CATCH AT AGE MATRIX OF INDIAN OCEAN YELLOWFIN TUNA ESTIMATED ON A QUARTERLY BASIS AND USING AN AGE LENGTH KEY

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SUMMARY

This document presents the method used to estimate a new quarterly catch at age matrix for the Indian Ocean yellowfin tuna. The IOTC working group held in Shanghai in June 2002 made an estimate of a yearly catch at age done by a simple slicing of the extrapolated yearly catch at size by gear. As this method as well as this large time intervals were estimated to be not really satisfactory, it was recommended to improve the estimation of this catch at age table. This work is a first follow up of this recommendation. All calculations are done on the quarterly catches at size of each gear. The growth used in the present calculation was the two-stanza growth curve proposed by Lumineau, used on a quarterly scaling. A length-age key was built and used to estimate the contribution of the various ages taken at each 2 cm class of fork length. Seasonal patterns of catch at age are examined. The catch at age matrix obtained by this method can be compared to the yearly table obtained by slicing by the Shanghai working group.

1 INTRODUCTION

The Shanghai WG work has widely provided a confirmation that it was possible, and also very interesting, to estimate quite well the catch at size and the catch at age of yellowfin tuna during the entire history of the fishery. The WG did this analysis of catch by age using a slicing method of a yearly catch at size table by gear. The only advantage of this method was its simplicity. However, it is quite obvious, first that it would be better to use improved methods that would allow to estimate the mixture of ages that are always increasingly observed when fished are growing (as a consequence of the variability of growth among individual fishes). Second, it is also obvious that a quarterly catch at age table is preferable because size modes are more easily identified on a quarterly scale than on a yearly scale; furthermore, there is no doubt that the results of such quarterly analysis are much more realistic in all subsequent yield per recruit and simulation studies, because they will allow to take into account the marked seasonality of most tuna fisheries. This problem was already fully recognized by the Shanghai WG but due to a lack of time available, this task was not done during the WG. This paper will justify better the interest to estimate a quarterly catch at size and it will present a first estimate of such quarterly catch at age estimated using an age key table.

2- WHY A QUARTERLY CATCH AT SIZE IS EASIER AND PREFERABLE?

2-1- Easier to analyse

Cohorts of yellowfin tunas exploited by the fisheries are permanently growing. Modes are often visible and easy to identify at a monthly or quarterly time scales, at least when fishes are still small. At small sizes, any modern software of modal decomposition would easily identify the modes and their apparent modal progression due to growth, at least when the size data are the original ones, without strata substitutions. However, when these data are pooled on a yearly scale it becomes more difficult to identify and to follow the same modes. This problem is easily visualised and understood on simulated data, simulating sizes taken on a given cohort on a monthly, quarterly ad yearly scales. The simulated exploited yellowfin cohort shown figure 1 is assumed to follow the Stequert growth model with a moderate variability of its birth dates and growth parameters (t_0 and L infinity) (following the model proposed by Fonteneau 1974). It appears that short intervals of time are always easier to analyze and that the quarterly intervals are often a good practical choice. Shorter intervals would be better, but it would be more difficult or unrealistic to estimate the catch at size on a monthly basis.

2-2- Why quarterly catch at age are always more interesting than yearly one's?

Yellowfin tuna are exploited by multi gear fisheries where each gear is targeting a given size of fishes with a marked seasonality. Also, the life expectancy of this species appears to be quite limited (most fishes being taken during an interval of 6 years?). Its growth pattern is also possibly quite complex with a 2 stanza pattern that has been hypothesised during this short life. The complexity of these events, fisheries and growth, should of course preferably be taken into account in a realistic modelling of the fishery. The marked seasonality of catches at size taken by most fisheries is also a parameter hat is essential to take into account in the subsequent analysis of the catch at age. When fisheries are seasonal, it is easy to understand that VPA can be widely biased by yearly intervals (Fonteneau 1994). These VPA can be easily and widely improved when they are conducted with shorter intervals of time.

In parallel, all yield per recruit analysis would also be widely improved using quarterly intervals of catches, fishing mortality and growth, instead of the yearly intervals that are poorly realistic in a yield per recruit analysis, even when the real yearly fishing mortalities are perfectly known. The main reasons underlying this conclusion are in relation with the fact that, when the yearly catches are predominantly taken during the first or during the last period of the year, they should not be treated in the same way than when they are randomly scattered during the entire year. Furthermore, this quarterly yield per recruit analysis can easily be done on a multi gear basis, taking into account the size specific seasonality of each gear, then providing better results that take into account seasonal patterns of catchability and growth.

It should be better to use shorter interval in the VPA and subsequent yield per recruit/simulation analysis, for instance monthly ones, but unfortunately, it would be very difficult to create an exhaustive catch at size database as a function of these short time intervals.

3-METHOD USED

The quarterly catch at size by gear (estimated for four gears: purse seiners, longliners, pole and line, and other gears) was estimated by the Shanghai WG for the entire period 1950-2000. The present length-age correspondence was done upon this quarterly matrix of catch at size, and not on the yearly figures used in Shanghai. The 2 stanza Lumineau growth has been used as a working hypothesis (Lumineau 2002).

The simple method used to estimate the catch at age was the method proposed by Gascuel 1994, applying a quarterly key to the size distribution (instead of the monthly figure proposed by Gascuel). This method is a development of the algorithm proposed by Kimura and Chikuni 1987. It has been shown by Gascuel that the results of this method tend to be the same than the maximum likelihood adjustment when the method is ran correctly. This method was programmed on an excel sheet with a series of macro.

The same age- length key has been used during the entire period 1950-2000 assuming that growth and its variance as a function of age was cons tant over time and was the same for all cohorts. An hypothesis that variability of sizes within cohorts are assumed to be increasing with growth, as shown by figure 2, was accepted as being a reasonable one and later used in the calculations. It has been shown by Gascuel 1994 that this method was quite insensitive to errors in the variability of sizes assumed. Details concerning the calculations done are given by Lumineau 2002. This simple but reasonably efficient method has been chosen and used, primarily because of the quite poor nature of the data base of extrapolated sizes. Knowing that this data base contains a large proportion of strata substitutions (including between years and quarters), it appears that more traditional methods used to analyse multi normal size frequency distribution (for instance Hasselblad, Macdonald and Pitcher, or MULTIFAN methods) could not be used efficient ly on the catch at size figures present ly available.

4-RESULTS

The catch at size estimated for the entire fisheries are given table 1. This catch at age matrix is available for each gear as well as for the combined fisheries. This matrix can be compared with the table obtained by the Shanghai WG but it is hypothesized that this table obtained on quarterly size distributio ns and using a length-age key is probably more realistic that the one obtained by yearly slicing. This new table well shows that there is a seasonality in the catch at age figures and that this seasonal pattern of catches is variable between cohorts (figur e 3).

The final use of this result is to run subsequent VPA and yield per recruit on a quarterly basis as well as multi gear analysis (multi gear yield per recruit based on the quarterly partial F of each gear). In fact these calculations have already been done (and their results are available under request), but the agenda of the present meeting do not allow to compare these new results with the Shanghai figures.

5-CONCLUSION AND RECOMMENDATION

This simple but improve processing of the catch at age tables estimated during the Shanghai meeting are probably an improvement in the work done by the WG, even though this improvement remains difficult to evaluate precisely. The subsequent conclusion will still be that quarterly size decomposition should preferably be conducted and used in all subsequent SPA and yield per recruit analysis. The method used is only a first step in that positive direction. However, it is clear that improved and realistic methods, well adapted to the uncertainties in the data base, sho uld be developed and used to do this work. Such delicate task should preferably be conducted in close cooperation between the IOTC secretariat and concerned scientists well before the working groups that will be planned by the IOTC (knowing that this is a difficult task).

BIBLIOGRAPHY

FONTENEAU (A.), 1974: Simulations stochastiques des structures démographiques. Application aux populations d'albacore (*Thunnus albacares*) de l'Atlantique. Doc. Scient. Centre de Recher. Océanogr. Abidjan, N°5 (3-4): 53-62

FONTENEAU (A.), 1994:- Time units to be used in the yellowfin VPA'S ?. Rec. Doc. Scient. ICCAT Vol. XLII(2) p 209-214

FOURNIER D. AND J. SIBERT, 1989: MULTIFAN, a likelihood method for estimating growth parameters and age composition from multiple length frequency samples with an application to southern bluefin tuna (*Thunnus maccoyi*). Otter software, PO Box 265, Nanaimo, Canada.

GASCUEL D. 1994: Une méthode simple d'ajustement des clés taille/âge : application aux captures d'albacore (*Thunnus albacares*) de l'Atlantique est. Can. J. Fish. Aquat. Sci. , Vol. 51, 723-733.

HASSELBLAD (V) 1966: Estimation of parameters for a mixture of normal distribution. Technometrics, 8: 431-444.

KIMURA D. AND S. CHIKUNI 1987: Mixtures of empirical distributions: an iterative application of the age- length key. Biometrics, 43: 23-35.

LUMINEAU (O.) 2002: Evaluation de l'état actuel et des perspectives d'exploitation durable du stock d'albacore (Thunnus albacares) de l'océan Indien (Mémoire de Certificat d'Etudes Supérieures Agronomiques de l'Ensar, mention Halieutique, 49 p.)

LUMINEAU (O.) 2002: Study of yellowfin tuna (*Thunnus albacares)* growth in the Western Indian ocean based on length frequency data. Document WPTT/02/18, 19p.

MACDONALD P. AND T. PITCHER, 1979: Age groups from size frequency data: a versatile and efficient method for analyzing distribution mixtures. Journal of the Fish. Res. Board Canada 36: 987-1001.

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
1	37975	38065	38113	38071	38110	50741	51365	52556	51846	51968	27446	40195	41414	43963	41928	30274	42360
2	25935	26219	26372	26243	26376	34915	36832	40034	38204	38502	22735	31896	34633	39932	35818	28534	36664
3	45780	46302	46571	46348	46561	61662	64931	70197	67146	67702	39525	55703	60194	68781	62046	48967	63354
4	50535	51586	52109	51727	52271	68712	74800	84271	78827	79818	50030	68497	76307	91174	79702	66010	82234
5	56145	56999	56369	57037	74604	84532	99598	90836	92510	61943	82855	95095	118294	101363	87456	104572	132643
6	8968	10177	9336	10271	11584	25719	49225	35440	38003	43476	49484	69009	103938	78168	84311	84557	118236
7	13949	15527	14508	15782	18291	37098	67843	49776	52849	58974	66542	92132	141393	107087	112921	121664	158883
8	23672	25415	24143	27058	32842	51895	87813	65441	69628	70790	87053	111241	163488	124617	137731	136384	183156
9	12394	11536	13511	18123	36772	69960	53096	50465	60804	74281	98432	153753	109763	125527	119027	169037	206201
10	10074	9647	11861	16573	33609	60557	46209	48417	53518	63605	77119	153637	88997	116733	103815	137230	170879
11	5502	5394	6040	6459	17855	40306	26450	28637	34776	65295	83064	109630	63697	110407	75301	110196	118837
12	4724	10210	5851	12700	17859	30070	19785	25645	28701	31675	52313	94523	52632	103021	74072	111141	189385
13	10742	14628	16468	26199	40940	36193	39208	64506	54213	99101	97243	72672	50171	144156	113445	444310	398531
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21+	133265	194536	164758	103650	54238	76136	58144	80023	47394	46888	64345	72415	72840	112182	47658	35471	49397
22+	130554	139911	87060	59835	52878	75084	37862	34364	32196	46782	35604	45919	63722	68845	29008	15874	13582
23+	56580	95040	30428	8128	18051	38840	22211	54407	17093	38269	17173	50347	9837	21869	24421	16120	20479
24+	80310	85960	42110	30879	31442	37424	94752	43141	42195	30263	16788	42771	7521	6115	4473	14261	3264

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	49602	50080	50800	69964	41537	63995	186711	114791	94948	105705	182274	127456	80025	110939	162775	79588	142936	229393
2	44811	45894	50113	49958	35836	54924	116941	94299	130748	89869	68965	61621	114689	90828	115510	48328	256544	196875
3	77222	78807	76072	91366	47995	119791	234447	162107	180637	206696	178535	131049	182359	197585	195467	244338	283887	531407
4	102165	104956	98295	90686	92186	85706	246834	261200	100380	225239	146805	177212	159600	124197	211576	222266	683140	1835715
5	136902	124949	147335	100213	147828	312865	217584	188065	207491	311316	235892	179866	227894	307587	241079	449696	564487	797600
6	124686	100223	90809	78186	106832	101894	108721	110084	112772	101402	100320	133495	134451	143182	135305	181990	170474	690636
7	169345	135956	127425	104339	147971	147734	149991	153661	163081	148955	140392	181007	190290	185079	206077	255116	450315	873388
8	192735	159425	153553	130111	160946	192239	216383	155727	206037	169300	179416	206398	199615	223707	227676	302019	524639	436442
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17	87385	84832	81037	67006	51683	66650	79523	160871	147290	76383	59805	76179	74797	225562	332366	458107	414060	565425
18	19683	25909	29945	34469	31824	39697	77634	46447	62064	43151	32475	27812	68815	111705	162460	103484	59601	273105
19	25545	14882	21970	19769	31803	24073	54233	24429	31388	26678	22173	23679	34976	76418	56879	57333	43745	93340
20	3304	2653	34438	20238	3474	16668	79692	24220	14445	22362	13277	19819	49224	113092	21593	22135	48655	147092
21+	25966	47219	49866	34550	40827	58470	88715	38487	55034	42963	49003	60946	142842	261913	285537	232197	298852	422813
22+	14083	14694	22584	22937	19531	61842	25621	35219	28027	28941	19570	42475	92677	153438	69830	38600	191393	65531
23+	12781	15136	15862	24603	19948	39797	20366	22473	21473	18906	18868	27371	67104	47270	46374	34912	74256	51895
24+	3002	32172	21547	3643	18314	74123	24394	13497	23011	14115	19221	49017	108182	22347	21208	49353	137402	3605

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	163170	240822	142337	170042	110148	73817	145534	403920	362552	508419	550552	613372	389075	482751	595820	408791
2	116765	133179	173126	65348	457647	29481	83267	331053	324596	1080432	784199	607311	1427852	764936	1973821	806051
3	973329	536680	795228	1169566	1727226	1017001	1940383	1303563	1825291	3563848	2712212	3822335	4114460	3240762	5744432	5913062
4	4071490	626128	780950	2310316	1558937	1298288	1313515	1415506	1788329	2174719	2022587	3958914	5435786	2159648	4353141	2206817
5	824655	518450	1158036	1283298	2450231	409657	1234364	1202288	1576196	2530396	1514601	3939211	3291470	4092275	2628023	
6	1497428	918217	965978	1077899	999178	535245	1023804	673586	1165832	2307719	1161217	2036168	2132796	2937556	2756786	
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18	104529	147223	111936	174392	165557	304787	296292	316315	243425	233903	188148	220925				
19	56325	98944	97334	246081	211812	114603	72676	367295	112018	75666	138732	157592				
20	3004	90830	49235	54708	154382	299764	106714	103364	6686	95005	145118	94204				
21+	323763	490017	620235	725364	595089	293718	277466	591676	287893	398099	486624					
22+	89910	78326	148188	167475	289055	252518	221215	175356	177468	128947	136295					
23+	83889	79574	192331	206041	108324	77942	378705	92831	70215	115861	133663					
24+	80866	45580	51709	147413	282719	105418	98749	8826	98497	130785	93367					

Table 1: Quarterly total catch at age estimated by the present method;
Quarterly catches taken by each gear are also estimated and available.

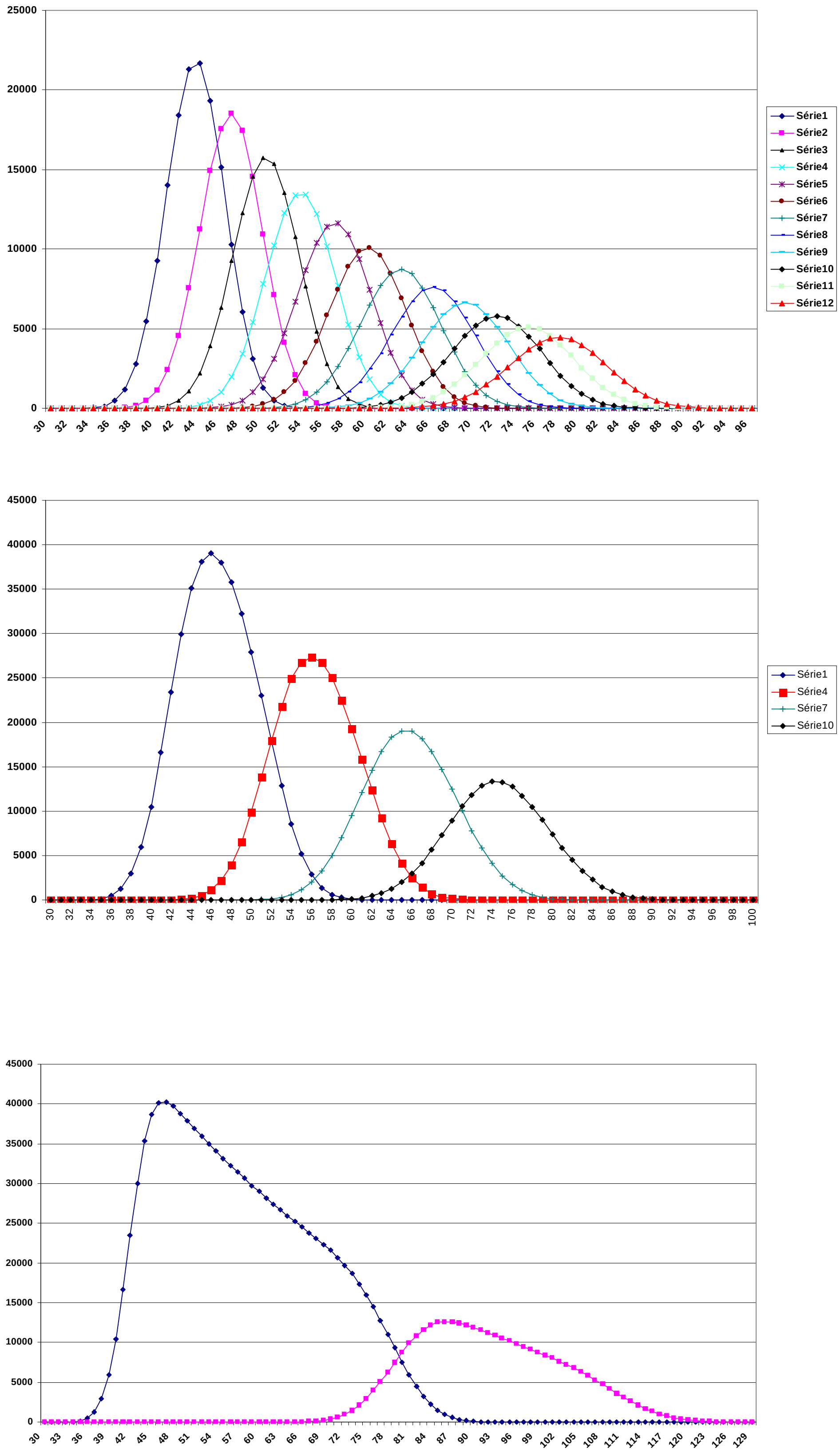

Figure 1: Exemple of simulated histograms of size, tabulated on a monthly, quarterly or yearly basis; the first 2 figures shows the sizes taken on a given cohort during its firts year of exploitation, the bottom figure shows sizes taken during the 1st and 2nd years of exploitation

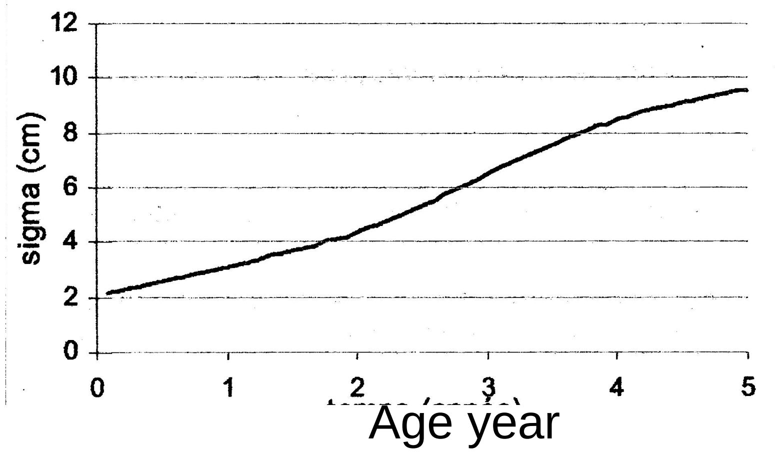

Figure 2: Standard deviation of sizes assumed as a function of age in the size-age length key presently used.

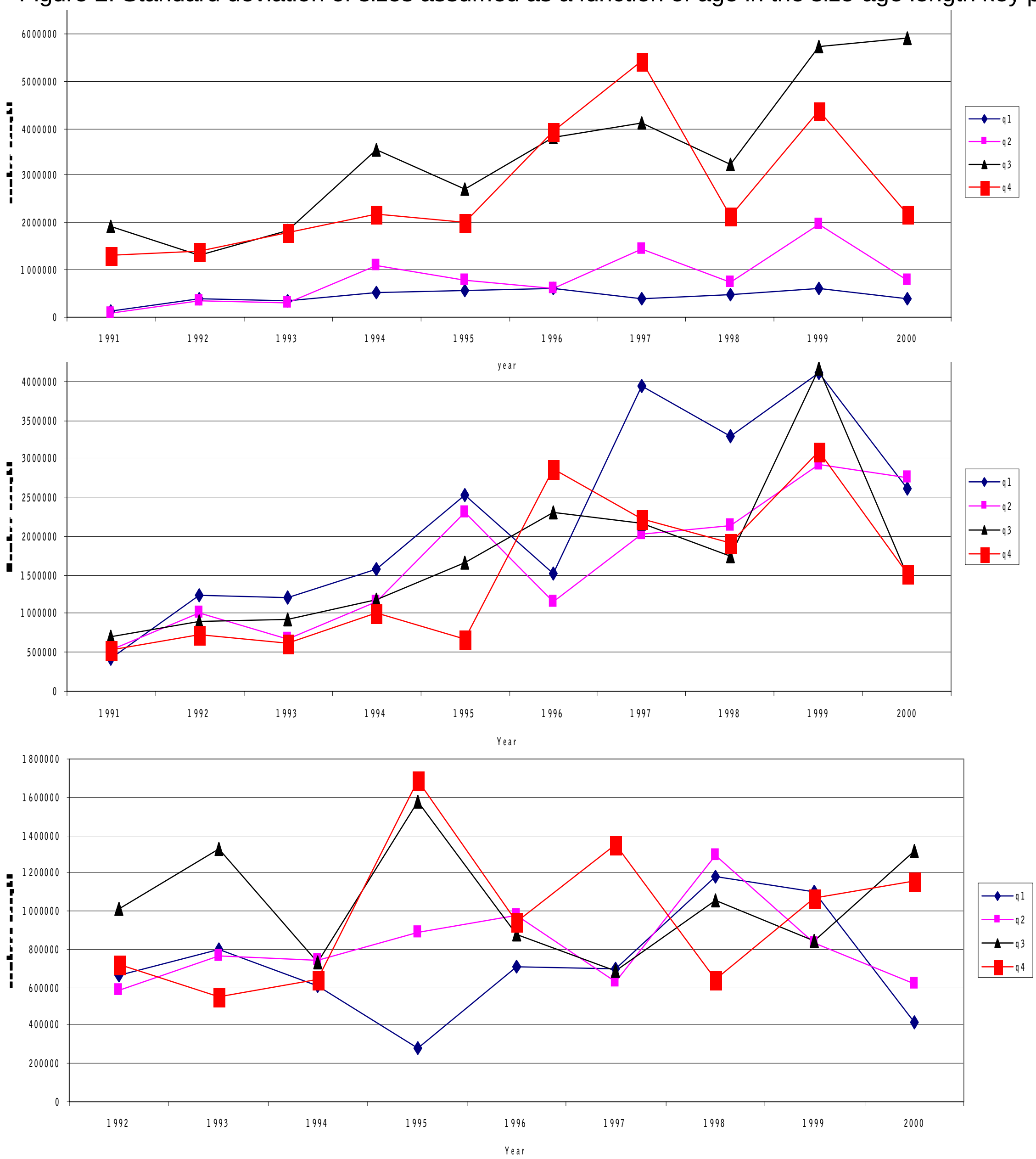

Figure 3: Exemples of variabilty of the quarterly catch at age estimated during recent years , for age 1 (recruitment) upper figure, age 2 (middle) and age 4 (bottom)