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EFFECTS OF TRAWLING AND LONGLINING ON THE YIELD AND BIOMASS OF COD STOCKS - NUMERICALLY SIMULATED

by

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ABSTRACT

Numerical studies were conducted on the effects of trawl and longline catches on a cod stock and possible yields from it.

Five year mean age composition of Pacific cod (Gadus macrocephalus) from the Bering Sea was used as initial age composition of the stock, which was normalized to 1 ton. Age specific Z (total mortality) was computed from this distribution and natural mortality was derived by subtracting fishing mortality from Z. Age compositions of catches were either prescribed from empirical data or created with fishing mortality coefficient (F), which was assumed constant with age after the age of full recruitment. The computations were done with different catch levels for six years assuming average constant recruitment.

Essential results of this study are: a) The stock left in the sea decreases with increasing catch and reaches an equilibrium if recruitment and catches remain constant. With similar catch levels this equilibrium is reached earlier with longline and is higher than that of trawl. b) If a given level of stock in sea is desired, higher annual catches can be taken with longlines than with trawl. c) By the same catch size longlines remove more older and more piscivorous fish which is beneficial to recruitment if the latter is largely controlled by predation.

The above mentioned essential results indicate, among others that some longline fishing might be allowed to continue when TAC for trawlers has been reached.

INTRODUCTION

Until the 1950-ies it was believed that fishing had a minor impact on the size and variability of the fish stocks. The relative impact of fishing on stocks versus natural fluctuations is to some extent still unclear. However, increased fishing effort and improvement of fishing gear and methods have during the last 30 years coincided with a considerable decrease of major fish stocks despite a rising number of regulations to manage the fish resources.

Today there seems to be general agreement among fisheries scientists that fishing has a significant impact on the dynamics of fish populations, and that this impact is dependent on the status of the stocks. Further, it is known that the main fishing gears operate with different principles of capture and with different size- and species-selective properties. Proper management of fish stocks should therefore not only be based on recommendations on total catch quotas but also on how these quotas should be taken. However, the catching regime for harvesting a given quota is to a large extent decided on the basis of the traditional composition of gear types within a fishing fleet, with little attention to the conservation effects on the fish stock of given gear types.

Some authors have recently focused on multigear exploitation of groundfish stocks. Laevastu and Favorite (1988) reviewed the effects of fishing and the "optimum take". Analyzing the effect of different trawl gears in a mixed species fishery, Murawski et al. (1989) pointed out the negative impact of discards of undersized target species on proper stock assessment and future yield. Wespestad et al. (1982) recommended restrictions on bottom trawling to reduce the by-catch problem of crabs and halibut in the Bering Sea groundfish fishery, while similar restrictions were not found necessary for longlines and off bottom trawling. O'Boyle et al. (1989) compared the bioeconomical effects of trawl and longline fishing in the Scotian shelf groundfish fishery and concluded that the yield and employment picture was superior for the longline fishing and that regulatory acts were necessary only for the trawler fleet. Comparing the size distribution of landed cod catches (not including discards), Bjordal (1989) showed that trawl and seine net catches contained 19% small cod while corresponding values for longline and gillnet were 6% and 2%, respectively. He also compared the conservation aspects of trawls and longlines and, although data are scarce on several conservation topics such as discards, survival after escapement and environmental effects, existing knowledge clearly indicates the conservational superiority of longlines versus trawl.

In order to recommend an optimal catching regime (gear type and effort) in a certain fishery, total bioeconomical models should be developed which include data on the conservational aspects of the different gear types: species- and size selectivity, discards, survival after escapement, fish quality, ghost fishing, environmental aspects and energy conservation as a basis for socio-economic and management considerations.

In the present study we have focused on the effects of trawling and longlining with different catch levels and age composition of catch on the stock remaining in the sea, using a numerical model.

Materials and Methods

A numerical simulation was used in this study. The initial age composition of the stock in the sea was taken as the five year mean (1983 to 1987) age composition of the cod (Gadus macrocephalus) stock in the Bering Sea (Fig. 1). The recruitment to the exploitable stock was assumed to be constant and equal to the five year mean recruitment. The initial stock size was normalized to 1000 kg and the corresponding initial distribution of numbers in different age classes was computed.

The five year mean age composition of the stock was also used to compute total mortality (Z) (Fig. 2), from which age dependent natural (or senescent) mortality was obtained by subtracting estimated fishing mortality which was assumed to be 15 percent of exploitable population and constant with age after full recruitment to the exploitable stock.

Two different age compositions of trawl and longline catches were used in the study. In one set of simulation runs, a number based fishing mortality was used, which was assumed to be constant with age after the age of full recruitment. In the second set of runs mean age compositions of Japanese trawl and longline catches from the Bering Sea in 1983 were used (Fig. 3). Computations were done for six years with each prescribed catch level (80kg, 160kg, and 240kg, and F=0.10, 0.15, and 0.20). The quantitative interaction between fishing mortality and senescent

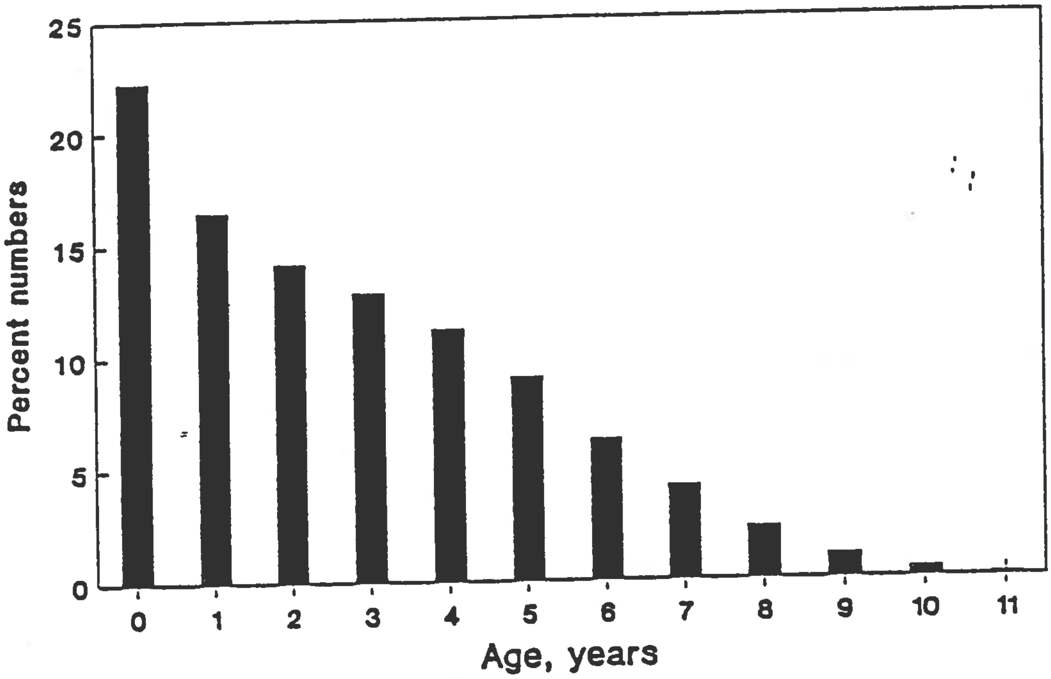

Figure 1. Initial age composition of Bering Sea cod stock (five year mean, 1983-87).

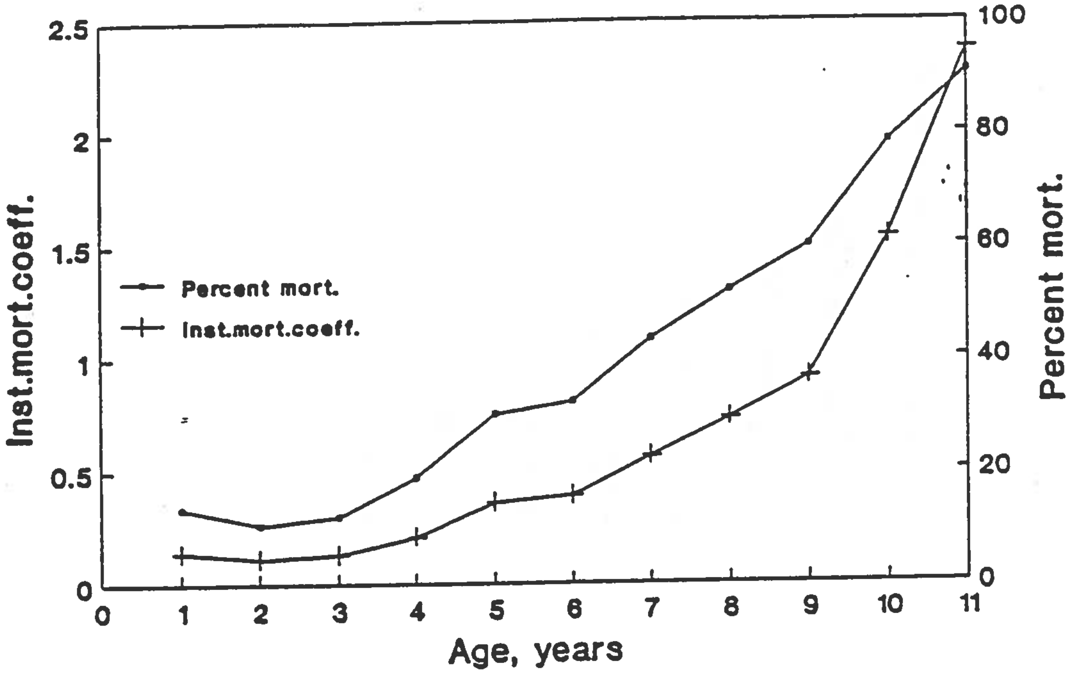

Figure 2. Total mortality of Bering Sea cod, expressed as instantaneous fishing mortality coefficient and as percentage mortality of a given age group (re. numbers).

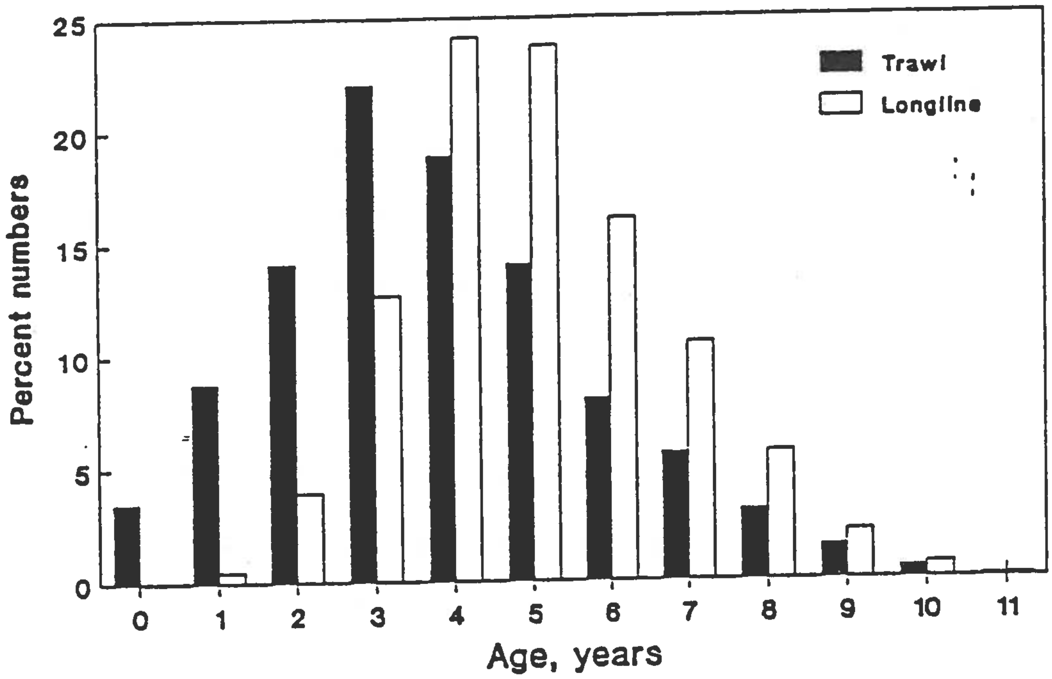

Figure 3. Age composition of Japanese trawl and longline catches (cod, Bering Sea, 1983).

mortality was taken from a numerical study by Laevastu and Bax (1986). The numerical simulation model (documented in the Appendix) can be used for the study of the effects of trawling and longline fishing in any combination of effort (catch) by these gears. In this report we present only some essential differences of these gears on the biomass remaining in the sea.

Results

The basic difference between the age composition of trawl and longline catches is that the age (size) of full recruitment to exploitable stock is one year earlier in trawl catches than in longline catches (Fig. 3). More prefishery juveniles are caught with trawls than with longlines, and consequently the amount of discards is higher from the trawl catch than from the longline catch. The amount of discards depends on several conditions. In our model the trawl was assumed to catch 26 percent of fish (numbers) younger than the fully recruited age class (3 year old). The corresponding value for longlines was assumed to be 17 percent (4 year old).

In the runs with prescribed catch amount both trawl and longline were assumed to catch equal given weight. However, if the catch is prescribed with number based fishing mortality coefficient F the amount (in weight) caught by the same F is not necessarily equal due to higher catch of young fish by trawl. The senescent (or natural) mortality remains higher than the fishing mortality even if fishing mortality (F) is 0.2.

If the recruitment to prefishery juveniles remains constant from one year to another (as was prescribed in the simulation runs), then with equal fishing mortality (F) a lower number of fish remain in the sea with trawl than with longline fishing (Fig. 4). This is mainly because the fishing mortality of trawl catches starts one year earlier than longline catches. The difference in fish biomass (weight) remaining in the sea after four years of fishing with trawls versus longlines is even more noticeable than the difference in numbers (Fig. 5).

With increasing annual catches the number of fish left in the sea decreases. By the same amount (weight) of catch this decrease is considerably greater when the stock is exploited by trawl compared with that of longlining (Figs. 6 and 7). Consequently the fish biomass in the sea decreases with increasing annual catch during the first 4 to 5 years. However, if the annual catch remains constant, the biomass left in the sea reaches an equilibrium level which is dependent on the size of the annual catch. At the same catch level this equilibrium biomass is higher in case of longline catches than trawl catches (Figs. 8 and 9).

Discussion

This numerical study demonstrates that the exploitation strategy may have a marked influence on the dynamics of a fish stock. In this case it is predicted that if a given catch quota of cod is taken by longlines, a higher biomass will remain in the sea than if the same quota is fished with trawls. This effect is mainly caused by the different selective properties of the two gears, as the first fully recruited year class in the trawl

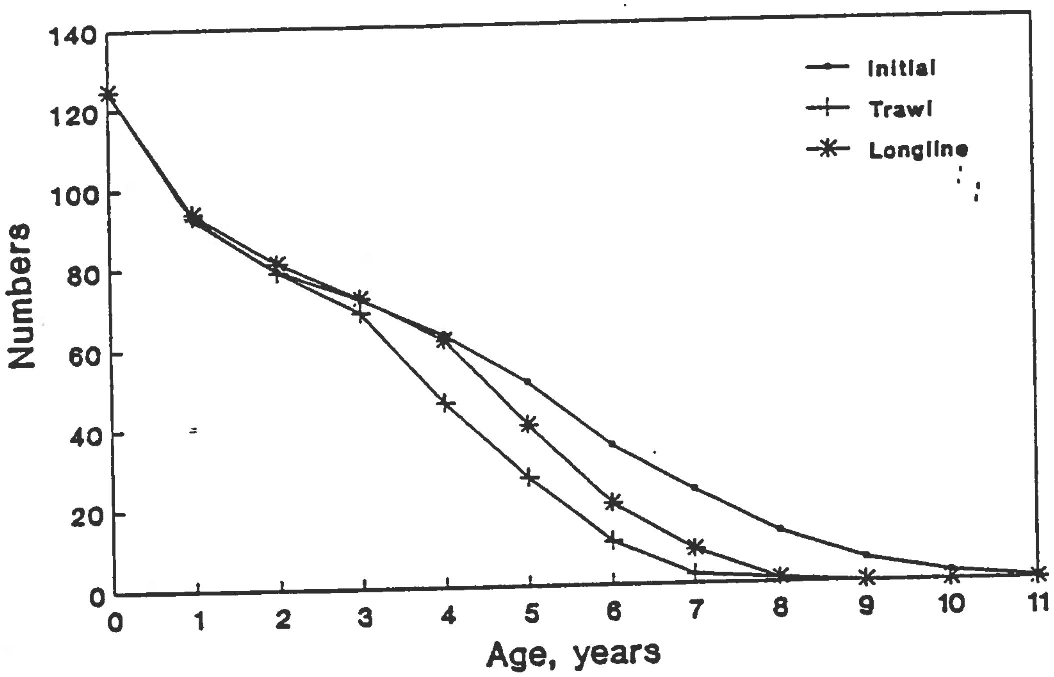

Figure 4. Number of fish in the sea of different age groups, initially and after four years of trawling or longlining (F=0.2).

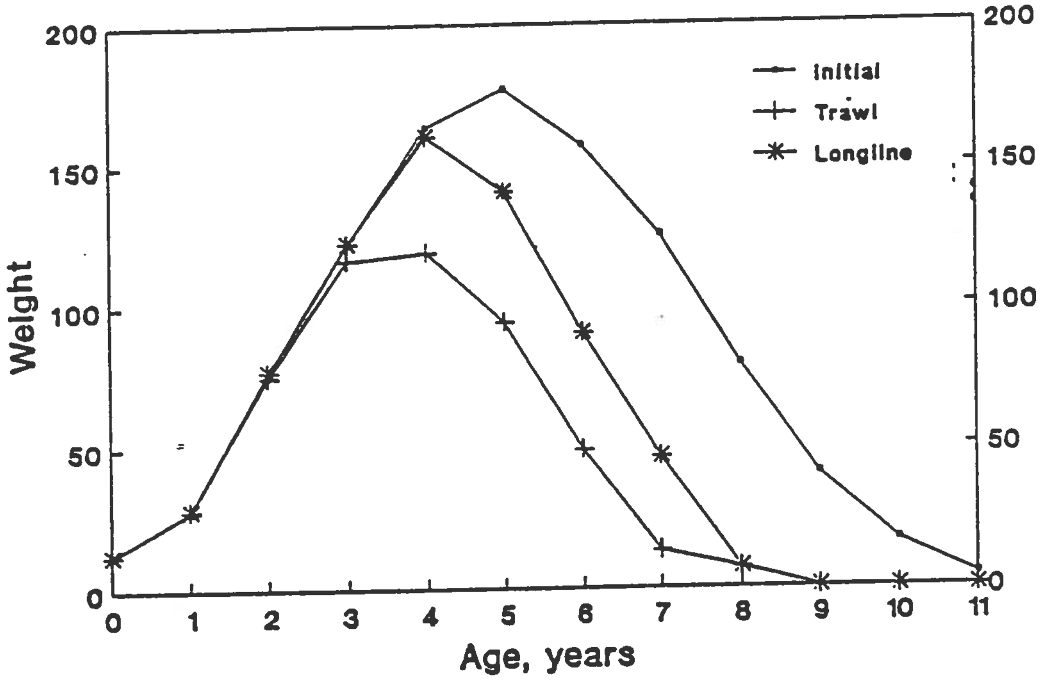

Figure 5. Weight of fish in the sea of different age groups, initially and after four years of trawling or longlining (F=0.2).

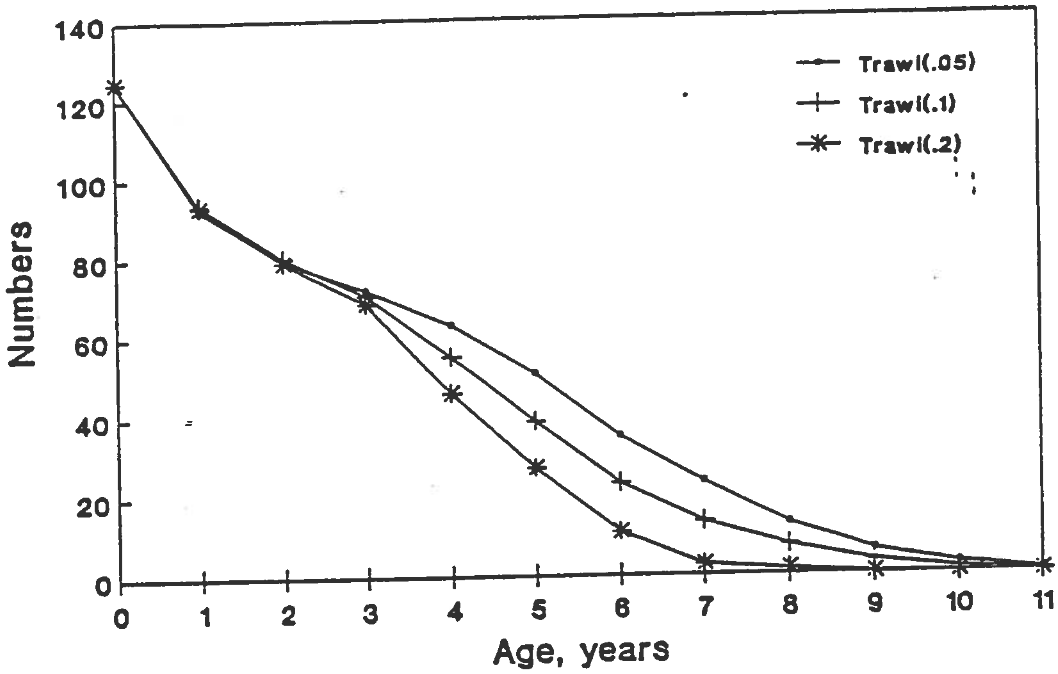

Figure 6. Age composition of fish in the sea after 4 years of trawling with different fishing mortalities (F=0.05, 0.10, and 0.20).

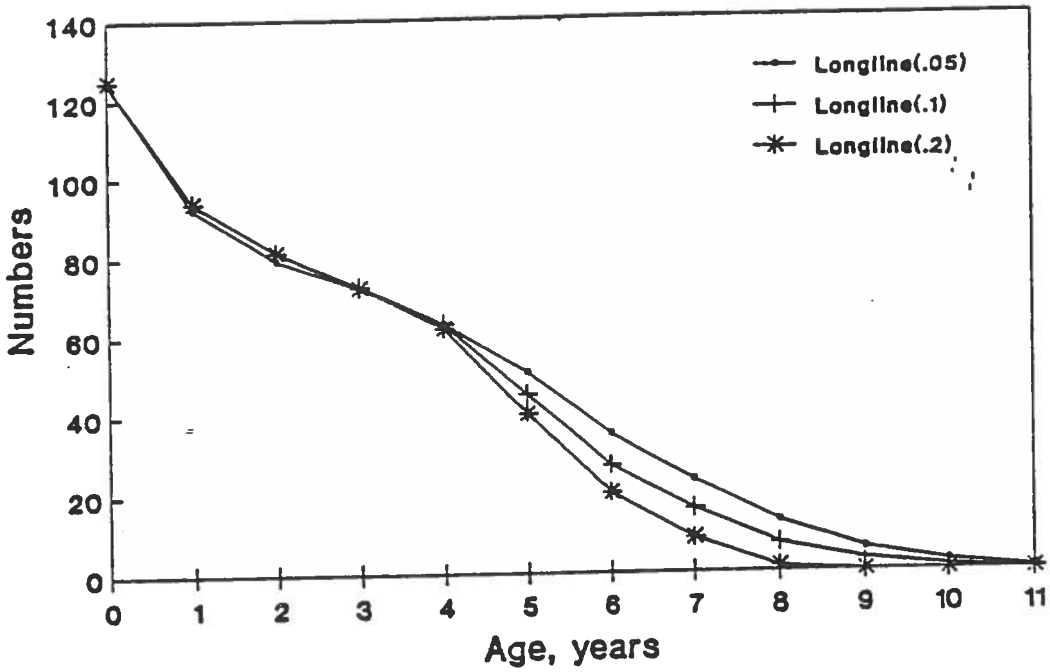

Figure 7. Age composition of fish in the sea after 4 years of longlining with different fishing mortalities (F=0.05, 0.10, and 0.20).

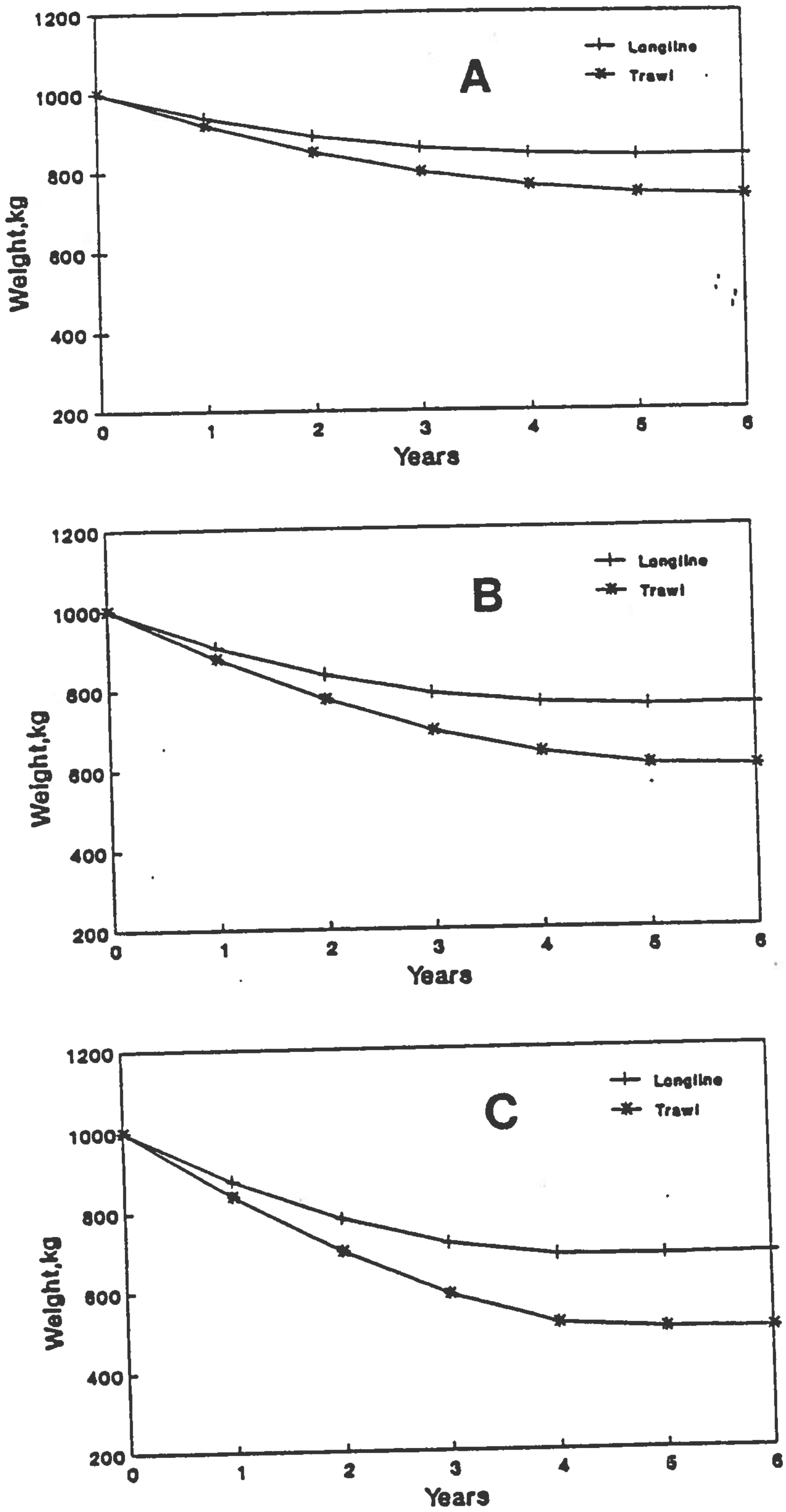

Figure 8. Biomass reduction during six years of trawling or longlining with fishing mortalities of 0.1 (A), 0.15 (B), and 0.2 (C) (initial biomass = 1000 kg).

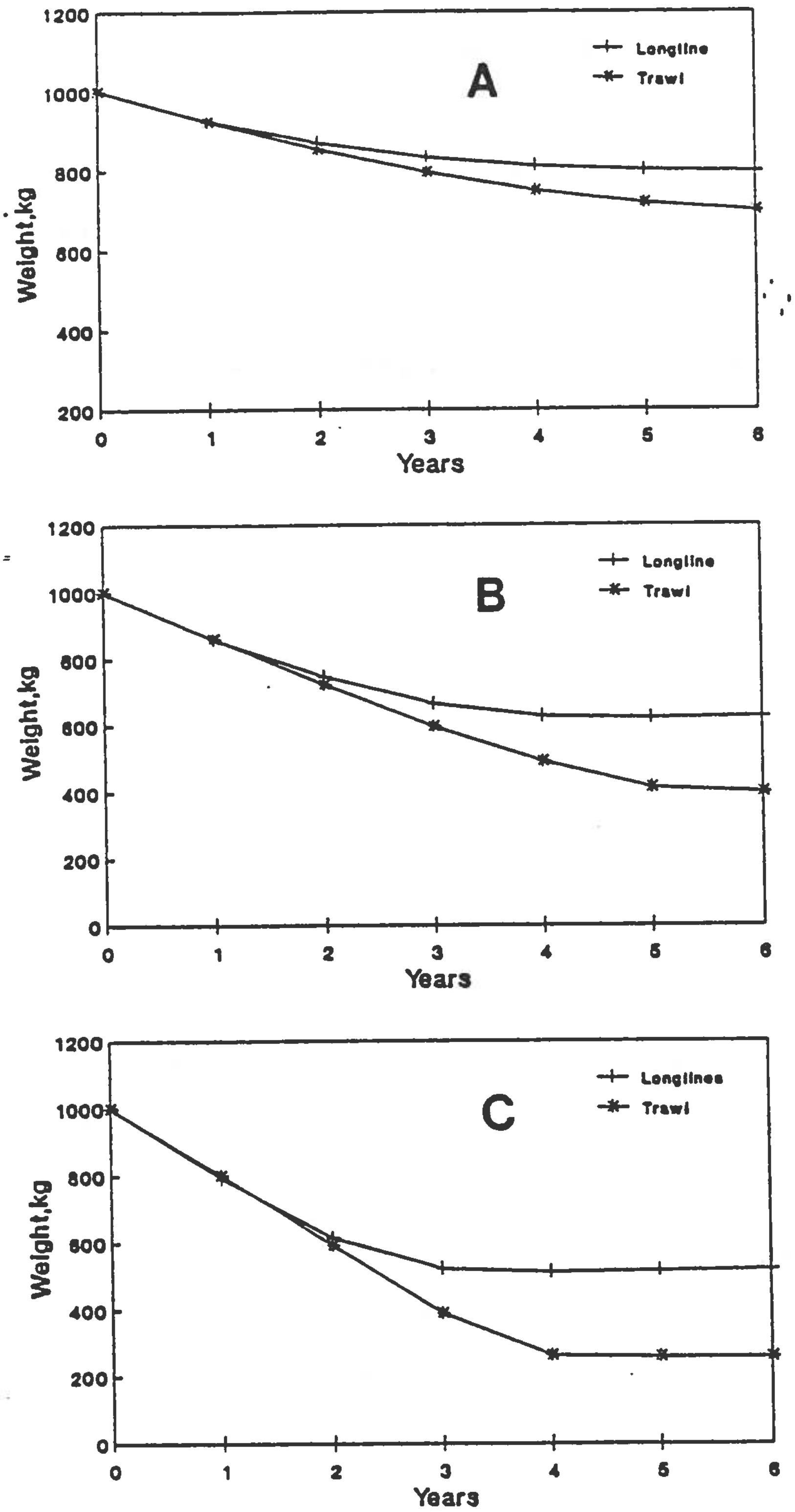

Figure 9. Biomass reduction (from original 1000kg) of longlining or trawling at 3 different catch levels, a) 80kg, b) 160kg, and c) 240kg.

catches is one year younger than in the longline catches. Cod also become more piscivorous with increasing age. As the longline catches include more large fish, longlines do thus remove more piscivorous and potentially cannibalistic individuals. If recruitment to the exploitable population is largely influenced by predation on juveniles, then longline fishing may also be more beneficial to recruitment.

After sustained fishing the model predicts that the biomass do stabilize around a certain equilibrium level, determined by fishing method and exploitation level. With reference to Figs. 8 and 9, it is apparent that the choice of catching strategy is relatively unimportant at low catch levels or in periods with good recruitment. However, with increasing exploitation rate, care should be taken with respect to choice of fishing gear and catching strategy. The trends that are predicted in Figs. 8 and 9 also suggest that this simulation model can be used to determine the total allowable catch taken by different gears, if a biologically or economically determined minimum level of remaining biomass is prescribed.

This study clearly indicates that the catching strategy should be taken into consideration for proper management of fish stocks. In this case the model is used in a fairly simple approach on one stock that alternatively is exploited by two different gears. As a management tool it could be extended for application on different multigear and multispecies situations.

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Appendix
Programme GEAREF
Determination of the effects of trawl and longline on the stock of cod

List of Abbreviations and Symbols
(*-inputs)

AFA	-Adjustment factor (to adjust numbers to 1000 kg biomass)
AFRL	-ARL+1
AFRT	-ART+1
AGI(12)	-Age group weight
*AMA	-Age at which 60% of population is mature
*ARL	-Age of full recruitment, longlines
*ART	-Age of full recruitment, trawl
*BM	-Factor to reduce "natural" mortality
BTR	-Weight of fish left in sea
BTS(10)	-Total biomass in sea (1-initial, 2-after first year, 3-after second year, others are intermediate bins)
*CAI(12)	-Initial age composition, normalized (%)
CLNF(12)	-Catch, longlines, numbers
CLWF(12)	-Catch, longlines, weights
CNU	-Total number of full recruited with given catch
*CTC(12)	-Normalized trawl catch (%)
*CTL(12)	-Normalized longline catch (%)
CTNF(12)	-Catch, trawl, numbers
CTWF(12)	-Catch, trawl, weights
DCLW	-Discards, longline
DCTW	-Discards, trawl
DIFA	-Difference of fishing mortality from 15%
FA	-Approximate F for total population (in fraction of numbers)
FAC	-Factor (intermediate)
*FL	-Initial catch estimates for longline (kg from 1000 kg biomass)
FAR	-F for first fully recruited age-class
*FLP(3)	-"Prerecruit" catches by longlines (in fraction of first fully recruited åge class)
*FLPD(3)	-Fraction of prerecruits discarded (trawl)
*FSI	-Factor to reduce mortality difference
*FT	-Initial catch estimates for trawl (kg from 1000 kg biomass)
*FTP(3)	-"Prerecruit" catches by trawls (in fraction of first fully recruited age class)
*FTPD(3)	-Fraction of prerecruits discarded (trawl)
*IPC	-Index, IPC=0 - catch prescribed as quantity, IPC=1 - catch prescribed as fraction of catch (F constant with age, except prerecruits)
K	-Counter of number of catch iterations
LEF(12)	-Longlines, inst. F mortality
LME(12)	-Longlines, instant. senesc. mort. coeff.
LMF(12)	-Longlines, %mortality
LO	-Counter

LPD	-Discards, longlines (weight)
LPDN	-Discards, longlines (numbers)
LPF	-Longlines, % removed
M,N	-Counters, indices
*M	-Indice for trawl (1) or longline (2), both (0)
MM	-Intermediate (N+1)
*MO(12)	-Predation and senescent mortality, F=0
MORY	-Intermediate (mortality)
MR	-Intermediate (mortality)
MTN(12)	-Mortality, numbers
MTW(12)	-Mortality, weight
N	-Counter, index
NSF(12)	-Number in sea after first year
NSI(12)	-Number in sea (initially) re. 1000 kg total biomass
NSS(12)	-Number in sea after second year
*PCFL	-Prescribed longline catch as fraction (0.05, 0.10, 0.15 etc.) (Number based F)
*PCFT	-Prescribed trawl catch as fraction (0.05, 0.10, 0.15 etc.) (Number based F)
PRE(12)	-Numbers in sea (intermediate)
PUK(12)	-Catch (intermediate)
R	-Intermediate (for inst. mort.)
*RAD	-Recruitment change (adjustment) factor
RFL	-Recruitment, first year, longlines
RFT	-Recruitment, first year, trawl
*RL	-Recruitment to first fully recruited age class in percent of initial age composition, F=0 (longlines)
RLN	-Recruitment (number), longlines (norm. 1000 kg)
RSL	-Recruitment, second year, longlines
RST	-Recruitment, second year, trawl
*RT	-Recruitment to first fully recruited age class in % of initial age composition, F=0 (trawl)
RTN	-Recruitment (number), trawl (norm. 1000 kg)
S	-Intermediate (for inst. mort.)
SCN	-Total catch number
SCNT	-Total catch numbers (intermediate)
SLNF(12)	-Spawning stress mortality longlines, numbers
SLNS(12)	-Spawning stress mortality, total numbers
SLTF	-Total spawning stress mortality, longlines
SLTS	-Total spawning stress mortality
SLWF(12)	-Spawning stress mortality longlines, weights
SLWS(12)	-Spawning stress mortality, total, weights
STNF(12)	-Spawning stress mortality, trawl, numbers
STTF	-Total spawning stress mortality, trawl
STWF(12)	-Spawning stress mortality, trawl, weights
TEF(12)	-Trawl, instantaneous fishing mortality (first year)
TME(12)	-Trawl, instantaneous mortality coefficient
TMP(12)	-Trawl, mortality in %, first year
TMT	-Total mortality (weight)
TNI	-Total initial numbers
TPD	-Discards, trawls (weight)
TPDN	-Discards, trawls (numbers)

TPF(12)	-Trawl, percent of fish removed by fishing (first year, number)
TWI	-Total initial weight (input)
TWIT	-Total catch (intermediate)
VAD(12)	-Intermediate, working array
VAT(12)	-Intermediate, working array
*WM(12)	-Weight, midyear
WSF(12)	-Weights in sea after first year
WSI(12)	-Initial weights (re. 1000 kg biomass)
WSS(12)	-Weights after second year
X	-Counter (M+1)

```
10 REM PROGRAMME GEBIEF
20 REM BIOLOGICAL EFFECTS OF DIFFERENT GEAR
30 DIM CAI(12).CTC(12).CTL(12),WM(12).MO(12),FLP(3).FTP(3)
40 DIM FLPD(3),FTPD(3),NSI(12),NSF(12),NSS(12),VAO(12),FA(3)
50 DIM WSI(12),WSF(12),WSS(12),BTS(10),CLNF(12),CLWF(12)
60 DIM CTNF(12),CTWF(12),MTN(12),MTW(12),TPF(12),TEF(12)
70 DIM SLNF(12),SLWF(12),SLNS(12),AGI(12),TMP(12),TME(12)
80 DIM SLWS(12),STNF(12),STWF(12),PUK(12),PRE(12)
90 DIM VAT(12),FAR(3),LPD(3),TPD(3),LPF(12),LEF(12),LMF(12),LME(12
100 DIM TPDN(3),LPDN(3)
110 REM XXXXXINPUTSXXXXX
120 REM INITIAL AGE COMP.,NORMALIZED
130 FOR N=1 TO 12
140 READ CAI(N)
150 NEXT N
160 DATA 22.24,16.45,14.13,12.83,11.21,9.03
170 DATA 6.21,4.13,2.27,1.04,0.39,0.09
180 REM NORMALIZED AGE COMP., TRAWL CATCH
190 FOR N=1 TO 12
200 READ CTC(N)
210 NEXT N
220 DATA 3.51,8.77,14.10,22.05,18.84,14.04
230 DATA 8.01,5.58,3.06,1.47,0.49,0.08
240 REM NORMALIZED AGE COMP., LONGLINE CATCH
250 FOR N=1 TO 12
260 READ CTL(N)
270 NEXT N
280 DATA 0.0,0.46,3.92,12.66,24.11,23.76
290 DATA 16.06,10.51,5.64,2.13,0.65,0.09
300 REM WEIGHT,MIDYEAR
310 FOR N=1 TO 12
320 READ WM(N)
330 NEXT N
340 DATA 0.1,0.3,0.95,1.7,2.6,3.5
350 DATA 4.5,5.4,6.2,6.9,7.6,8.2
360 REM PREDATION AND SENESCENT MORT., F=0.
370 FOR N=1 TO 12
380 READ MO(N)
390 NEXT N
400 DATA 26.0,14.1,11.0,12.6,19.5,31.2
410 DATA 33.5,45.0,54.2,62.5,82.0,95.0
420 REM PRERECRUIT CATCHES, TRAWL, LONGLINES
430 FTP(1)=19.0 :FTP(2)=12.0 :FTP(3)=6.0
440 FLP(1)=14.0 :FLP(2)=7.5 :FLP(3)=2.0
450 REM FRACTION OF PRERECRUITS DISCARDED, TRAWL, LL
460 FTPD(1)=.55 :FTPD(2)=.8 :FTPD(3)=1!
470 FLPD(1)=.4 :FLPD(2)=.65 :FLPD(3)=1.
480 AMA=4 :ART=3 :ARL=4
490 AFRT=ART+1
500 AFRL=ARL+1
510 REM RECR. TO FIRST FULLY RECR. AGECL.
520 RT=12.83 :RL=11.21
530 REM BASE MORTALITY REDUCER - BM
540 BM=.06
550 FSI=.4
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560 REM RECR. ADJUST. FACTOR
570 RAD=1
580 REM XXXXEXPERIMENTAL INPUTSXXXXXXX   XXXXXXXX
590 REM GEAR INDICE
600 M=1
610 IPC=1
620 REM INITIAL CATCH, KG/YEAR PER 1000 KG.
630 FT=80   :FL=80
640 PCFT=.05
650 PCFL=.05
660 REM XXXXX OUTPUTS FOR CHECKING INP.XXXXX
670 LPRINT :LPRINT
680 LPRINT"   BIOLOGICAL EFFECTS OF TRAWLS AND LONGLINES"
690 LPRINT"                             INPUTS"
700 LPRINT :LPRINT
710 LPRINT"   AGE     NUMBER    WEIGHT    SEN. MORT"
720 FOR N=1 TO 12
730 NN=N-1
740 LPRINT USING" #####.##";NN;CAI(N);WM(N);MO(N)
750 NEXT N
760 LPRINT :LPRINT
770 LPRINT"   AGE COMPOSITION OF CATCHES (PRESCRIBED IF IPC=0)"
780 LPRINT"   AGE       TRAWL      LONGLINE"
790 FOR N=1 TO 12
800 NN=N-1
810 LPRINT USING" #####.##";NN;CTC(N);CTL(N)
820 NEXT N
830 LPRINT :LPRINT
840 LPRINT" PRERECRUIT CATCHES AND DISCARDS"
850 LPRINT"                    TRAWL"
860 LPRINT"   AGE       CATCH      DISCARD
870 FOR N=1 TO 3
880 NN=AFRT-N
890 LPRINT USING" #####.##";NN;FTP(N);FTPD(N)
900 NEXT N
910 LPRINT
920 LPRINT"                    LONGLINE"
930 LPRINT"   AGE       CATCH      DISCARD"
940 FOR N=1 TO 3
950 NN=AFRL-N
960 LPRINT USING" #####.##";NN;FLP(N);FLPD(N)
970 NEXT N
980 LPRINT
990 LPRINT"   AGE OF MAT.";AMA
1000 LPRINT"   AGE, FULL RECR.,TRAWL";ART;"LONGLINE";ARL
1010 LPRINT"   RECR. TO FIRST FULL AG. CL.,TRAWL";RT;"LONGLINE";RL
1020 LPRINT"   RECR. ADJUST. FACT.";RAD
1030 REM CONVERT MORTALITY TO FRACTION
1040 REM (OBS. REDUCTION BY 5 %)
1050 FOR N=1 TO 12
1060 MO(N)=(MO(N)/100!)*.95
1070 NEXT N
1080 REM NORMALIZE NUMBERS AND WEIGHTS TO 1000 KG
1090 TWI=0   :TNI=0
1100 FOR N=1 TO 12
```

```
1110 AGI(N)=CAI(N)*WM(N)
1120 TWI=TWI+AGI(N)
1130 NEXT N
1140 FAC=1000/TWI
1150 FOR N=1 TO 12
1160 NSI(N)=FAC*CAI(N)
1170 WSI(N)=AGI(N)*FAC
1180 TNI=TNI+NSI(N)
1190 NEXT N
1200 RLN=FAC*RL
1210 RTN=FAC*RT
1220 REM CATCHES, FIRST YEAR
1230 K=1
1240 REM LONG RUN COUNTER
1250 LO=0
1260 IF(IPC=0) THEN 1270 ELSE 1600
1270 IF(M-1<=0) THEN 1290 ELSE 1420
1280 REM TRAWL CATCH
1290 TWI=0    :SCN=0
1300 FOR N=1 TO 12
1310 VAO(N)=CTC(N)*WM(N)
1320 TWI=TWI+VAO(N)
1330 NEXT N
1340 FAC=FT/TWI
1350 FOR N=1 TO 12
1360 CTNF(N)=CTC(N)*FAC
1370 CTWF(N)=VAO(N)*FAC
1380 SCN=SCN+CTNF(N)
1390 NEXT N
1400 FA(1)=SCN/TNI
1410 FAR(1)=CTNF(4)/RTN
1420 IF(M-2=0) THEN 1450 ELSE 1430
1430 IF(M=0) THEN 1450 ELSE 2060
1440 REM LONGLINE CATCH
1450 TWI=0    :SCN=0
1460 FOR N=1 TO 12
1470 VAO(N)=CTL(N)*WM(N)
1480 TWI=TWI+VAO(N)
1490 NEXT N
1500 FAC=FL/TWI
1510 FOR N=1 TO 12
1520 CLNF(N)=CTL(N)*FAC
1530 CLWF(N)=VAO(N)*FAC
1540 SCN=SCN+CLNF(N)
1550 NEXT N
1560 FA(2)=SCN/TNI
1570 FAR(2)=CLNF(5)/RLN
1580 GOTO 2060
1590 REM XXXXXXXXXX
1600 IF(M-1<=0) THEN 1630 ELSE 1830
1610 REM PRESCRIBED CATCH AS CONSTANT FRACTION
1620 REM AFTER FULL RECRUITMENT
1630 REM TRAWL CATCH, F CONST. WITH AGE
1640 TWIT=0    :SCNT=0
1650 FOR N=AFRT TO 12
```

```
1660 CTNF(N)=PCFT*NSI(N)
1670 CTWF(N)=CTNF(N)*WM(N)
1680 NEXT N
1690 Y=AFRT
1700 CTNF(Y-1)=(FTP(1)/100!)*NSI(AFRT)*PCFT
1710 CTWF(Y-1)=CTNF(Y-1)*WM(Y-1)
1720 CTNF(Y-2)=(FTP(2)/100!)*NSI(AFRT)*PCFT
1730 CTWF(Y-2)=CTNF(Y-2)*WM(Y-2)
1740 CTNF(Y-3)=(FTP(3)/100!)*NSI(AFRT)*PCFT
1750 CTWF(Y-3)=CTNF(Y-3)*WM(Y-3)
1760 FOR N=1 TO 12
1770 SCNT=SCNT+CTNF(N)
1780 TWIT=TWIT+CTWF(N)
1790 NEXT N
1800 FAR(1)=PCFT
1810 FA(1)=SCNT/TNI
1820 REM XXXXXXXX
1830 IF(M-2=0) THEN 1860 ELSE 1840
1840 IF(M=0) THEN 1860 ELSE 2060
1850 REM LONGLINE CATCHES, F CONST. WITH AGE
1860 TWIL=0      :SCNL=0
1870 FOR N=AFRL TO 12
1880 CLNF(N)=PCFL*NSI(N)
1890 CLWF(N)=CLNF(N)*WM(N)
1900 NEXT N
1910 Y=AFRL
1920 CLNF(1)=0
1930 CLWF(1)=0
1940 CLNF(Y-1)=(FLP(1)/100!)*NSI(AFRL)*PCFL
1950 CLWF(Y-1)=CLNF(Y-1)*WM(Y-1)
1960 CLNF(Y-2)=(FLP(2)/100!)*NSI(AFRL)*PCFL
1970 CLWF(Y-2)=CLNF(Y-2)*WM(Y-2)
1980 CLNF(Y-3)=(FLP(3)/100!)*NSI(AFRL)*PCFL
1990 CLWF(Y-3)=CLNF(Y-3)*WM(Y-3)
2000 FOR N=1 TO 12
2010 SCNL=SCNL+CLNF(N)
2020 TWIL=TWIL+CLWF(N)
2030 NEXT N
2040 FAR(2)=PCFT
2050 FA(2)=SCNL/TNI
2060 REM TOTAL CATCHES FIRST Y AND NO AND W IN SEA
2070 IF (M=0) THEN 2080 ELSE 2340
2080 FA(3)=FA(1)+FA(2)
2090 FAR(3)=FAR(1)+FAR(2)
2100 TMT=0
2110 DIFA=FAR(3)-BM
2120 FOR N=1 TO 12
2130 IF (N-AMA<=0) THEN 2140 ELSE 2160
2140 MR=MO(N)
2150 GOTO 2170
2160 MR=MO(N)-FSI*DIFA
2170 MTN(N)=MR*NSI(N)
2180 VAO(N)=NSI(N)-CTNF(N)-CLNF(N)-MTN(N)
2190 MTW(N)=MTN(N)*WM(N)
2200 TMT=TMT+MTW(N)
```

```
2210 NEXT N
2220 BTS(4)=0
2230 FOR N=1 TO 11
2240 MM=N+1
2250 NSF(MM)=VAO(N)
2260 WSF(MM)=VAO(N)*WM(MM)
2270 BTS(4)=BTS(4)+WSF(MM)
2280 NEXT N
2290 NSF(1)=NSI(1)
2300 WSF(1)=NSI(1)*WM(1)
2310 BTS(4)=BTS(4)+WSF(1)
2320 GOTO 2990
2330 REM TRAWL CATCHES FIRST Y AND NO AND W IN SEA
2340 IF(M-1=0)THEN 2350 ELSE 2670
2350 TMT=0
2360 FOR N=1 TO 12
2370 DIFA=FAR(1)-BM
2380 IF(N-AMA<=0) THEN 2390 ELSE 2410
2390 MR=MO(N)
2400 GOTO 2420
2410 MR=MO(N)-FSI*DIFA
2420 MTN(N)=MR*NSI(N)
2430 VAO(N)=NSI(N)-CTNF(N)-MTN(N)
2440 MTW(N)=MTN(N)*WM(N)
2450 TMT=TMT+MTW(N)
2460 NEXT N
2470 BTS(5)=0
2480 FOR N=1 TO 11
2490 MM=N+1
2500 NSF(MM)=VAO(N)
2510 WSF(MM)=VAO(N)*WM(MM)
2520 BTS(5)=BTS(5)+WSF(MM)
2530 NEXT N
2540 NSF(1)=NSI(1)
2550 WSF(1)=NSI(1)*WM(1)
2560 BTS(5)=BTS(5)+WSF(1)
2570 FOR N=1 TO 12
2580 TPF(N)=(CTNF(N)/NSI(N))*100
2590 TMP(N)=(MTN(N)/NSI(N))*100
2600 R=NSI(N)/(NSI(N)-CTNF(N))
2610 TEF(N)=LOG(R)
2620 S=NSI(N)/(NSI(N)-MTN(N))
2630 TME(N)=LOG(S)
2640 NEXT N
2650 GOTO 2990
2660 REM LONGLINE CATCHES FIRST Y, NO IN SEA
2670 IF(M-2=0) THEN 2680 ELSE 2990
2680 TMT=0
2690 DIFA=FAR(2)-BM
2700 FOR N=1 TO 12
2710 IF(N-AMA<=0) THEN 2720 ELSE 2740
2720 MR=MO(N)
2730 GOTO 2750
2740 MR=MO(N)-FSI*DIFA
2750 MTN(N)=MR*NSI(N)
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```
2760 VAO(N)=NSI(N)-CLNF(N)-MTN(N)
2770 MTW(N)=MTN(N)*WM(N)
2780 TMT=TMT+MTW(N)
2790 NEXT N
2800 BTS(6)=0
2810 FOR N=1 TO 11
2820 MM=N+1
2830 NSF(MM)=VAO(N)
2840 WSF(MM)=VAO(N)*WM(MM)
2850 BTS(6)=BTS(6)+WSF(MM)
2860 NEXT N
2870 NSF(1)=NSI(1)
2880 WSF(1)=NSI(1)*WM(1)
2890 BTS(6)=BTS(6)+WSF(1)
2900 FOR N=1 TO 12
2910 LPF(N)=(CLNF(N)/NSI(N))*100
2920 LMP(N)=(MTN(N)/NSI(N))*100
2930 R=NSI(N)/(NSI(N)-CLNF(N))
2940 LEF(N)=LOG(R)
2950 S=NSI(N)/(NSI(N)-MTN(N))
2960 LME(N)=LOG(S)
2970 NEXT N
2980 REM XXXX FIRST YEAR OUTPUTS XXXX
2990 X=M+1
3000 ON X GOTO 3010, 3020, 3030
3010 BTS(2)=BTS(4)   :GOTO 3040
3020 BTS(2)=BTS(5)   :GOTO 3040
3030 BTS(2)=BTS(6)   :GOTO 3040
3040 LPRINT   :LPRINT
3050 LO=LO+1
3060 LPRINT"    M=";M
3070 LPRINT
3080 IF(IPC=0) THEN 3110 ELSE 3090
3090 LPRINT"  FISHING MORTALITY COEFF.,TRAWL  ";PCFT;" LONGL. ";PCF
3100 GOTO 3120
3110 LPRINT" PRESCRIBED CATCH FT=";FT;"  FL=";FL
3120 LPRINT
3130 LPRINT" INITIAL NO AND WEIGHT, NORM. 1000KG"
3140 LPRINT"      AGE    NUMBER   WEIGHT
3150 FOR N=1 TO 12
3160 MM=N-1
3170 LPRINT USING"######.#";MM;NSI(N);WSI(N)
3180 NEXT N
3190 LPRINT" NUMBER OF RECRUITS,TRAWL";RTN;"LONGL.";RLN
3200 LPRINT
3210 IF(M-1<=0) THEN 3220 ELSE 3370
3220 LPRINT" FIRST YEAR CATCH, REMAIN. IN SEA AND MORT., TRAWL"
3230 LPRINT"                CATCH          IN SEA        MORTALITY"
3240 LPRINT"  AGE  NUMBER  WEIGHT  NUMBER WEIGHT  NUMB. WEIGHT"
3250 FOR N=1 TO 12
3260 MM=N-1
3270 LPRINT USING "#####.#";MM;CTNF(N);CTWF(N);NSF(N);WSF(N);MTN(N)
N)
3280 NEXT N
3290 LPRINT
3300 LPRINT"  FISHING AND SENESC. MORT.,  % AND INST. COEFF.(EX)"
```

```
3310 LPRINT"   AGE     %FM     FM,EX.   %SM    SM,EX."
3320 FOR N=1 TO 12
3330 MM=N-1
3340 LPRINT USING "####.##";MM;TPF(N);TEF(N);TMP(N);TME(N)
3350 NEXT N
3360 LPRINT
3370 IF(M-2=0) THEN 3390 ELSE 3380
3380 IF(M=0) THEN 3390 ELSE 3640
3390 LPRINT" FIRST YEAR CATCH, REMAIN. IN SEA AND MORT., LONGLINES"
3400 LPRINT"                CATCH             IN SEA       MORTALITY"
3410 LPRINT"   AGE  NUMBER  WEIGHT NUMBER WEIGHT  NUMB. WEIGHT"
3420 FOR N=1 TO 12
3430 MM=N-1
3440 LPRINT USING "#####.#";MM;CLNF(N);CLWF(N);NSF(N);WSF(N);MTN(N)
N)
3450 NEXT N
3460 LPRINT
3470 LPRINT"  FISHING AND SENESC.MORT., % AND INST. COEFF.(EX)"
3480 LPRINT"   AGE     %FM     FM,EX.   %SM    SM,EX."
3490 FOR N=1 TO 12
3500 MM=N-1
3510 LPRINT USING "####.##";MM;LPF(N);LEF(N);LMP(N);LME(N)
3520 NEXT N
3530 LPRINT
3540 IF(M=0) THEN 3550 ELSE 3640
3550 LPRINT" FIRST YEAR TOT. CATCH, REMINDER AND MORTALITY"
3560 LPRINT"               CATCH            IN SEA          MORTALITY"
3570 LPRINT"   AGE  NUMBER  WEIGHT NUMBER WEIGHT  NUMBER WEIGHT"
3580 FOR N=1 TO 12
3590 MM=N-1
3600 VAO(N)=CTNF(N)+CLNF(N)
3610 VAT(N)=CTWF(N)+CLWF(N)
3620 LPRINT USING "#####.#";MM;VAO(N);VAT(N);NSF(N);WSF(N);MTN(N);M
3630 NEXT N
3640 LPRINT
3650 LPRINT" FI.MOR.   FAR(1)=";FAR(1);"FAR(2)=";FAR(2);"FAR(3)=";F
3660 LPRINT" FI.MOR.TOT.% FA(1)=";FA(1);"FA(2)=";FA(2);"FA(3)=";FA(
3670 LPRINT
3680 LPRINT" WEIGHT OF FISH IN SEA AFTER FIRST YEAR";BTS(2)
3690 LPRINT
3700 LPRINT" TOTAL MORTALITY, WEIGHT";TMT
3710 REM XXXXXX SECOND YEAR XXXXX
3720 IF(M=0) THEN 3730 ELSE 4030
3730 TOTAL CATCHES AND SECOND YEAR IN SEA
3740 DIFA=FAR(3)-BM
3750 FOR N=1 TO 12
3760 IF(N-AMA<=0) THEN 3770 ELSE 3790
3770 MR=MO(N)
3780 GOTO 3800
3790 MR=MO(N)-FSI*DIFA
3800 VAO(N)=NSF(N)-CTNF(N)-CLNF(N)-(MR*NSF(N))
3810 NEXT N
3820 BTS(7)=0
3830 FOR N=1 TO 11
3840 MM=N+1
3850 NSS(MM)=VAO(N)
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3860 WSS(MM)=VAO(N)*WM(MM)
3870 BTS(7)=BTS(7)+WSS(MM)
3880 NEXT N
3890 NSS(1)=NSI(1)
3900 WSS(1)=NSI(1)*WM(1)
3910 BTS(7)=BTS(7)+WSS(1)
3920 DIFA=FAR(3)-BM
3930 SLTS=0
3940 FOR N=1 TO 12
3950 IF(N-AMA<=0) THEN 3960 ELSE 3980
3960 SLNS(N)=MO(N)*NSF(N)
3970 GOTO 4010
3980 SLNS(N)=(MO(N)-FSI*DIFA)*NSF(N)
3990 IF(SLNS(N)<=0) THEN 4000 ELSE 4010
4000 SLNS(N)=0
4010 SLTS=SLTS+SLNS(N)
4020 NEXT N
4030 REM TRAWL CATCHES AND SECOND YEAR IN SEA
4040 IF(M-1<=0) THEN 4050 ELSE 4280
4050 DIFA=FAR(1)-BM
4060 STTF=0
4070 FOR N=1 TO 12
4080 IF(N-AMA<=0) THEN 4090 ELSE 4110
4090 STNF(N)=MO(N)*NSF(N)
4100 GOTO 4140
4110 STNF(N)=(MO(N)-FSI*DIFA)*NSF(N)
4120 IF(STNF(N)<=0) THEN 4130 ELSE 4140
4130 STNF(N)=0
4140 VAO(N)=NSF(N)-CTNF(N)-STNF(N)
4150 STTF=STTF+STNF(N)
4160 NEXT N
4170 BTS(8)=0
4180 FOR N=1 TO 11
4190 MM=N+1
4200 NSS(MM)=VAO(N)
4210 WSS(MM)=VAO(N)*WM(MM)
4220 BTS(8)=BTS(8)+WSS(MM)
4230 NEXT N
4240 NSS(1)=NSI(1)
4250 WSS(1)=NSI(1)*WM(1)
4260 BTS(8)=BTS(8)+WSS(1)
4270 REM LONGLINE CATCHES AND SECOND YEAR IN SEA
4280 IF(M-2=0) THEN 4300 ELSE 4290
4290 IF(M=0) THEN 4300 ELSE 4530
4300 DIFA=FAR(2)-BM
4310 SLTF=0
4320 FOR N=1 TO 12
4330 IF(N-AMA<=0) THEN 4340 ELSE 4360
4340 SLNF(N)=MO(N)*NSF(N)
4350 GOTO 4390
4360 SLNF(N)=(MO(N)-FSI*DIFA)*NSF(N)
4370 IF(SLNF(N)<=0) THEN 4380 ELSE 4390
4380 SLNF(N)=0
4390 VAO(N)=NSF(N)-CLNF(N)-SLNF(N)
4400 SLTF=SLTF+SLNF(N)
```

```
4410 NEXT N
4420 BTS(9)=0
4430 FOR N=1 TO 11
4440 MM=N+1
4450 NSS(MM)=VAO(N)
4460 WSS(MM)=VAO(N)*WM(MM)
4470 BTS(9)=BTS(9)+WSS(MM)
4480 NEXT N
4490 NSS(1)=NSI(1)
4500 WSS(1)=NSI(1)*WM(1)
4510 BTS(9)=BTS(9)+WSS(1)
4520 REM RECRUITMENT AND DISCARDS
4530 RTN=NSF(4)
4540 RTL=NSF(5)
4550 DIST=0  :DISL=0
4560 FOR N=1 TO 3
4570 I=5-N
4580 J=4-N
4590 TPD(N)=FTPD(N)*CTWF(J)
4600 TPDN(N)=FTPD(N)*CTNF(J)
4610 LPD(N)=FLPD(N)*CLWF(I)
4620 LPDN(N)=FLDP(N)*CLNF(I)
4630 DIST=DIST+TPD(N)
4640 DISL=DISL+LPD(N)
4650 NEXT N
4660 X=M+1
4670 ON X GOTO 4680, 4690, 4700
4680 BTS(3)=BTS(7)   :GOTO 4710
4690 BTS(3)=BTS(8)   :GOTO 4710
4700 BTS(3)=BTS(9)   :GOTO 4710
4710 REM XXXX SECOND YEAR OUTPUTS XXXX
4720 LPRINT   :LPRINT
4730 LO=LO+1
4740 IF(IPC=0) THEN 4750 ELSE 4770
4750 LPRINT" SECOND YEAR, SAME GEAR AND CATCH"
4760 GOTO 4780
4770 LPRINT"  SECOND YEAR, CATCH, TRAWL "; TWIT;"  LONGLINE  ";TWI
4780 LPRINT" NUMBERS AND WEIGHTS IN SEA AFTER SECOND YEAR CATCH"
4790 LPRINT"    AGE  NUMBER  WEIGHT"
4800 FOR N=1 TO 12
4810 MM=N-1
4820 LPRINT USING "#####.#";MM;NSS(N);WSS(N)
4830 NEXT N
4840 LPRINT
4850 LPRINT"   WEIGHT OF FISH IN SEA";BTS(3)
4860 LPRINT   :LPRINT
4870 LPRINT"           RESIDUAL MORTALITY"
4880 IF(M=0) THEN 4890 ELSE 4970
4890 LPRINT" RESIDUAL MORT., TOTAL
4900 LPRINT"     AGE  MORT. NUMBERS"
4910 FOR N=1 TO 12
4920 MM=N-1
4930 LPRINT USING  "#####.#";MM;SLNS(N)
4940 NEXT N
4950 LPRINT"   TOTAL SENESCENT MORT. SUM, NOS";SLTS
```

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4960 GOTO 5140
4970 IF(M-1=0) THEN 4980 ELSE 5060
4980 LPRINT"   RESIDUAL MORT. TRAWL"
4990 LPRINT"      AGE     MORT. NUMBERS"
5000 FOR N=1 TO 12
5010 MM=N-1
5020 LPRINT USING "######.#";MM;STNF(N)
5030 NEXT N
5040 LPRINT" TRAWL, RESIDUAL MORT. SUM, NOS";STTF
5050 GOTO 5140
5060 IF(M-2=0) THEN 5070 ELSE 5140
5070 LPRINT" RESIDUAL MORT. LONGLINES"
5080 LPRINT"      AGE   MORT. NUMBERS"
5090 FOR N=1 TO 12
5100 MM=N-1
5110 LPRINT USING "######.#";MM;SLNF(N)
5120 NEXT N
5130 LPRINT"   LONGLINE, RESIDUAL MORT. SUM, NOS";SLTF
5140 LPRINT: LPRINT
5150 LPRINT"   RECRUITMENT NO'S,SECOND YEAR,TRAWL";RTN
5160 LPRINT"   RECRUITMENT, LONGLINES";RTL
5170 LPRINT
5180 LPRINT"   DISCARDS KG, TRAWL";DIST;"  LLINES,";DISL
5190 LPRINT"                 TRAWL           LONGLINES
5200 LPRINT"      AGE     NO'S  WEIGHT  NO'S   WEIGHT
5210 FOR N=1 TO 3
5220 LPRINT USING "#####.#";N;TPDN(N);TPD(N);LPDN(N);LPD(N)
5230 NEXT N
5240 LPRINT:LPRINT
5250 LPRINT:LPRINT
5260 IF(LO-5<=0) THEN 5370 ELSE 5280
5270 REM XXXXXXXXX
5280 FT=FT+80
5290 FL=FL+80
5300 PCFT=PCFT+.05
5310 PCFL=PCFL+.05
5320 K=K+1
5330 LO=0
5340 IF(IPC=0) THEN 5360 ELSE 5350
5350 IF(K-4<=0) THEN 1260 ELSE 5930
5360 IF(K-3<=0) THEN 1260 ELSE 5930
5370 IF(M=0) THEN 5280 ELSE 5380
5380 IF(M-1=0) THEN 5390 ELSE 5430
5390 FOR N=1 TO 12
5400 PUK(N)=CTNF(N)
5410 NEXT N
5420 GOTO 5470
5430 FOR N=1 TO 12
5440 PUK(N)=CLNF(N)
5450 NEXT N
5460 REM ENTER 3 TO 5 YEAR LOOP
5470 FOR N=1 TO 12
5480 PRE(N)=NSS(N)
5490 NEXT N
5500 IF(M-1=0) THEN 5510 ELSE 5530
```

```
5510 DIFA=FAR(1)-BM
5520 GOTO 5540
5530 DIFA=FAR(2)-BM
5540 BTR=0
5550 FOR N=1 TO 12
5560 IF(N-AMA<=0) THEN 5570 ELSE 5590
5570 MORY=MO(N)*PRE(N)
5580 GOTO 5600
5590 MORY=(MO(N)-FSI*DIFA)*PRE(N)
5600 IF(MORY<=0) THEN 5610 ELSE 5620
5610 MORY=0
5620 VAO(N)=PRE(N)-PUK(N)-MORY
5630 IF(VAO(N)<=0) THEN 5640 ELSE 5650
5640 VAO(N)=0
5650 NEXT N
5660 FOR N=1 TO 11
5670 MM=N+1
5680 NSS(MM)=VAO(N)
5690 WSS(MM)=VAO(N)*WM(MM)
5700 BTR=BTR+WSS(MM)
5710 NEXT N
5720 NSS(1)=NSI(1)
5730 WSS(1)=NSI(1)*WM(1)
5740 BTR=BTR+WSS(1)
5750 LO=LO+1
5760 REM XXXXXXXXXXX OUTPUTS Y 3 TO 5 XXXXXXXXXXXXXXX
5770 LPRINT
5780 LPRINT"   YEAR  ";LO;"  GEAR  ";M
5790 LPRINT
5800 IF(IPC=0) THEN 5820 ELSE 5810
5810 LPRINT"   CATCH, TRAWL  ";TWIT;"  LONGLINE  ";TWIL
5820 LPRINT"   IN SEA AFTER YEAR  ";LO
5830 LPRINT
5840 LPRINT"     AGE  NUMBER  WEIGHT"
5850 FOR N=1 TO 12
5860 MM=N-1
5870 LPRINT USING"#####.#";MM;NSS(N);WSS(N)
5880 NEXT N
5890 LPRINT
5900 LPRINT"   WEIGHT OF FISH IN SEA AFTER Y ";LO;"  ";BTR
5910 LPRINT  :LPRINT
5920 IF(LO-5<=0) THEN 5460 ELSE 5280
5930 END
```