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An Investigation of Early-Season Abundance Indices for Short-finned Squid (*Illex illecebrosus*) in Subareas 3+4.

by

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Abstract

A commercial catch per unit effort (CPUE) index of squid biomass was produced based on 1977-1999 squid by-catch from the directed fishery for silver hake (*Merluccius bilinearis*) during July on the Scotian Shelf (Subarea 4). Although this index was not standardized to account for variation in fleet composition, it was included with 3 other input variables in multiple regression analysis with SA 3+4 squid catch as the dependent variable. Other regressors included squid biomass and body size from July Scotian Shelf surveys as well as an environmental index. The CPUE index did not contribute significantly in explaining variation in catch, but a final model which included the July survey biomass index and mean weight, as well as spring ice extent, accounted for considerably more of the variation in annual catch than any single-variable model.

Introduction

The purpose of this paper is to attempt to develop an early-season predictive model of short-finned squid abundance level in Subareas 3+4 using several indices. Initially, commercial catch and effort data from the international fishery for silver hake, squid and argentine are analysed toward establishing a CPUE index. The resultant CPUE index is then included with 3 other indices in a multiple regression analysis toward predicting annual catch level early in the fishing season.

Materials and Methods

Annual Subarea 3+4 squid catch was assumed to reflect annual abundance level since 1977, and was used as the dependent variable in regression analysis. Catches for Subarea 3 are predominately derived from a directed small-boat jig fishery which is prosecuted in shallow near-shore areas of insular Newfoundland. Subarea 4 catches are from the international bottom trawl fishery for silver hake, squid and argentine on the Scotian Shelf. Commercial CPUE of squid in this Subarea 4 fishery is thought to vary considerably depending on the species for which effort is directed. Commercial catch and effort data, from fishing activity monitored by observers since 1977, were compared among 3 categories of directed effort (squid, silver hake, and other species), by month, toward developing an unbiased early-season CPUE index of squid abundance. Only a small portion of the annual fishing activity was monitored by observers and used in this analysis.

Two additional early-season predictors were available from July Scotian Shelf (Div. 4VWX) bottom trawl surveys. These include a biomass index (kg/tow), and a mean body weight index (Dawe and Hendrickson, 1998; Hendrickson, 1999; NAFO, 1999, Dawe et al. (this meeting).

An environmental variable was also selected as a fourth predictor for regression analysis. A variety of environmental variables are known to be related to squid abundance level (Dawe et al., in press). The index selected for the current modelling exercise was winter (Jan-Mar) sea ice area (sq. km.) because it represents a very early index.

The 4 regressors selected were:

SURVEY; July survey kg/tow
CPUE; July squid by-catch CPUE from the directed SA 4 silver hake fishery (kg/h)
WT; July SA 4 survey mean squid body wt (kg.)
ICE; Jan-Mar Northwest Atlantic area of sea ice extent (‘000 sq km.)

All correlation and regression analysis was performed using SAS basics. The approach taken in developing the model was to start with a full model including all 4 regressors and progressively eliminate unimportant variables until a final model is accepted.

Results and Discussion

Commercial CPUE Index

Commercial CPUE of squid from the Subarea 4 mixed-species fishery was variable but generally low in June of most years (Fig.1). It increased considerably in July. Data were scanty or lacking in August. It was apparent, especially in July (Fig. 1),that squid CPUE was much higher in the directed squid fishery than when effort was directed for silver hake or other species. However it also appeared that annual trends were similar among all 3 categories of directed fishing. Annual trends in squid CPUE agreed fairly well with July survey catch rates for both the squid and the silver hake directed fisheries (Fig. 2). However annual effort levels were low and variable from the directed squid fishery. Therefore squid by-catch CPUE from the directed silver hake fishery was selected for further consideration as a commercial index. Annual trends in CPUE were compared among the months April- August (Fig. 3) toward identifying the earliest month which could provide a useful index. Annual trends for the months earlier than July did not agree well with catch or July survey trends, due especially to high CPUE values for the period 1987-1999 relative to 1977-1981. The August series appeared to agree well with catch trends (Fig.4) as did a SA 4 September survey index. However the August series is incomplete (Table 1) and relatively late. Therefore, the July CPUE series from the directed silver hake fishery was selected for use in the modelling exercise.

Model Development

Simple correlation analysis (Table 2) showed that all 4 selected predictors were significantly correlated with annual catch. The July survey biomass index and mean weight were especially strongly correlated with catch ($p<0.001$).

Annual July fishing effort levels varied considerably among years so the effect of weighting CPUE by effort was initially investigated. The fit of regressions of CPUE on catch was only marginally improved when weighting was applied (r-square=0.33, Table 4) versus unweighted regression (r-square=0.32). Therefore weighting was not applied in multiple regression analysis.

The full model, with 4 regressors, provided a highly significant fit and accounted for 71 percent of the variability in catch (Table 5). However CPUE did not contribute significantly to the model ($p=0.71$) and so it was rejected. The resultant 3-regressor model accounted for 70 percent of the variability in catch (Table 6) and was accepted as the final model. Although mean wt was significant only at the 0.20 probability level it was retained in the final model because its rejection resulted in r-square declining from 0.70 to 0.67.For comparison, a simple model with only survey biomass index as a single regressor accounted for only 49 percent of the variation in catch (Table 7) and that simple model did not fit the catch series as well as did the final model (Fig. 5). Catches predicted by the final model tended to underestimate empirical values during years of high abundance and overestimate those in years of low abundance, particularly in the past 3 years.

Acknowledgements

We thank Doug Swain for updating the September survey series for the southern Gulf of St. Lawrence, Eugene Colbourne for providing the ice area index and Don Parsons for helpful suggestions.

References

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Hendrickson, L. C. MS. 1999. Fishery effects on spawner escapement in the Northwest Atlantic *Illex Illecebrosus* stock. NAFO SCR Doc. 99/66, Ser N4125, 8 p.

NAFO 1999. Report of the Scientific Council. June 1999 meeting. NAFO Scientific Council Report 1999: 167-170.

Table 1. Distribution of fishing effort (h) directed for silver hake over the months Apr-Aug, by year, 1977-1999

Year	Apr	May	Jun	Jul	Aug
77	3	375.4		46.3	578.9
78	9.7	17.8	1037.1	310.3	73.1
79		846.6	286.1	389.7	114.6
80	31.5	1236.9	3370.2	2244.5	143.9
81	24.8	400	3111.1	2258.5	104.7
82	6.3	64.7	432	895.4	26
83	49.3	437.5	394.5	20.2	
84	138.7	237	1228.9	1393.7	207.7
85	88.5	94.2	1096.6	1603.8	402.7
86	2.2	250.7	1255.3	1132.1	472.1
87	10.2	949.7	2032.8	5159	917.8
88	97	2224.8	5912.1	1996.6	
89	126.7	5922.2	5236.6	673.7	
90	1214.1	3314.9	5886.3	2002.9	254.4
91	531.9	3460.8	8433.2	3696.7	
92	321.4	2715.5	1578.1	954.3	1297
93	812.4	1978.1	4105.1	4448.1	311.7
94	184.4	2079	1724.8	639.4	
95	775.2	1144.7	3449.8	1789.9	
96	450.2	1584.6	2304	1604.3	2.4
97	285	780.9	3210.3	1121.7	104.5
98	136.3	174.9	1426	574.5	132
99	538		538.8	419.8	

Table 2. Correlation matrix for all variables,1977-1999.

```
                          Correlation Analysis

        5 'VAR' Variables:  CATCH     SURVEY    CPUE      WT        ICE


                           Simple Statistics

Variable          N        Mean     Std Dev          Sum      Minimum      Maximum

CATCH            23    22.49813    41.04724    517.45700      0.11100    162.09200
SURVEY           23     3.57652     3.20532     82.26000      0.40000     14.20000
CPUE             23   233.54348   232.40945         5372      9.90000    894.80000
WT               23     0.09196     0.03865      2.11500      0.02700      0.18700
ICE              23     2.20783     0.72520     50.78000      1.18000      3.44000


    Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 23

                  CATCH        SURVEY          CPUE            WT           ICE

  CATCH         1.00000       0.69903       0.56166       0.68998      -0.45703
                 0.0           0.0002        0.0053        0.0003        0.0283

  SURVEY        0.69903       1.00000       0.51807       0.54138      -0.03438
                 0.0002        0.0           0.0113        0.0076        0.8762

  CPUE          0.56166       0.51807       1.00000       0.60144      -0.28639
                 0.0053        0.0113        0.0           0.0024        0.1852

  WT            0.68998       0.54138       0.60144       1.00000      -0.46727
                 0.0003        0.0076        0.0024        0.0           0.0246

  ICE          -0.45703      -0.03438      -0.28639      -0.46727       1.00000
                 0.0283        0.8762        0.1852        0.0246        0.0
```

Table 3. Glm output, model catch=cpue, unweighted.

```
                         General Linear Models Procedure

Dependent Variable: CATCH
                                   Sum of            Mean
Source                  DF        Squares          Square   F Value      Pr > F

Model                    1   11693.390937    11693.390937      9.68      0.0053

Error                   21   25373.871244     1208.279583

Corrected Total         22   37067.262181

                  R-Square           C.V.        Root MSE              CATCH Mean

                  0.315464       154.5031       34.760316               22.498130


Source                  DF      Type I SS     Mean Square   F Value      Pr > F

CPUE                     1   11693.390937    11693.390937      9.68      0.0053

Source                  DF    Type III SS     Mean Square   F Value      Pr > F

CPUE                     1   11693.390937    11693.390937      9.68      0.0053


                                       T for H0:    Pr > |T|    Std Error of
Parameter                Estimate    Parameter=0                  Estimate

INTERCEPT            -.6690329887          -0.06      0.9493     10.39196704
CPUE                 0.0991985030           3.11      0.0053      0.03188736
```

Table 4. Glm output, model catch=cpue, weighted by effort.

```
                          General Linear Models Procedure

Dependent Variable: CATCH
Weight:             EFFJ
                                  Sum of              Mean
Source                  DF       Squares            Square   F Value      Pr > F

Model                    1  7193548.3427      7193548.3427     10.12      0.0045

Error                   21 14926408.3422       710781.3496

Corrected Total         22 22119956.6849

                  R-Square          C.V.          Root MSE            CATCH Mean

                  0.325206      6817.449       843.07850             12.366481


Source                  DF     Type I SS       Mean Square   F Value      Pr > F

CPUE                     1  7193548.3427      7193548.3427     10.12      0.0045

Source                  DF   Type III SS       Mean Square   F Value      Pr > F

CPUE                     1  7193548.3427      7193548.3427     10.12      0.0045


                                           T for H0:    Pr > |T|   Std Error of
Parameter                  Estimate      Parameter=0                 Estimate

INTERCEPT              -1.029116075            -0.17      0.8687     6.15003003
CPUE                    0.078809174             3.18      0.0045     0.02477269
```

Table 5. Glm output, full model catch=survey cpue wt ice.

```
                    General Linear Models Procedure

Dependent Variable: CATCH
                                   Sum of            Mean
Source                  DF        Squares          Square   F Value     Pr > F

Model                    4   26161.423867     6540.355967     10.79     0.0001

Error                   18   10905.838314      605.879906

Corrected Total         22   37067.262181

                  R-Square           C.V.        Root MSE           CATCH Mean

                  0.705782       109.4074       24.614628            22.498130


Source                  DF      Type I SS     Mean Square   F Value     Pr > F

SURVEY                   1   18112.852430    18112.852430     29.90     0.0001
CPUE                     1    2016.811603     2016.811603      3.33     0.0847
WT                       1    3285.832477     3285.832477      5.42     0.0317
ICE                      1    2745.927358     2745.927358      4.53     0.0473

Source                  DF    Type III SS     Mean Square   F Value     Pr > F

SURVEY                   1   6421.2343645    6421.2343645     10.60     0.0044
CPUE                     1     86.0363558      86.0363558      0.14     0.7107
WT                       1    702.8138506     702.8138506      1.16     0.2957
ICE                      1   2745.9273576    2745.9273576      4.53     0.0473


                                    T for H0:    Pr > |T|   Std Error of
Parameter               Estimate   Parameter=0                Estimate

INTERCEPT             15.2892645          0.52     0.6099     29.4410877
SURVEY                 6.9577329          3.26     0.0044      2.1372325
CPUE                   0.0111730          0.38     0.7107      0.0296497
WT                   219.3355044          1.08     0.2957    203.6488944
ICE                  -18.3231467         -2.13     0.0473      8.6069407
```

Table 6. Glm output, final model catch=survey wt ice.

```
                        General Linear Models Procedure

Dependent Variable: CATCH
                                     Sum of            Mean
Source                  DF          Squares          Square   F Value      Pr > F

Model                    3     26075.387511     8691.795837     15.02      0.0001

Error                   19     10991.874669      578.519719

Corrected Total         22     37067.262181

                  R-Square             C.V.        Root MSE            CATCH Mean

                  0.703461         106.9086       24.052437             22.498130


Source                  DF        Type I SS     Mean Square   F Value      Pr > F

SURVEY                   1     18112.852430    18112.852430     31.31      0.0001
WT                       1      5089.354218     5089.354218      8.80      0.0079
ICE                      1      2873.180863     2873.180863      4.97      0.0381

Source                  DF      Type III SS     Mean Square   F Value      Pr > F

SURVEY                   1     7569.0767524    7569.0767524     13.08      0.0018
WT                       1     1004.8484901    1004.8484901      1.74      0.2032
ICE                      1     2873.1808635    2873.1808635      4.97      0.0381


                                     T for H0:    Pr > |T|   Std Error of
Parameter              Estimate     Parameter=0                Estimate

INTERCEPT            15.2976550            0.53     0.6011     28.7686535
SURVEY                7.2010527            3.62     0.0018      1.9908274
WT                  245.9664120            1.32     0.2032    186.6313499
ICE                 -18.6484171           -2.23     0.0381      8.3679596
```

Table 7. Glm output, model catch=survey.

```
                      General Linear Models Procedure

Dependent Variable: CATCH
                                     Sum of             Mean
Source                  DF          Squares           Square   F Value     Pr > F

Model                    1     18112.852430     18112.852430     20.07     0.0002

Error                   21     18954.409751       902.590941

Corrected Total         22     37067.262181

                  R-Square             C.V.         Root MSE           CATCH Mean

                  0.488648         133.5362        30.043151            22.498130


Source                  DF        Type I SS      Mean Square   F Value     Pr > F

SURVEY                   1     18112.852430     18112.852430     20.07     0.0002

Source                  DF      Type III SS      Mean Square   F Value     Pr > F

SURVEY                   1     18112.852430     18112.852430     20.07     0.0002


                                        T for H0:    Pr > |T|    Std Error of
Parameter                 Estimate     Parameter=0                  Estimate

INTERCEPT             -9.518225733           -1.00     0.3280      9.50382744
SURVEY                 8.951813662            4.48     0.0002      1.99831107
```

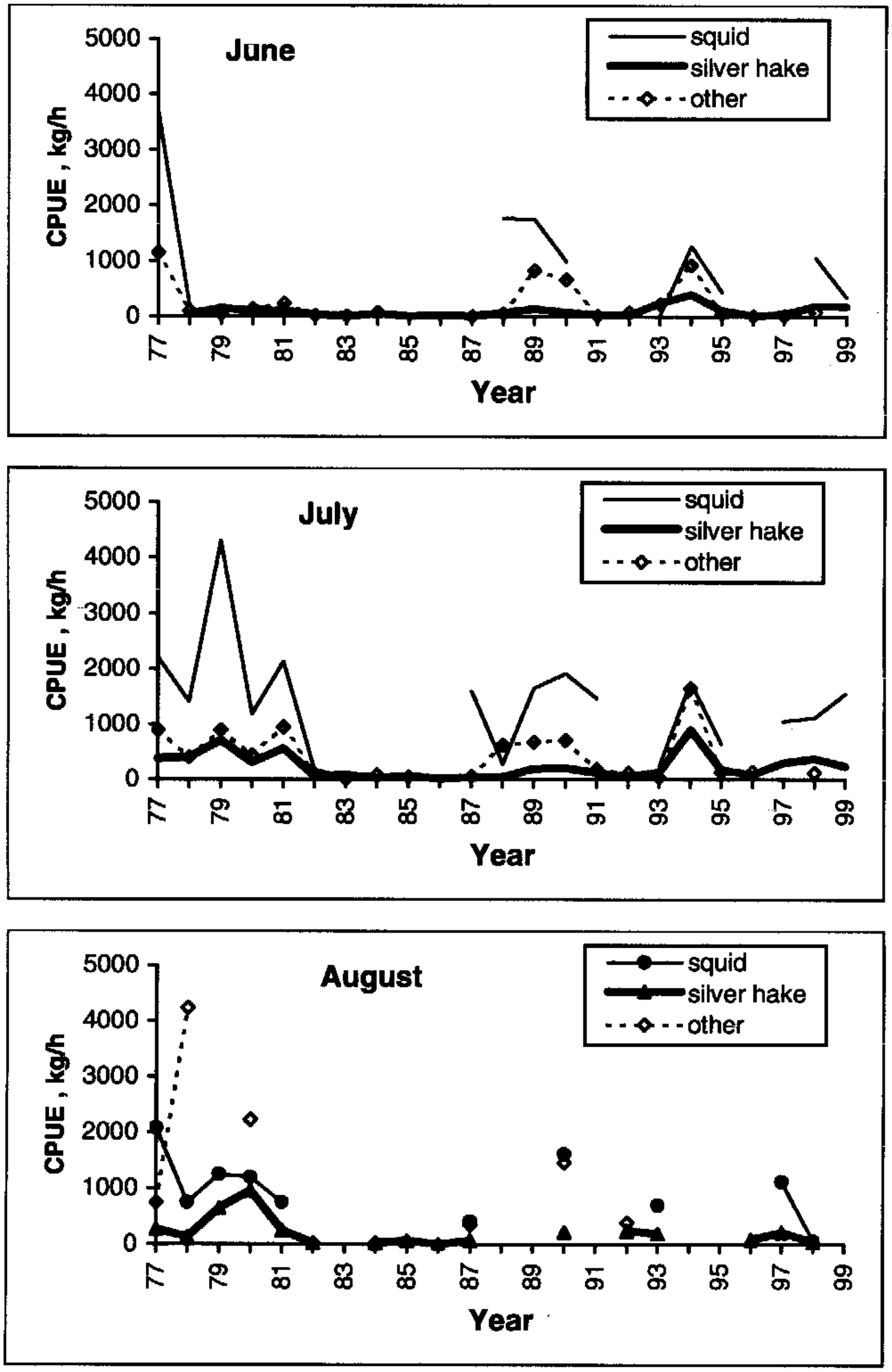
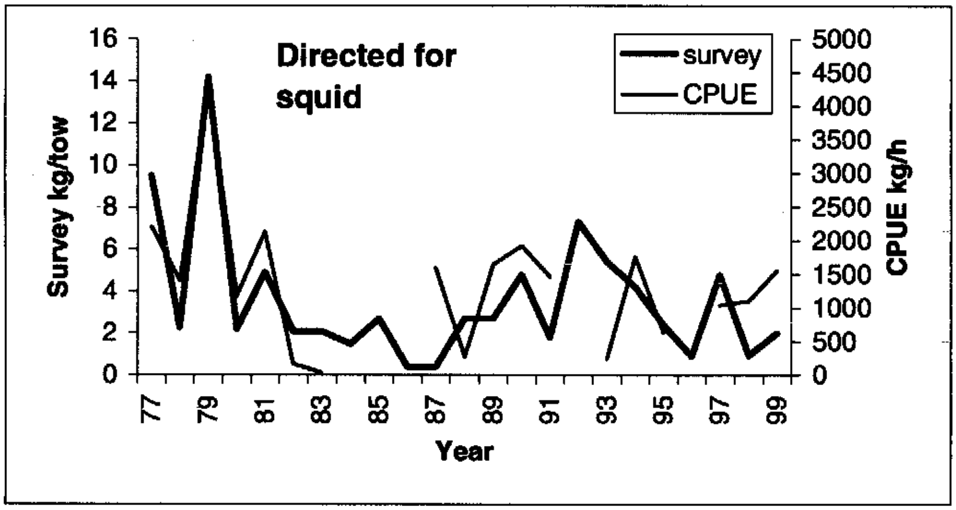


Fig. 1. Comparison of SA 4 commercial CPUE of short-finned squid for each of 3 categories of directed fishing effort by year for the months June, July, and August.



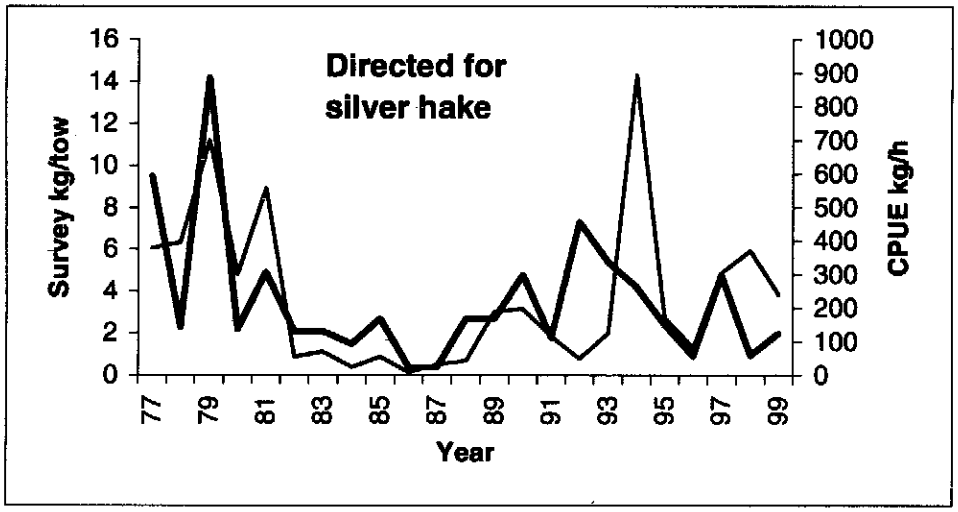


Fig. 2. Comparison of SA 4 July survey catch rate of squid with commercial CPUE when effort is directed for squid (top) versus silver hake (below).

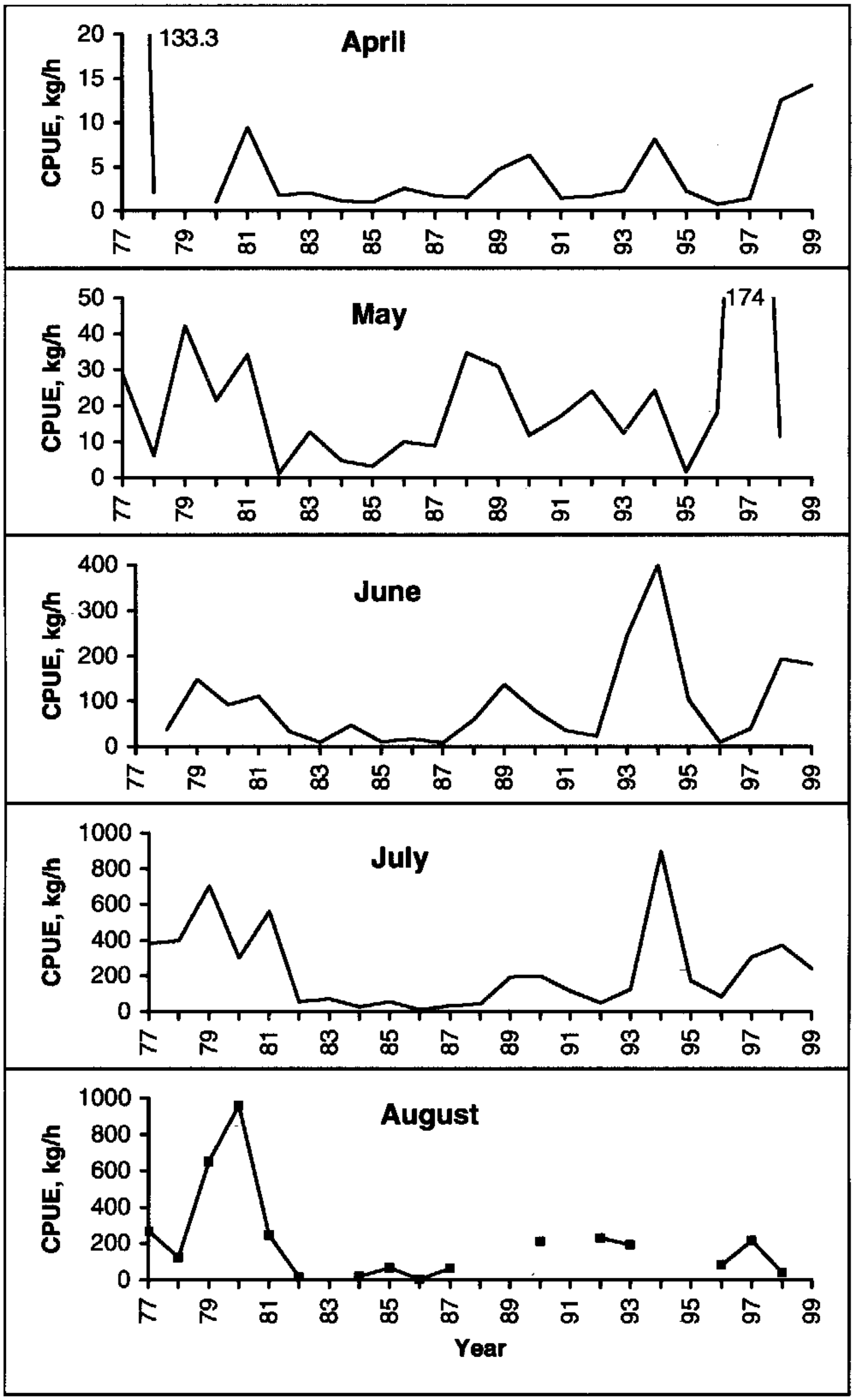


Fig.3. Annual trends in squid CPUE from the SA 4 directed fishery for silver hake for the months April-August, 1977-1999.

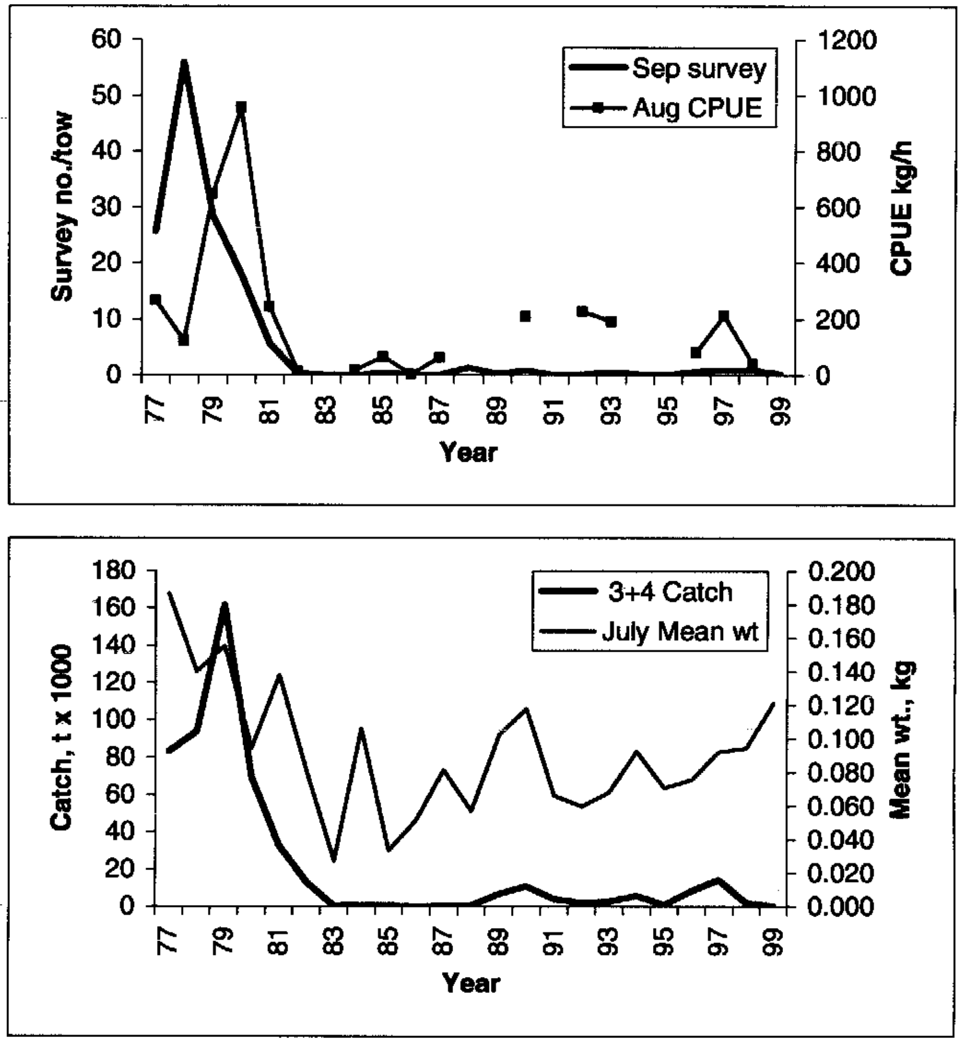
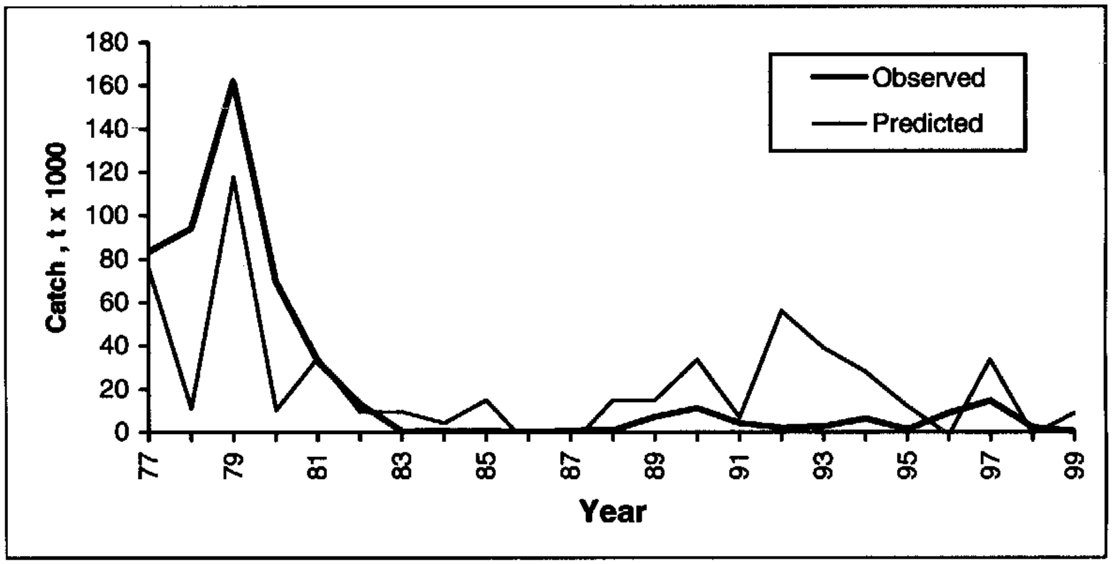


Fig. 4. Annual trends in SA 4 August CPUE from the directed silver hake fishery and Sept. Div. 4T survey abundance index (top) and in annual SA 3+4 catch and July SA 4 suurvey mean squid body weight (below).



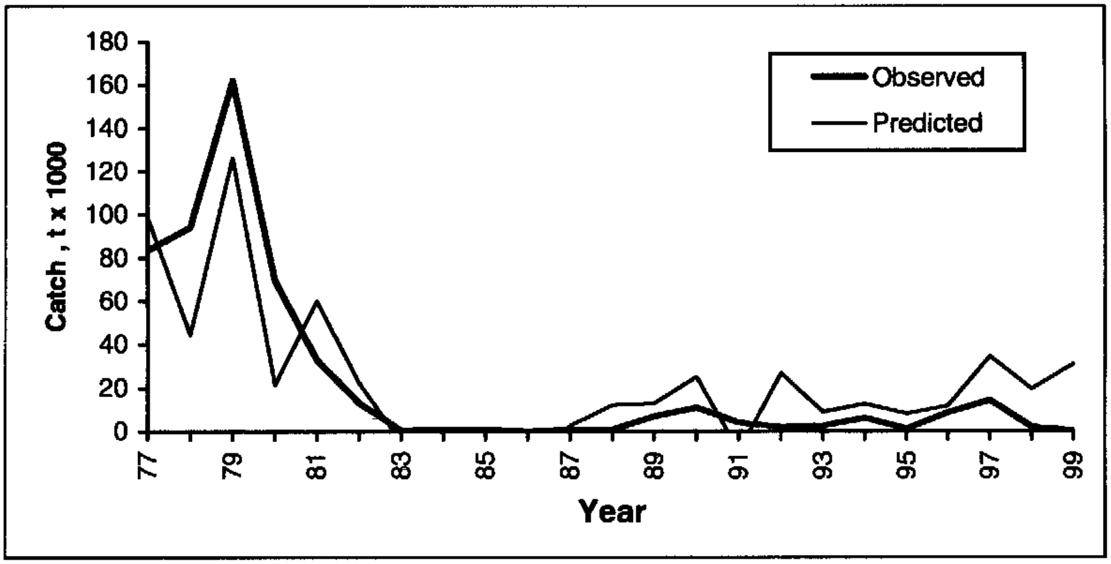


Fig. 5. Comparison of observed SA 3+4 Catch with that predicted by the July survey catch rate alone (top) and with that predicted by the final model that includes July survey catch rate, winter ice extent, and mean July survey body weight as predictors (below).