SIMULATION STUDY FOR APPRAISING THE VALIDITY OF PARRACK'S VPA TUNING METHOD

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SUMMARY

A simulation study was made using the artificial catch-at-age and CPUE data with and/or without random noise to examine the validity of the VPA tuning method developed by Parrack (1986) which has been used in estimating the bluefin tuna stock abundance at ICCAT for these three years. It was indicated that the tuning method could not find the true value, and that the simulation results fluctuated greatly with fairly small noise involved in the data used, even when the partial recruitment was known. It is concluded that this tuning method is sensitive to the accuracy of the data set and, therefore, not robust as a stock assessment tool in the area of Atlantic tunas stock analysis.

It is the purpose of this report to examine the validity of the VPA tuning method developed by Parrack (1985) by simulation studies.

RESUME

Une étude de simulation a été effectuée sur des données artificielles de prise à un âge donné et de CPUE, avec et sans interférences, pour vérifier le degré d'exactitude de la méthode d'ajustement des VPA élaborée par Parrack (1986), qui est employée depuis trois ans par l'ICCAT pour estimer l'abondance du stock de thon rouge. Il a été signalé que la méthode d'ajustement ne pouvait pas trouver la valeur réelle, et que les résultats de la simulation fluctuaient de façon importante du fait des légères interférences en jeu dans les données utilisées, même lorsque le recrutement partiel était connu. Il en a été conclu que cette méthode d'ajustement est sensible au degré de précision du jeu de données, et n'est donc pas robuste en tant que moyen d'évaluer le stock dans le domaine de l'analyse des stocks de thonidés de l'Atlantique.

RESUMEN

Se hizo un estudio de simulación empleando datos artificiales de captura por edad y de CPUE, con y/o sin interferencias, para examinar la validez del método de ajuste por VPA desarrollado por Parrack (1986), que ha sido el método empleado en ICCAT los últimos tres años para estimar la abundancia del stock de atún rojo. Se indicó que el método de ajuste no daría el valor real y que los resultados de la simulación fluctuaban ampliamente a causa de las ligeras interferencias en los datos empleados, incluso en el caso de que el reclutamiento parcial fuese un dato conocido. La conclusión es que este método de ajuste es sensible a la precisión del conjunto de datos y, por lo tanto, no tiene la solidez necesaria para servir de instrumento de evaluación del stock de túnidos atlánticos.

1. Materials and Methods

<u>The artifitial data without random noise</u>

The parameters were set to make an artifitial data without random noise with considering the recent assessment work of west Atlantic bluefin tuna stock (ICCAT 1985, 1986). The period and ages of artifitial data were set to ten years and 15 ages, respectively. The recruits, partial recruitment pattern (s_j), catchability (q), natural mortality (M), and year specific fishing effort (f_i) were assumed (Table 1). Based on the following three equations,

(1) $F_{ij} = q\, s_j\, f_i$

(2) $N_{i+1,j+1} = N_{ij} \exp(-(F_{ij}+M))$

(3) $C_{ij} = F_{ij}\, N_{ij}\ (1 - \exp(-(F_{ij}+M)))/(F_{ij}+M)$

the population number at age and fihing mortalities were calculated as shown in Table 1, and the resultant catch-at-age in Table 2.

As the population number and catchability were known, the true CPUE's were calculated from the following equation,

(4) $CPUE_i = q\, s_j\, \Sigma_j N_{ij}$

Three fisheries composed of the large fish fishery for 8-15 year olds, the medium fish fishery for age 5, and the small fish fishery for ages 2 to 4 fish were assumed. In case of small fish fishery, it was supposed that three fisheries were made for each age group, separately. Those calculated CPUE's were shown in Table 3.

<u>The data with random noise</u>

By using the generated normal random errors, noise was added to C_{ij} and $CPUE_i$ at one level among 5%, 10%, and 20% in coefficient of variation.

<u>Tuning method in VPA calculation</u>

VPA run can be tuned using a unique and/or some CPUE's on the assumption that there is a correlationship between CPUE and estimated population size. The terminal fishing mortality (Ft) is dertermined so as to minimize the objective function mentioned below (Parrack 1986).

(5) $SS = \Sigma_k \Sigma_i (CPUE_{m,ob}(k,i) - CPUE_{m,est}(k,i))^2$

where k, i, m are the number of available abundance indices, years, and ages, respectively. SS, $CPUE_{m,ob}$, and $CPUE_{m,cal}$ indicate the residual sum of squares, observed CPUE, and estimated CPUE. In practice, the CPUE's shown in Table 2 and /or those with random noise were used as $CPUE_{m,ob}$, while CPUE's estimated from the equation (4) as $CPUE_{m,cal}$.

<u>The computer program used</u>

The computer program coded in Nss-basic (Nagai and Miyabe 1987) which is substantially the same as that developed by Parrack(1986) were applied in the following analysis by using NEC PC-9801.

<u>The cases analyzed by simulation and the number of trials</u>

8 cases listed in the following table were analyzed by simulation. In Cases 1 and 6, no noise is involved in both of C_{ij} and $CPUE_i$. The former case is tuned with single CPUE, the latter with three CPUE's. Except the above-mentioned two cases, random noise was added to C_{ij} and/or $CPUE_i$. 100 trials were made for each case on the assumption that a real partial recruitment pattern was already known. Because the real solution was set at Ft= 0.08 and M= 0.20, the response surface was examined within the Ft range of 0.03-0.13 and for M inside the range of 0.15 -0.25 with changing both the parameters by 0.01.

	CPUE series used in tuning VPA	noise* (%) C_{ij}	noise* (%) $CPUE_i$
Case 1	Large fish	0	0
Case 2	Large fish	0	5
Case 3	Large fish	0	10
Case 4	Large fish	0	20
Case 5	Large fish	10	10
Case 6	Small(Age2), Medium, Large fish	0	0
Case 7	Small(Age2), Medium, Large fish	10	10
Case 8	Small(Age2,3,4), Medium, Large fish	10	10

*: Expressed in coefficient of variation.

2. Results

Table 4 shows the ralative response surfaces in Case 1 and 6 without random noise. The sum of squares stands at minimum with M = 0.20 and Ft = 0.08 for each case. It is concluded that the tuning procedure mentioned above is theoretically correct from the fact that the method found the true solution.

Regarding Cases 2 to 5 and Case 7 and 8, 100 trials being made for each case, the number of trials giving a minimum sum of squares were shown in a M-Ft plane (Fig.1).

Fig.1 shows that the points giving a minimum sum of squares locate lowering in the right side for each case. As a matter of course,the larger noise, the more dispersed points from the real solution.

In this type of simulation, the choise of an acceptable range for estimating the real solution is in itself a problem. It seems to be difficult how to determine the allowable range in practical use.

The population estimates in final year is the most important to make a projection for estimating a surplus production. Under the condition that partial recruitment is known, the ratios of population estimates ($N_{84,est}$) to real population size ($N_{84,real}$) are constant irrespective of ages at any combination of M and Ft. Therefore, it was decided to count the number of trials where SSMIN's locate within the range of 90-110% and 80-120% of $N_{84,est}$/ $N_{84,real}$ ratio(Fig. 1), and to use it as a temporary standard to know whether tuning the VPA is well done or not (Table 5).

The results of Cases 2 to 5 with a single CPUE are as follows; Compared to Case 2 with 5% noise, the number of trials occurred within the two ranges became half the size in Case 4 where 20% noise is involved in $CPUE_i$. In Cases 2 to 4 without noise in C_{ij}, the larger noise in $CPUE_i$'s, the fewer trials occurred in ±10% and ±20% of $N_{84,est}$/ $N_{84,real}$. In Case 5 with 10% noise involved in C_{ij} and $CPUE_i$,the number of trials occurred in the two ranges decreased at about 60% compared to Case 3 with 10% noise contained only in $CPUE_i$. In Case 5, only six and 24 trials of 100 runs located in the ±10% and ±20% range of $N_{84,est}$/ $N_{84,real}$,respectively.

The results of Cases 7 to 8 with multiple CPUE's used in tuning are as follows ; In Case 7 with three CPUE's, the number of trials occurred in the ±10% range became about two times and in the ±20% range about 1.5 times compared to Case 5 with a single CPUE. However, those trials occurring in the two ranges are only 11 and 38, respectively. In Case 8 with five CPUE's, the number of trials occurred within the above-mentioned two ranges was increased slightly .

3. Discussions

Table 4 shows that the area giving a small sum of squares in response surface distributes in a narrow band in Case 1 and Case 6. It indicates that M and Ft are interdependent in estimating these two parameters. Those two cases exhibit the existing problem clear.

Comparing Case 5, 7 and 8, it seems that increasing the number of CPUE's used in tuning is effective to get the true value,though the effectiveness being not necessarily proportional to the number of CPUE series used. Even in Case 8, there were only 13% and 41% in probabilities where SSMIN locates within the ±10 % and ±20% range of $N_{84,est}$/ $N_{84,real}$, respectively.

Though a partial recruitment was assumed to be already known in this paper, it could be possible to estimate it from the used catch-at-age data by separable VPA (Pope and Shepherd 1982) as is proposed by Conser(1987). However, a partial recruitment pattern estimated from separable VPA is always biased, unless four input parameters necessarry for separable VPA are coincident with the true values. Based on our preliminary analysis, the SSMIN's were more or less biased corresponding to the extent of bias involved in the used partial recruitment pattern.

From the aforementioned point of view, it is clear that the VPA tuning method developed by Parrack(1986) is sensitive to the data with a noise.

Generally speaking,a fairly large noise is always involved in the catch-at-age and CPUE data which we actually obtain. In case of demersal fish in the

Canadian Atlantic waters where the quite large amount of efforts expended in sampling, the level of noise was estimated as several percents in coefficient of variation at the dominant ages in catches, while that was 20-30% at the border ages [See Doubleday and Rivard (1985)].

A reliability on the catch-by-length of west Atlantic bluefin tuna is low especially in the early 1970's because of the poor samling (Nagai 1984). Based on the catch-by-length of the stock concerned, some well-separated age groups were observed below 140-150 cm (5-6 years-old), while unlike above that length. In particular, a unique widely spread length group was occurred above 200 cm. The 200 cm fish in length being nearly 10 years-old, more than 10 age groups, at least, were seemed to get mixed to some extent, because the life span of the species is estimated to be somewhere from 20 to 30 years-old. In case of the bluefin tuna stock, a length-age conversion has been made by using a growth equation due to an age-length key being not available. Therefore, it seems that the catch-at-age data contains a fairly large noise, especially, for the fish older than 10 years-old(Nagai, Hayasi and Yonemori 1986). Consequently, it is not appropriate to apply the Parrack's VPA tuning method to those bluefin tuna catch-at-age data with a large noise, because the method is not robust as indicated in this study.

4. Conclusion

Based on the present simulation study, it was found that the VPA tuning method developed by Parrack(1985) was very sensitive even to the small level of noise involved in the used data set. The conclusion, therefore, is that the tuning method is not appropriate as a stock assessment tool in case of Atlantic tunas stock analysis.

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Table 1. The assumed parameters (recruits, partial recruitment, fishing effort) and resultant N_{ij} and F_{ij} matrix under the condition that M equal to 0.2 and q equal 0.00001.

--- POPULATION NUMBER ---

YEAR	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1975	300000	250000	250000	120000	90000	150000	90000	120000	70000	50000	30000	70000	40000	30000	25000
1976	250000	245373	204274	204070	97856	73318	122075	73099	97270	56741	40529	24318	56741	32423	24318
1977	150000	204274	200093	166245	165747	79320	59312	98360	58663	78061	45536	32526	19515	45536	26020
1978	330000	122442	166245	162354	134486	133682	63783	47409	78150	46610	62022	36180	25843	15506	36180
1979	180000	268296	98853	133281	129254	106321	104948	49377	36191	59658	35581	47346	27619	19728	11837
1980	150000	145178	213171	77373	102767	98178	79556	76208	34796	25503	42041	25073	33365	19463	13902
1981	120000	121466	116275	168864	60621	79636	75247	59648	55894	25521	18705	30835	18390	24471	14275
1982	250000	96979	96896	91557	131248	46508	60308	55522	42882	40184	18347	13448	22168	13221	17593
1983	140000	201636	77053	75841	70595	99693	34801	43792	39126	30219	28317	12929	9476	15621	9317
1984	90000	112352	158612	59412	57319	52298	72392	24280	29355	26227	20256	18981	8667	6352	10471

--- F MATRIX --- (q = 0.00001)

YEAR	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	--- FISHING EFFORT --- (UNIT: 1000)
1975	0.0010	0.0020	0.0030	0.0040	0.0050	0.0060	0.0080	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	1
1976	0.0020	0.0040	0.0060	0.0080	0.0100	0.0120	0.0160	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	2
1977	0.0030	0.0060	0.0090	0.0120	0.0150	0.0180	0.0240	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	0.0300	3
1978	0.0070	0.0140	0.0210	0.0280	0.0350	0.0420	0.0560	0.0700	0.0700	0.0700	0.0700	0.0700	0.0700	0.0700	0.0700	7
1979	0.0150	0.0300	0.0450	0.0600	0.0750	0.0900	0.1200	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	15
1980	0.0110	0.0220	0.0330	0.0440	0.0550	0.0660	0.0880	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	11
1981	0.0130	0.0260	0.0390	0.0520	0.0650	0.0780	0.1040	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	0.1300	13
1982	0.0150	0.0300	0.0450	0.0600	0.0750	0.0900	0.1200	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	15
1983	0.0200	0.0400	0.0600	0.0800	0.1000	0.1200	0.1600	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	20
1984	0.0080	0.0160	0.0240	0.0320	0.0400	0.0480	0.0640	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	8
Sj	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	

Table 2. C_{ij} matrix without random noise.

---- Cij ----

YEAR	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1975	272	453	679	434	407	813	650	1082	631	451	271	631	361	271	225
1976	453	888	1108	1474	883	793	1757	1312	1746	1019	728	437	1019	582	437
1977	407	1108	1625	1798	2237	1283	1275	2636	1572	2092	1220	872	523	1220	697
1978	2087	1543	3132	4065	4195	4987	3151	2908	4794	2859	3805	2219	1585	951	2219
1979	2429	7190	3945	7042	8475	8306	10778	6249	4580	7551	4503	5992	3495	2497	1498
1980	1488	2864	6275	3021	4989	5690	6083	7208	3291	2412	3976	2372	3156	1841	1315
1981	1405	2827	4034	7762	3461	5423	6748	6605	6189	2826	2071	3414	2036	2710	1581
1982	3374	2599	3867	4837	8606	3633	6193	7027	5427	5086	2322	1702	2806	1673	2227
1983	2513	7171	4071	5292	6099	10238	4676	7219	6450	4981	4668	2131	1562	2575	1536
1984	650	1617	3410	1697	2038	2223	4072	1694	2048	1830	1413	1324	605	443	731

Table 3. Assumed CPUE's without random noise.

--- CPUE SERIES (CPUEob) ---

YEAR	SMALL FISH AGE2	SMALL FISH AGE3	SMALL FISH AGE4	MEDIUM FISH	LARGE FISH
1975	0.5000	0.7500	0.4800	0.4500	4.3500
1976	0.4907	0.6128	0.8163	0.4893	4.0544
1977	0.4085	0.6003	0.6650	0.8287	4.0422
1978	0.2449	0.4987	0.6494	0.6724	3.4790
1979	0.5366	0.2966	0.5331	0.6463	2.8734
1980	0.2904	0.6395	0.3095	0.5138	2.7035
1981	0.2429	0.3488	0.6755	0.3031	2.4774
1982	0.1940	0.2907	0.3662	0.6562	2.2337
1983	0.4033	0.2312	0.3034	0.3530	1.8880
1984	0.2247	0.4758	0.2376	0.2866	1.4459

Table 4. Relative response surface of residual sum of squares in Case 1 and 6.

Case 1

*** SCALED SUM OF SQUARES SURFACE ***

--- NATURAL MORTALITY ---

FT	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25
0.03	9999	8116	6422	4927	3639	2562	1702	1059	634	425	428
0.04	6983	5504	4196	3068	2124	1370	807	437	259	271	471
0.05	4884	3712	2699	1848	1165	652	313	146	152	329	675
0.06	3414	2482	1695	1058	575	248	79	68	214	516	971
0.07	2384	1640	1032	563	236	54	17	126	381	779	1318
0.08	1666	1073	606	271	68	0	68	272	612	1085	1690
0.09	1172	700	349	120	17	41	193	474	881	1414	2071
0.10	840	468	210	69	48	147	367	709	1171	1752	2451
0.11	627	337	157	89	134	295	571	963	1470	2091	2824
0.12	502	281	166	158	259	471	794	1228	1772	2425	3185
0.13	442	279	218	261	410	665	1026	1495	2070	2750	3533

SSMIN: .317371E-14
SSMAX: .472618E-05
SCALED SS = (SS-SSMIN)*(9999/(SSMAX-SSMIN))

Case 6

*** SCALED SUM OF SQUARES SURFACE ***

--- NATURAL MORTALITY ---

FT	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25
0.03	9999	8126	6440	4951	3665	2588	1725	1076	643	424	415
0.04	6995	5520	4216	3090	2146	1389	821	445	259	262	451
0.05	4894	3726	2714	1863	1179	664	320	147	147	316	651
0.06	3419	2489	1703	1066	582	253	81	65	206	501	948
0.07	2382	1640	1033	565	238	55	16	123	373	766	1299
0.08	1657	1067	603	269	67	0	68	270	608	1078	1678
0.09	1157	690	342	117	17	43	196	476	882	1414	2068
0.10	822	455	203	66	49	151	374	717	1180	1761	2458
0.11	607	324	151	88	139	304	584	979	1488	2110	2842
0.12	482	269	162	161	269	487	815	1252	1799	2454	3216
0.13	423	270	218	270	426	688	1056	1530	2108	2791	3576

SSMIN: .195717E-13
SSMAX: .498755E-05
SCALED SS = (SS-SSMIN)*(9999/(SSMAX-SSMIN))

Table 5. The number of trials of 100 runs in cases where SSMIN being estimated within the 10% and 20% range of $N_{84,est}/N_{84,real}$

	noise(%)		No. of CPUE	$N_{84,est}/N_{84,real}$	
	C_{ij}	$CPUE_i$	used for VPA	±10%	±20%
Case 2	0	5	Single	20	58
Case 3	0	10	Single	10	36
Case 4	0	20	Single	10	26
Case 5	10	10	Single	6	24
Case 7	10	10	Three	11	38
Case 8	10	10	Five	13	41

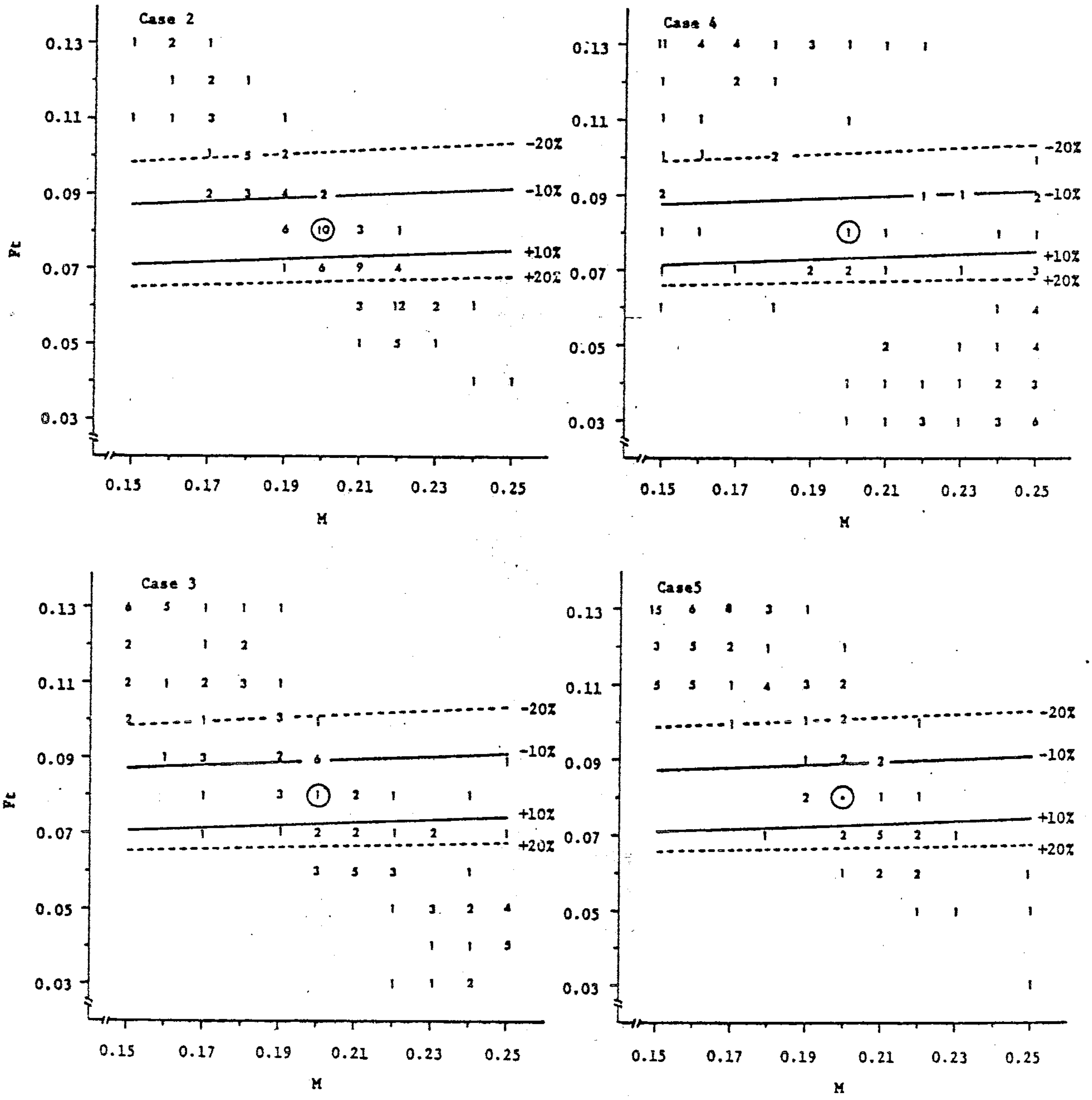
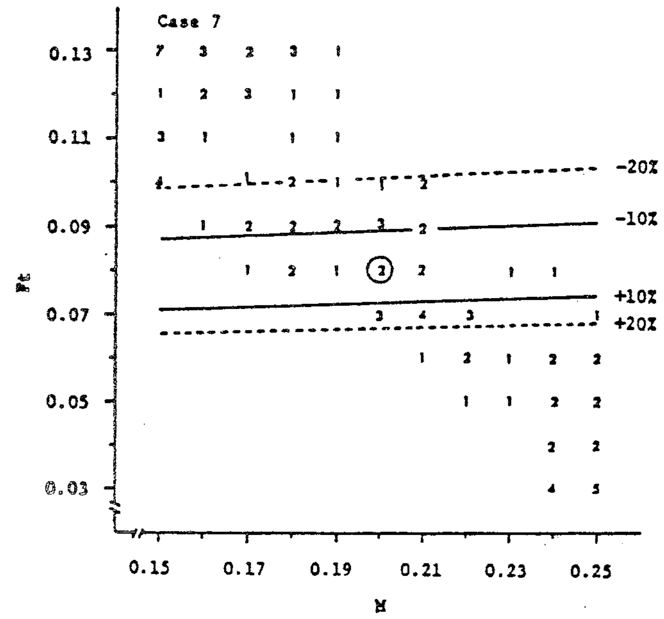


Fig. 1. The simulation results were shown in M-Ft plane where the number of trials of 100 runs giving the minimum sum of squares was plotted.
(10% and 20% indicate $N_{84,est}$ / $N_{84,real}$ ratio.)



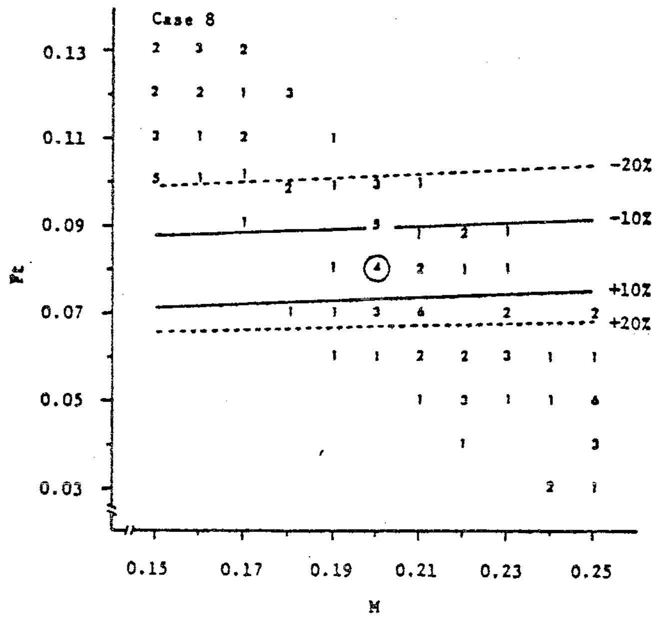


Fig.1. (Continued)