 - supplemented fish

```
data a ;
   input X Y ;
   cards ;
6       0.203607  6       0.393959  6       0.000000  6       0.109409
6       0.274725  7       0.158443  7       0.000000  7       0.000000
7       0.000000  8       0.102249  8       0.157563  8       0.037425
8       0.000000  8       0.137552  9       1.446718  9       0.492005
9       1.205757  9       0.452944  9       0.485437  10      0.285714
10      0.417141  10      0.337079  10      0.477327  10      0.596910
11      0.174390  11      0.379795  11      0.445576  12      0.392003
12      0.557103  12      0.281426  12      0.495495  12      0.283286
13      0.178571  13      0.380785  13      0.257922  13      0.406504
13      0.645482  14      0.394945  14      0.770328  14      0.278164
14      0.416667  14      0.226757  15      0.339982  15      0.433369
15      0.868167  15      0.622877  15      0.290192  16      1.186376
16      0.159299  16      0.211149  16      1.122544  16      0.251889
17      0.690938  17      0.462072  17      0.611829  17      0.443319
17      0.563380  18      0.814076  18      0.077280  18      0.400400
18      0.481696  18      0.420610  19      0.157092  19      0.436840
19      0.472519  19      0.639205  19      0.284091  20      0.051697
20      0.288600  20      0.648607  20      0.674624  20      0.167973
21      0.449775  21      0.331263  21      0.644607  21      0.240096
21      0.076570  22      0.180701  22      0.042159  22      0.124585
```

```
22      0.324675  22      0.137112  23      0.195791  23      0.000000
23      0.000000  23      0.000000  23      0.000000  24      0.364409
24      0.315126  24      0.461023  24      0.162338  1       0.030257
1       0.045746  1       0.000000  1       0.000000  2       0.211149
2       0.000000  2       0.000000  2       0.561167  2       0.000000
3       0.127348  3       0.000000  3       0.183554  3       0.045434
3       0.000000  4       0.000000  4       0.000000  4       0.098912
4       0.000000  4       0.000000  5       0.000000  5       0.501630
5       0.025170  5       0.045106
;
proc nlin method=dud ;
   parms  J1=0.15  J2=1.7  J3=0.35  E=0.7  T1=7.8  T2=9.1  T3=13.5  T4=16
      T5=21  ;
   file print ;
   Sr1=(J1/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T5))*(1-exp(-E*(T5-T1)))+
((J2-J1)/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1)))+
(((J3-J1)/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T3-T4))*(1-exp(-E*(T4-T3)))*
exp(-E*(T4-T3))+((J3-J1)/E)*(1-exp(-E*(T4-T3))))*exp(-E*(24+T1-T4))  ;
   Sf1=Sr1*exp(-E*(T2-T1))+(J2/E)*(1-exp(-E*(T2-T1))) ;
   Sf2=Sf1*exp(-E*(T3-T2))+(J1/E)*(1-exp(-E*(T3-T2))) ;
   Sf3=Sf2*exp(-E*(T4-T3))+(J3/E)*(1-exp(-E*(T4-T3))) ;
   Sf4=Sf3*exp(-E*(T5-T4))+(J1/E)*(1-exp(-E*(T5-T4))) ;
   So=Sf4*exp(-E*(24-T5)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr1*exp(-E*(X-T1))+(J2/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=T3 then do ;
      model Y=Sf1*exp(-E*(X-T2))+(J1/E)*(1-exp(-E*(X-T2))) ;
   end ;
   else if T3<X<=T4 then do ;
      model Y=Sf2*exp(-E*(X-T3))+(J3/E)*(1-exp(-E*(X-T3))) ;
   end ;
   else if T4<X<=T5 then do ;
      model Y=Sf3*exp(-E*(X-T4))+(J1/E)*(1-exp(-E*(X-T4))) ;
   end ;
   else if T5<X<=24 then do ;
      model Y=Sf4*exp(-E*(X-T5)) ;
   end ;
   run ;
```

January 1997 - supplemented fish

```
data a ;
   input X Y ;
   cards ;
1       0.083667  1       0.100400  1       0.195708  1       0.065712
2       0.288880  2       0.074586  2       0.000000  2       0.000000
2       0.000000  3       0.000000  3       0.000000  3       0.227514
3       0.000000  3       0.000000  4       0.057456  4       0.102037
4       0.060746  4       0.032430  4       0.061381  5       0.126512
5       0.013131  5       0.030435  5       0.091863  5       0.080900
6       0.032279  6       0.258238  6       0.206165  6       0.062867
6       0.142546  7       0.038505  7       0.000000  7       0.163882
7       0.180982  7       0.000000  8       0.124588  8       0.131837
8       0.091661  8       0.056435  8       0.071905  9       0.338260
9       0.434855  9       0.547096  9       0.607066  9       0.274190
10      0.744097  10      0.201700  10      0.066735  10      0.801138
10      0.253100  11      0.328561  11      0.553527  11      0.975227
11      0.123565  11      0.507816  12      0.546604  12      0.866272
12      0.355771  12      0.228402  12      0.179049  13      0.231309
13      0.264233  13      0.564736  13      0.535522  13      0.454491
14      0.152534  14      0.164882  14      0.283827  14      0.653117
14      0.273726  15      0.303730  15      0.417645  15      0.111308
```

```
15      0.546936  15      0.355832  16      0.873120  16      0.553230
16      0.400770  16      0.305863  16      0.425720  17      0.566199
17      0.534352  17      0.546651  17      0.414718  17      0.661953
18      0.743916  18      0.827147  18      0.756518  18      0.267456
18      0.348550  19      0.387121  19      0.188156  19      0.134233
19      0.456211  19      0.187034  20      0.387699  20      0.571824
20      0.363495  20      0.450822  20      0.356168  21      0.407464
21      0.505034  21      0.230179  21      0.549802  21      0.148347
22      0.287163  22      0.543883  22      0.532246  22      0.420887
22      0.235259  23      0.348115  23      0.331642  23      0.368095
23      0.305319  23      0.216871  24      0.237340  24      0.078420
24      0.424078  24      0.023083  24      0.054827
;
proc nlin method=dud ;
   parms  J1=0.1  J2=0.27  E=0.365  T1=5.5  T2=8  T3=10.75  T4=14.75
T5=17.4  T6=22.67 ;
   file print ;
   Sr1=(J1/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T6))*(1-exp(-E*(T2-T1)))+
(((J2-J1)/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T3-T4))*(1-exp(-E*(T5-T4))*
(1-exp(-E*(24+T2-T5))*(1-exp(-E*(T3-T2)))))*exp(-E*(T5-T4))+((J2-J1)/E)*
(1-exp(-E*(T5-T4))))*exp(-E*(24-T5)) ;
   Sr2=Sr1*exp(-E*(T2-T1))+(J1/E)*(1-exp(-E*(T2-T1))) ;
   Sf1=Sr2*exp(-E*(T3-T2))+(J2/E)*(1-exp(-E*(T3-T2))) ;
   Sr3=Sf1*exp(-E*(T4-T3))+(J1/E)*(1-exp(-E*(T4-T3))) ;
   Sf2=Sr3*exp(-E*(T5-T4))+(J2/E)*(1-exp(-E*(T5-T4))) ;
   Sf3=Sf2*exp(-E*(T6-T5))+(J1/E)*(1-exp(-E*(T6-T5))) ;
   So=Sf3*exp(-E*(24-T6)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr1*exp(-E*(X-T1))+(J1/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<=X<T3 then do ;
      model Y=Sr2*exp(-E*(X-T2))+(J2/E)*(1-exp(-E*(X-T2))) ;
   end ;
   else if T3<=X<T4 then do ;
      model Y=Sf1*exp(-E*(X-T3))+(J1/E)*(1-exp(-E*(X-T3))) ;
   end ;
   else if T4<=X<T5 then do ;
      model Y=Sr3*exp(-E*(X-T4))+(J2/E)*(1-exp(-E*(X-T4))) ;
   end ;
   else if T5<=X<T6 then do ;
      model Y=Sf2*exp(-E*(X-T5))+(J1/E)*(1-exp(-E*(X-T5))) ;
   end ;
   else if T6<X<=24 then do ;
      model Y=Sf3*exp(-E*(X-T6)) ;
   end ;
   run ;
```

January 1997 - unsupplemented fish

```
data a ;
   input X Y ;
   cards ;
1     0.000000    1     0.060091    1     0.000000    1     0.018318
1     0.055668    2     0.022144    2     0.000000    2     0.000000
2     0.029800    2     0.000000    3     0.000000    3     0.000000
3     0.034642    3     0.039488    3     0.000000    4     0.000000
4     0.000000    4     0.029086    4     0.000000    4     0.000000
5     0.000000    5     0.072523    5     0.036726    5     0.000000
5     0.000000    6     0.000000    6     0.000000    6     0.048059
6     0.102421    6     0.047098    7     0.012333    7     0.042549
7     0.000000    7     0.052599    7     0.019086    8     0.436791
8     0.072311    8     0.318276    8     0.032116    8     0.083968
9     0.062692    9     0.141428    9     0.195380    9     0.018252
```

```
9     0.000000    10    0.204863    10    0.067972    10    0.144459
10    0.172762    10    0.067934    11    0.354608    11    0.076151
11    0.231506    11    0.724788    11    0.137532    12    0.108915
12    0.132630    12    0.142806    12    0.068397    12    0.167802
13    0.191545    13    0.230974    13    0.295847    13    0.550194
13    0.532323    14    0.190861    14    0.243283    14    0.664061
14    1.132808    14    0.490785    15    0.125829    15    0.587737
15    0.491036    15    0.632411    15    0.353745    16    0.155654
16    0.159051    16    0.501368    16    0.336813    16    0.244220
17    0.200645    17    0.115785    17    0.061511    17    0.060227
17    0.311610    18    0.105150    18    0.019050    18    0.203525
18    0.173385    18    0.277696    19    0.386161    19    0.117110
19    0.312434    19    0.335873    19    0.422115    20    0.014601
20    0.021218    20    0.000000    20    0.246499    20    0.303642
21    0.011078    21    0.028918    21    0.140634    21    0.345855
21    0.137893    22    0.025004    22    0.093584    22    0.029800
22    0.000000    22    0.139817    23    0.000000    23    0.056346
23    0.040982    23    0.031191    23    0.046123    24    0.000000
24    0.029385    24    0.042399    24    0.032826    24    0.000000
;
proc nlin method=dud ;
   parms  J=0.13  E=0.21  T1=8.75  T2=14.25 ;
   file print ;
   Sr=(J/E)*(1/(1-exp(-24*E)))*exp(-E*(24+T1-T2))*(1-exp(-E*(T2-T1))) ;
   Sf=Sr*exp(-E*(T2-T1))+(J/E)*(1-exp(-E*(T2-T1))) ;
   So=Sf*exp(-E*(24-T2)) ;
   if 0<=X<=T1 then do ;
      model Y=So*exp(-E*X) ;
   end ;
   else if T1<X<=T2 then do ;
      model Y=Sr*exp(-E*(X-T1))+(J/E)*(1-exp(-E*(X-T1))) ;
   end ;
   else if T2<X<=24 then do ;
      model Y=Sf*exp(-E*(X-T2)) ;
   end ;
   run ;
```

Appendix 3

Calculation of confidence limits to the daily ration

Sainsbury (1986) in his further presentation of the Elliott & Persson (1978) model, which was the basis for the development of the MAXIMS model, gave a formula for the calculation of confidence limits to the daily ration in Model 1.1. He himself pointed out that the determination of confidence limits in the inversely dependent models was not possible by straightforward means since the formula for these include exponential functions so that a jackknife method would have to be applied. The general principle behind the calculation for constant ingestion models was summarised by Rasch (1976) and may be demonstrated here with the aid of the formula for the daily ration to the MAXIMS Model 2.1. This involves three steps:

1. Determination of the partial derivatives matrix from the daily ration formula

2. Determination of the covariance matrix from the parameter correlation coefficients and standard errors

3. Multiplication of the first matrix with the second matrix and then multiplying the product with the inverse of the first matrix.

1. Partial derivatives matrix

For the sake of example, the formula for the calculation of the daily ration to the MAXIMS model 2.1 (Eq. (24)) will be treated here. The daily ration is calculated as:

$$R_{\mathrm{d}} = J \times (T_{\mathrm{f1}} - T_{\mathrm{r1}} + T_{\mathrm{f2}} - T_{\mathrm{r2}})$$

From this, the partial derivatives are obtained by differentiating R_{d} with respect to each parameter as follows:

$$dR_d/dJ_1 = T_{f1} - T_{r1} + T_{f2} - T_{r2}$$

$$dR_d/dT_{r1} = J_1$$

$$dR_d/dT_{f1} = J_1$$

$$dR_d/dT_{r2} = J_1$$

$$dR_d/dT_{f2} = J_1$$

2. Covariance matrix

The covariances are calculated from the correlation coefficients and the standard errors, both included in the SAS output, in the following manner:

$$\mathrm{Cov}_{[A,B]} = \mathrm{SE}_{[A]} \times \mathrm{SE}_{[B]} \times \mathrm{CC}_{[A,B]}$$

($\mathrm{Cov}_{[A,B]}$ = covariance between parameters A and B, $\mathrm{SE}_{[A]}$ & $\mathrm{SE}_{[B]}$ = standard errors for A and B respectively, $\mathrm{CC}_{[A,B]}$ = correlation coefficient between A and B

Naturally, the covariance between a parameter and itself is merely the variance of that parameter.

3. Matrix calculation

The variance of the daily ration is then calculated as follows:

$$\mathrm{Var}_{[R_d]} = \begin{pmatrix} T_{f1} - T_{r1} + T_{f2} - T_{r2} & J_1 & J_1 & J_1 & J_1 \end{pmatrix} \times$$

$$\begin{pmatrix} \mathrm{Var}_{[J_1]} & \mathrm{Cov}_{[J_1,T_{r1}]} & \mathrm{Cov}_{[J_1,T_{f1}]} & \mathrm{Cov}_{[J_1,T_{r2}]} & \mathrm{Cov}_{[J_1,T_{f2}]} \\ \mathrm{Cov}_{[T_{r1},J_1]} & \mathrm{Var}_{[T_{r1}]} & \mathrm{Cov}_{[T_{r1},T_{f1}]} & \mathrm{Cov}_{[T_{r1},T_{r2}]} & \mathrm{Cov}_{[T_{r1},T_{f2}]} \\ \mathrm{Cov}_{[T_{f1},J_1]} & \mathrm{Cov}_{[T_{f1},T_{r1}]} & \mathrm{Var}_{[T_{f1}]} & \mathrm{Cov}_{[T_{f1},T_{r2}]} & \mathrm{Cov}_{[T_{f1},T_{f2}]} \\ \mathrm{Cov}_{[T_{r2},J_1]} & \mathrm{Cov}_{[T_{r2},T_{r1}]} & \mathrm{Cov}_{[T_{r2},T_{f1}]} & \mathrm{Var}_{[T_{r2}]} & \mathrm{Cov}_{[T_{r2},T_{f2}]} \\ \mathrm{Cov}_{[T_{f2},J_1]} & \mathrm{Cov}_{[T_{f2},T_{r1}]} & \mathrm{Cov}_{[T_{f2},T_{f1}]} & \mathrm{Cov}_{[T_{f2},T_{r2}]} & \mathrm{Var}_{[T_{f2}]} \end{pmatrix} \times \begin{pmatrix} T_{f1} - T_{r1} + T_{f2} - T_{r2} \\ J_1 \\ J_1 \\ J_1 \\ J_1 \end{pmatrix}$$

The variance may then be used to calculate confidence limits using Student's t-distribution, the degrees of freedom being the number of data points used less the number of parameters in the model.