RESTRICTED

International Commission for the Northwest Atlantic Fisheries

Serial No. 3610
(D.c. 9)

ICNAF Res.Doc. 75/117

ANNUAL MEETING - JUNE 1975

Estimates of probability of recovery of the Subarea 5 and Statistical Area 6 biomass under various levels of 2nd tier TAC

by

J.A. Brennan and B.E. Brown
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Mass., USA

Introduction

At the April 1975 ICNAF Assessments Subcommittee meeting, estimates of the likely number of years before the Subarea 5 and 6 stock recovered to a size of 4,000,000 tons, were made (ICNAF, Sum. Doc. 75/18). In making these estimates, it was assumed that the current stock size was 2,500,000 tons, that the current sustainable yield (CSY) was 850,000 tons, that a specified 2nd tier TAC would be maintained once set, and that there would be a three-year lag in biological response. Under these assumptions, the periods of time until recovery of the stock to 4,000,000 tons (including 1976) for different levels of 2nd tier TAC were calculated (Table 1).

The present paper estimates the probability that recovery of the stock (*i.e.* that some surplus production accrues to the stock) can begin over the next three years (1976-1978), under various levels of 2nd tier total allowable catch (TAC). It is assumed that recovery commences if the TAC is set below CSY for each year, where the true CSY is unknown but is assumed distributed with a known mean and standard deviation. Since new estimates of MSY for individual stocks may revise present predictions of overall MSY, and since environmental conditions cannot easily be assumed constant over a long period, the probabilities that recovery will begin are calculated only for these first three years, during which time the increased stock size does not contribute to an increase in the CSY toward the estimated maximum of 1,000,000 tons.

Methods and materials

The probability that recovery of the stock biomass commences can be considered to be the probability that the 2nd tier TAC is set below the current sustainable yield (CSY). Over a three-year period, the probability that recovery begins can be considered as the probability that the TAC is set below the CSY each year. In mathematical terms,

$$\Pr(\text{recovery commences}) = \Pr(TAC_1 < CSY_1;\ TAC_2 < CSY_2;\ TAC_3 < CSY_3)$$

$$= \Pr(TAC_1 < CSY_1) * \Pr(TAC_2 < CSY_2) * \Pr(TAC_3 < CSY_3), \qquad (1)$$

assuming independence of the occurrence that a TAC is less than the (unknown) CSY for successive years. By treating CSY as a random variable from a distribution with mean CSY* and a known standard deviation, the probability that recovery can begin in year i can be interpreted as the probability that the random variable CSY exceeds TAC_i. A distribution of CSY's with means between 750-950,000 tons was derived from the Shaefer model (Figure 1) and yield curve (Figure 2) developed for the finfish plus squid Subarea 5 and 6 biomass (Brown, *et al.*, 1975). These models were based on 1961-1972 data (Table 2), using effort which was adjusted for learning, standardized to US Otter Trawl (Side), tonnage class 2 units, and averaged over three-year intervals (Brown, *et al.*, 1975). From the standardized effort which corresponds to a given level of CSY (Figure 2), the estimated catch/effort and its standard deviation were calculated, based on a linear fit of the 1963-1972 points to the model:

$$y_{ij} = \hat{a}x_i + \hat{b} + e_{ij}$$

y_i = catch/effort at effort x_i,

x_i = average effort over the years i, i-1, and i-2, and

e_{ij} = error associated with observation y_{ij}, where e_{ij} $:N(o,\sigma^2)$

$\hat{a},\hat{b}$ = least squares estimates of slope and intercept, respectively.

Using the data given in Table 2, the following statistics were calculated:

$\hat{a}$ = 7.1535

$\hat{b}$ = -.0000129

r = -.86; F - 23.83

$\overline{x}$ = 173,711; standard dev. (x) = 46,342

$\overline{y}$ = 4.913; standard dev. (y) = .6908

standard dev. $(\hat{y})$ = .3673.

Using the formula (Snedecor, page 171),

$$\text{standard dev. } (\hat{y}_x1) = z*\sqrt{1 + \frac{1}{n} + \frac{(x^1-\overline{x})^2}{\Sigma(x_i-\overline{x})^2}}, \qquad (3)$$

where $\hat{y}_x1$ = predicted catch/effort at effort $x = x^1$,

n = number of sample pts. from which model was derived (here, n = 10), and

z = standard dev. $(\hat{y})$,

estimates of standard deviation of predicted catch/effort were calculated (Table 3). It follows that the standard deviation (s.d.) of the variable CSY is:

$$\text{s.d(CSY) = standard effort * s.d(catch/effort).} \qquad (4)$$

These values are also listed in Table 3. From Normal deviate tables (Snedecor), the probability that a random variable CSY from a population with mean CSY* and standard deviation as listed, is exceeded, can be determined. These probabilities are listed in Table 4. Using formula (1), the probability that recovery commenced in the years 1976-1978 were calculated, assuming that the 2nd tier TAC remained the same for three years (Table 5).

Results and conclusions

The probabilities that recovery will commence during the next three years, under various levels of 2nd tier TAC, were greater than 50% in all cases where the CSY* was more than 200,000 tons above the TAC. Assuming the (true) CSY to be from a distribution whose mean is 850,000 tons, a one-year 2nd tier TAC of 800,000 tons will produce the same probability of recovery as a three-year 2nd tier TAC of 600-650,000 tons. However, these data suggest that a substantial reduction of the 800,000 ton TAC would be required during the succeeding two years, in order to guarantee the same probability of recovery as the three-year 600-650,000 ton TAC. Analagously, a one-year 2nd tier TAC of 550,000 tons will result in the same 90% probability of recovery as a three-year 2nd tier TAC of 400-450,000 tons. Again, however, under the one-year TAC, a substantial reduction in the 2nd tier TAC during the succeeding two years would be required to affect the same probability of recovery over the three-year period. If there were certainty that a TAC for 1976 of 550,000 tons would allow the stocks to begin recovery, then the probability that that same level of TAC would provide for recovery over three years, assuming CSY for the following two years to be unknown, would be increased to .81. Using the same reasoning, if the 2nd tier TAC were set at 650,000 tons for 1976, and if it were known that that level was less than the (true) CSY for 1976, then the probability that recovery to a MSY of 1,000,000 tons would commence over the next three years, would be only .64.

Literature cited

Brown, B.E., J. A. Brennan, M. D. Grosslein, E. G. Heyerdahl, and R. C. Hennemuth, 1975. The effect of fishing on the marine finfish biomass in the Northwest Atlantic from the eastern edge of the Gulf of Maine to Cape Hatteras. ICNAF Res. Doc. 75/18.

ICNAF Report of Assessments Subcommittee, April, 1975. ICNAF Summ. Doc. 75/18.

Snedecor, G. W., and W. G. Cochran, 1967. Statistical Methods. Iowa State Univ. Press, Ames, Iowa, 6 ed.

Table 1. Number of years required until recovery of the stock to a level of MSY = 1,000,000 tons, assuming the current systainable yield = 850,000 tons, and the current stock size = 2,500,000 tons. (From ICNAF, 1975, p. 36).

2nd tier TAC (000's tons)	Year to recovery including 1976
800	13
750	11
700	9
650	7
600	6
550	5
500	4
450	4
400	4
350	3

Table 2. Standard effort (US side trawler - 2) with learning adjustment, total catch and CPUE for Subarea 5 and 6 finfish biomass, 1961-1972. (From Brown, *et al.*).

Year	Standard effort w/learning adjustment	3-yr average of standard effort of learning	CPUE of learning adjustment	Total catch
1961	53,879		6.39	344,286
1962	108,816		4.34	472,263
1963	108,834	90,510	5.98	650,825
1964	165,896	127,849	4.74	786,346
1965	169,895	148,208	5.62	954,808
1966	191,583	175,791	5.16	988,568
1967	143,104	168,194	5.31	759,881
1968	180,260	171,649	5.23	942,762
1969	221,137	181,500	4.65	1,029,391
1970	182,667	194,688	4.60	840,267
1971	267,190	223,665	4.21	1,124,872
1972	315,316	255,058	3.63	1,144,597

Table 3. Mean CSY (CSY*), standard effort, standard deviation of CPUE, and standard deviation of CSY, derived from data of Table 2.

CSY * (tons)	Standard effort	Standard dev. (catch/effort)	Standard dev. (CSY)
750,000	400,000	.712	284,992
820,000	390,000	.689	268,768
850,000	370,000	.646	239,027
900,000	350,000	.606	212,149
950,000	320,000	.548	175,249

Table 4. Probability of recovery commencing, assuming a random variable CSY has a distribution with mean CSY, for various levels of 2nd tier TAC.

Mean (CSY*) of population of CSY's (000's tons)	2nd tier TAC (000's tons) 350	400	450	500	550	600	650	700	750	800
750	.92	.89	.85	.81	.76	.70	.64	.57	-	-
800	.95	.93	.90	.87	.82	.77	.71	.64	.57	-
850	.98	.97	.95	.93	.90	.85	.80	.74	.66	.58
900	.99	.99	.98	.97	.95	.92	.88	.83	.76	.68
950	.99	.99	.99	.99	.99	.98	.96	.92	.87	.80

Table 5. Probability of recovery over three years, assuming a random variable CSY is from a distribution with mean CSY*, for various levels of 2nd tier TAC.

CSY* (000's tons)	2nd tier TAC (000's tons) 350	400	450	500	550	600	650	700	750	800
750	.78	.70	.61	.53	.44	.34	.26	.19	-	-
800	.86	.80	.73	.66	.55	.46	.36	.26	.19	-
850	.94	.91	.86	.80	.73	.61	.51	.41	.18	.20
900	.99	.97	.94	.91	.86	.78	.68	.57	.44	.31
950	.98	.98	.98	.97	.97	.94	.88	.78	.66	.51

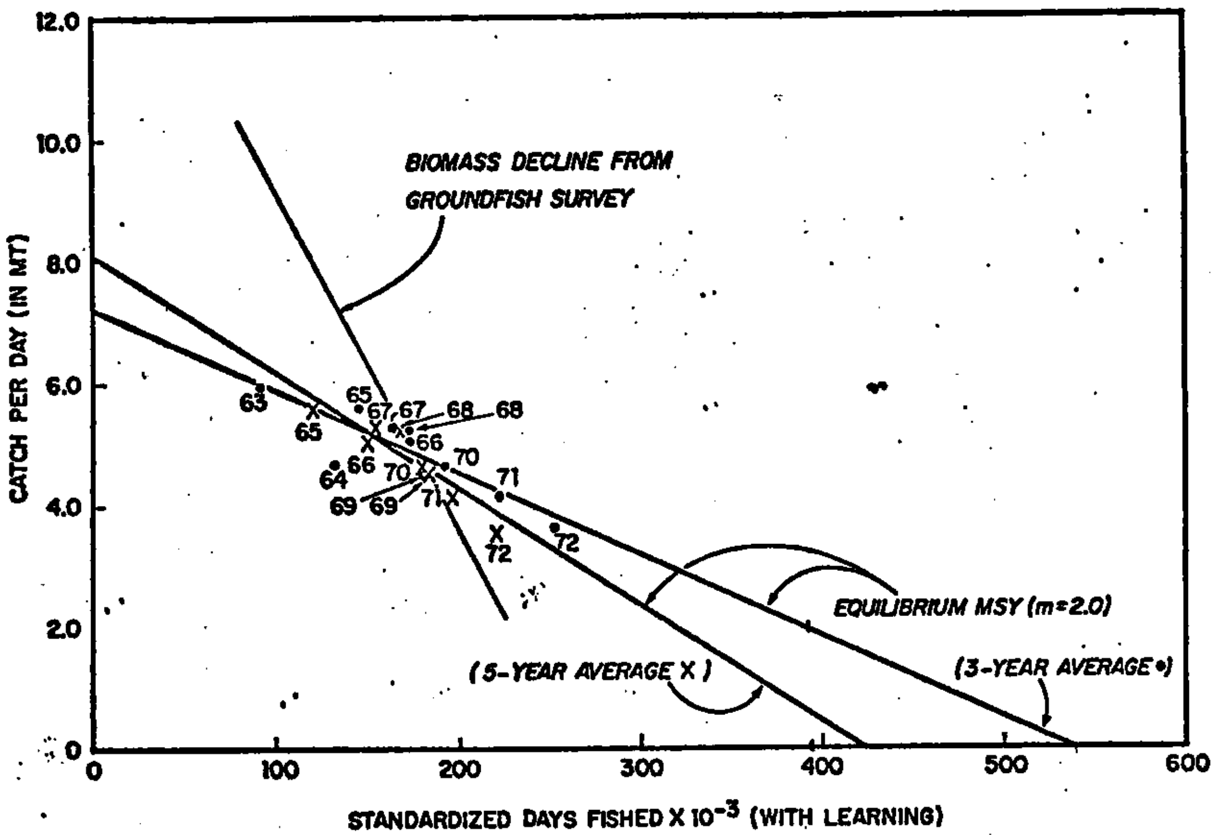

Figure 1. Shaefer model for SA 5 & 6 finfish plus squid biomass. (Brown, et al., 1975)

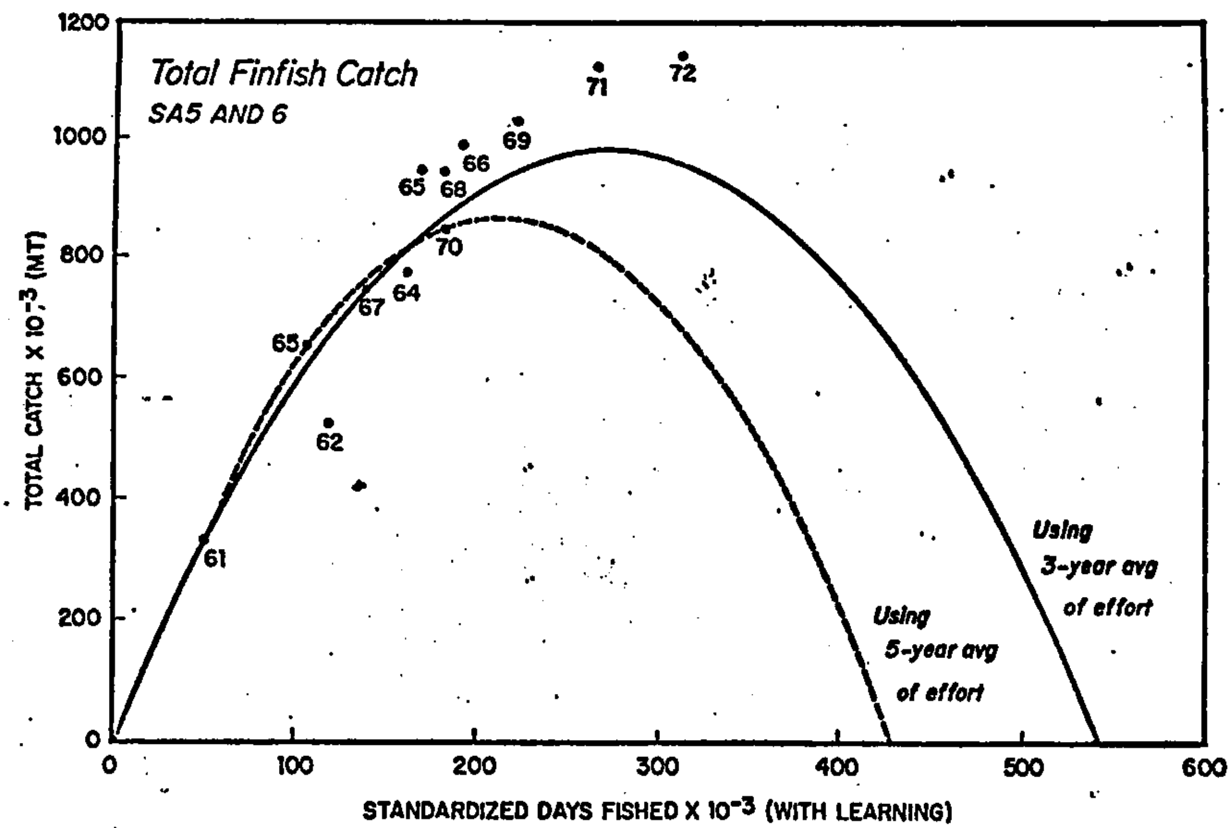

Figure 2. Yield curve for SA 5 & 6 finfish plus squid biomass (Brown, et al., 1975)