

**MODELING A SINGLE ATLANTIC YELLOWFIN STOCK WITH A MIXING MODEL**

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**SUMMARY**

This paper discusses the validity of the two stock structure hypotheses commonly adopted by SCRS scientists for the Atlantic yellowfin tuna: the "two stocks" and the "single stock" hypotheses. The most commonly used working hypothesis has been that two independent stocks are exploited in the Atlantic; this hypothesis had the practical advantage of simplicity, but has always been in contradiction with the continuous east-west distribution of the longline catches and the apparent migrations of adults suggested many years ago by the seasonality of the longline CPUEs. Recent transatlantic recoveries of tagged adults, observed each year since 1987, have added more doubts to the "two stocks" hypothesis. Consequently, this paper uses a two boxes mixing model in order to model the fishery: the fishing mortalities are calculated at the level of the total Atlantic. In this analytical model with two geographical components (east and west units), two gears (longline and purse seine) are exploiting the migratory resource. Hypothetical age-specific migration rates between the two units are estimated, based on the catch at age by area and the west-east migrations of adults suggested by tagging. For each migratory hypothesis, the local fishing mortalities in each unit are calculated, as well as the age-specific biomass by area. All results from this modelling are preliminary due to the fact that the data available were provisional and due to the number of analytically possible migratory hypotheses. However, this type of mixing models should be considered as a potentially realistic and useful tool for future stock assessments and management of this migratory stock.

**RESUME**

Cet article discute la validité des deux hypothèses classiques employées par les scientifiques du SCRS pour évaluer l'état des ressources d'albacore: l'hypothèse de deux stocks est et ouest, ou bien celle d'un stock atlantique unique. L'hypothèse la plus couramment employée est celle de deux stocks indépendants; cette hypothèse a l'avantage de la simplicité, mais a toujours été en contradiction avec la distribution continue de la ressource de l'est à l'ouest de l'Atlantique qui est claire dans la pêcherie palangrière, ainsi que des variations des CPUE palangrières qui ont toujours suggéré des migrations saisonnières est-ouest des adultes. Les récentes et régulières recaptures d'albacores marqués ayant effectué des migrations transatlantiques ont renforcé ces doutes à l'encontre de l'hypothèse de deux stocks isolés. En conséquence, cet article introduit l'usage d'un modèle migratoire à deux compartiments dans lequel la ressource migratrice est exploitée par deux engins (palangriers et senneurs). Des taux de migration possibles sont d'abord estimés en fonction de l'âge, ceci à partir des statistiques de pêche et des recaptures d'albacores marqués. Pour chaque hypothèse de taux de migration, les mortalités par pêche locales dans chaque unité géographique sont ensuite calculées, ainsi que la biomasse par âge et par zone. Tous les résultats de cette modélisation restent très préliminaires du fait du caractère provisoire des données qui étaient disponibles, et du fait de la multiplicité des hypothèses migratoires possibles analytiquement et qu'il conviendrait de préciser. Toutefois, ce type de modèle migratoire devrait être à présent considéré comme un outil potentiellement intéressant et réaliste pour les futures évaluations de ce stock et son aménagement.

## RESUMEN

Este documento discute la validez de dos hipótesis clásicas empleadas por los científicos del SCRS para evaluar la condición de los recursos de rabil atlántico: la hipótesis de dos stocks, este y oeste, o bien la de un solo stock en todo el Atlántico. La que se emplea usualmente es la hipótesis de dos stocks independientes, que presenta la ventaja de ser más sencilla pero que siempre ha estado en contradicción con la distribución continua del recurso, desde el este al oeste del Atlántico, que está clara en el caso de la pesquería palangrera, y también con las variaciones en las CPUEs del palangre, que sugieren migraciones estacionales de los adultos en dirección este-oeste. Las recientes, y regulares, capturas de rabiles marcados, que han llevado a cabo migraciones transatlánticas, son un argumento que refuerza las dudas sobre la hipótesis de dos stocks aislados. Por tanto, este documento introduce el empleo de un modelo migratorio con dos compartimientos, en el cual el recurso migratorio es explotado por dos artes (palangre y cerco). En primer lugar se estiman posibles tasas de migración en función de la edad, partiendo de estadísticas de pesca y de recaptura de rabiles marcados. A continuación, para cada hipótesis de tasa de migración, se calculan las mortalidades por pesca locales de cada unidad geográfica, así como la biomasa por edad y zona. Los resultados de este modelo son muy provisionales, por la misma naturaleza provisional de los datos que se emplean y por las múltiples hipótesis migratorias posibles desde el punto de vista analítico y sobre las que convendría precisar. Sin embargo, este tipo de modelo migratorio debería considerarse ya como un instrumento realista e interesante a emplear en las futuras evaluaciones del stock y en su gestión.

### I. INTRODUCTION

The paradigm concerning yellowfin stock structure in the Atlantic has been, since the early seventies, that there are intensive E-W. migrations of the adult stock. This hypothesis, first developed by Japanese scientists (1971), confirmed by further scientific works (by FONTENEAU 1981 or YANEZ et BARBIERI 1980, was based upon the longline and purse seine CPUE, which clearly show an equatorial continuity of the distribution associated with clear E-W. seasonal migrations.

However, this global paradigm concerning the stock structure was not taken into account by ICCAT scientists in their stock assessment: for practical reasons, the "two stocks" hypothesis has been used in most stock assessments.

The transatlantic recoveries recently observed for adult yellowfin (Bard and Scott 1991) confirm the traditional paradigm on stock structure, and urge the scientists to take into account for their stock assessment the obvious continuity of the yellowfin stock in the Atlantic.

The goal of this paper will be, first to analyze the available informations on the stock structure, especially those from cpue's and from tagging.

The further step of this paper will be to develop a conceptual stock structure model for the Atlantic yellowfin, and then to propose a modelling framework that could take into account the obvious east-west migrations of this species.

### II. A REVIEW OF YELLOWFIN EAST-WEST MIGRATIONS

Several parameters can be looked for.

#### 2.1. PURSE SEINE CPUE

Those cpue are limited to the eastern and western side of the Atlantic.

(a) Eastern Atlantic:

A review of those informations concerning juvenile yellowfin indicate only small scale and north south movements.

More interesting are the east-west apparent movements of adults, which are shown by the purse seine cpue of adults.

Those apparent East-West movements are suggested by the average cpue of large yellowfin by time and area strata (figure 1): the large yellowfin are first caught in the east (December and January) and show a seasonal apparent migration towards the western equatorial area where they disappear during April.

#### 2.2. LONGLINE CPUE AND CATCHES

It is clear that the longline fishing area are, on the yearly average, continuous from the eastern to the western side of the Atlantic (figure 2).

- A more detailed study of the seasonality of the cpue by areas was done, among other analysis, by Honma and Hisada 1971 in the early seventies and allowed their authors to propose a conceptual model describing the East-West migratory pattern of adults exploited by longliners (fig.3). This east-west migratory pattern of adult yellowfin is also well shown by the average time and area LL cpue (figure 4) which shows a maximum during the first quarter in the Gulf of Guinea and a maximum during the third quarter in the western Atlantic; those two alternate maxima can easily be interpreted as corresponding to an east-west migration of the adult stock, as it was concluded in 1971 by Honma and Hisada.

### 2.3. TAGGING AND RECOVERIES

In the eastern Atlantic, most of the tagging were conducted upon small and average yellowfin; those fishes were recovered during a limited period of time (less than 2 years) as shown by figure 5. All those tags were recovered in the eastern Atlantic, suggesting the existence of an eastern Atlantic isolated stock. None of those tags were recovered by longliners, suggesting, among other informations, some isolation between the yellowfin exploited by surface gears, and those exploited by longliners.

More recently, tagging has been conducted on adult yellowfin tunas in the western Atlantic by US sport fishermen. Those tagging have provided the first, but repeated, direct evidence for the west to east migration of adult yellowfin tunas (BARD and SCOTT 1991). The number of recoveries remains relatively small (10), but is probably very significant, because of the small number of yellowfin tagged and recovered. The constancy of those transatlantic recoveries, from one year to the other during a 3 years period, is also of major interest, because it indicates a seasonal migratory pattern.

### 2.4. CONCLUSION ON THE ATLANTIC YELLOWFIN STOCK STRUCTURE

All existing data presently available suggest that the two traditional hypothesis assuming, either two isolated stocks, or a single homogeneous stock, are both equally unrealistic. Instead, as it was concluded at the end of the yellowfin year program, a more complex "mixing model" assuming variable age specific migrations should be developed and used for the stock assessment and management of this resource. This conceptual migratory paradigm is shown in figure 6 (taken from the YYP report). The goal of this paper will be to develop a stock assessment method and to estimate its parameters which correspond well to this figure 6 describing a migratory concept, half way between the "one stock" or the "two stocks" hypothesis.

### III.A COMPARATIVE REVIEW OF SIZES TAKEN IN THE EASTERN AND WESTERN Atlantic

Capisano and Fonteneau 1991 (YYP report) recently conducted a detailed analysis of the monthly size structure of the yellowfin catches in the major fisheries.

This study concluded that there is some significant heterogeneity of monthly modal sizes :

- (1) between eastern and western Atlantic
- (2) within the different fishing areas of the western Atlantic

This heterogeneity is summarized in figure 7 and must be taken into account in modelling the stock structure.

Another important parameter to consider in the present analysis is the average catch by size taken from the two areas, east and west Atlantic. This result is shown in figure 8.

Major difference, are observed between the catch at sizes from the two areas :

. many very small yellowfin (less than 50 cm) are taken in the east Atlantic, but they are rare in the West Atlantic.

. yellowfin are taken at intermediate sizes in the east Atlantic, when they are dominant in the west.

. many very large yellowfin (more than 1.40 m) are taken in the east, and few in the west.

Those significant differences in the sizes taken are probably due to several combined factors, among others :

(1) the age specific catchability of the gears operating in each area.

(2) the age specific population size inhabiting each of the areas.

If it is assumed that the age specific catchability of each gear is constant from an area to the other, then it becomes possible to estimate the population sizes and the migrations from size or age specific cpue of the major gears.

This hypothesis of constant age specific catchability is unfortunately difficult to accept, because of the major oceanographical differences between the two areas. A major environmental difference is shown by the thermocline structure and depth in the two areas (figure 9).

- in the eastern Atlantic, the thermocline is shallow (20 to 50 meters) and marked (an average thermal gradient greater than 1°C per 10 meters depth)

- in the western Atlantic, the thermocline is deep (100 to 200 meters) and with a moderate thermal gradient (approximately 0.5°C per 10 meters).

It is therefore obvious that the age specific catchabilities of individual gears cannot be identical in those two areas.

However, the scarcity of large yellowfin in the west Atlantic can be reasonably interpreted as being due to their west to east migrations, shown indirectly by the cpue, and directly by the recent transatlantic recoveries. In that hypothesis, the scarcity of large yellowfin in the west could also be due to their eastward migration towards the Gulf of Guinea.

The scarcity of small yellowfin in the west can be interpreted as well under alternate hypothesis :

(1) small yellowfin are really rare in the west, most of the spawning and nurseries being located in the Gulf of Guinea

(2) small yellowfin are present at reasonably high levels in the west Atlantic (for instance similar to the eastern Atlantic nurseries), but not available because of the existing gear/fishing areas/oceanographical conditions.

Also, the bimodal structure of the catches at size in the eastern Atlantic, typical from this area, can easily be explained by a westward massive migration of the small yellowfin.

#### IV. A MIGRATORY MODEL

This set of hypothesis on yellowfin movements and a differential catchability between eastern and western Atlantic leads us to the conclusion that a migratory model should be used for the stock assessment of this stock.

A pending problem remains: the vertical depth structure and heterogeneity of the stock; FONTENEAU 1981 hypothesized a vertical heterogeneity between the adults exploited by surface gears and those exploited by longliners. This hypothesis was based on the yellowfin cpue trends in the early fishery and on some biological characteristics of the two groups of fishes. This vertical heterogeneity remains possible, but is difficult to take into account in the modelling, because of the various hypothetical parameters which are required to model it; this heterogeneity will consequently be rejected in the present study.

The mixing model used, will be the model described by FONTENEAU 1981 (see annex) in its simplest version of two fractions of yellowfin stocks, in the eastern and western Atlantic, exploited each one by two different gears, purse seine and longline.

This model requires a series of calculated and hypothetical parameters. Those parameters will be calculated or estimated by hypothesis as following :

(1) Recruitment by area: the total recruitment estimated by VPA will be assumed to be 90 % in the east and 10 % in the west.

(2) Age specific Migration rates :

As only 2 boxes are presently in use in the model, we need to hypothesize two vectors of age specific quarterly migration rates :

(a) from the eastern to the western compartment

(b) from the western to the eastern compartment

Those hypothetical migratory rates must be in agreement with the global hypothetical stock structure and with the catch at age in each area.

Those estimated rates used as working hypothesis are shown in the figure 10. Those rates estimated as a provisional working hypothesis can explain the catch at age by area of the present fisheries, as they have been tested through the simulation program under the present scheme of exploitation.

(3) M :

As previously hypothesized in most ICCAT works :

- 0.8 during the first 2 years
- 0.6 during the following 4 years

(4) Growth :

The growth curve previously used in the Eastern Atlantic by CAPISANO and FONTENEAU 1991(YYP report) has been used, for both parts of the Atlantic ocean, as well as the monthly

slicing method used by those authors to estimate catch at age from catch at sizes.

(5) Catch at size : the data were provided in march 1991 by ICCAT secretariat, but several problems are still pending in this data base which must be considered as provisional. This lack of finalized data has been a serious problem for any realistic final work.

(6) Age specific Fishing mortality

The method presently used is the following:

- First step has been to calculate the global fishing mortality applied on the total Atlantic yellowfin population

- Second step to calculate a local gear specific fishing mortality, exerted in each of the two areas.

The first one, global fishing mortality, is independent of the migration pattern for a given recruitment; the second one, local Fishing mortality, will vary following the recruitment patterns and migration rates used. In some case, the existing underlying populations at a given age, in an area, may be too small to explain the observed age specific catch at age. In such a case the migratory rates between areas must be modified in order to increase the local populations and allow the observed catches at age.

FIRST RUN: TOWARDS an EQUILIBRIUM

Those hypothetical parameters will be used during a preliminary run of 6 years of simulation at a rate of exploitation similar to the one observed for recent fisheries, which are limited for practical reasons to the two major fisheries, the PS and LL fisheries. At the end of this initial run, the local age specific fishing catchabilities are calculated and can be later assumed to be constant. Alternate migratory pattern can easily be introduced at this step in order to evaluate their agreement with fishery and tagging/recovery data

SECOND RUN: under known fixed age specific catchabilities by gear in each area, and under fixed migration patterns, PROJECTIONS are done to estimate the effects of changing fishing efforts or changing fishing patterns. The results concern the biomass per area, the fecundity of the stock and the catch rates of each individual gear.

#### V SOME PRELIMINARY RESULTS

##### 5.1-VPA

The first step of the analysis has been to conduct a VPA analysis on the total Atlantic catches. The catch at age table estimated on the provisional data base is given in table 1. The VPA were conducted under the hypothesis of a nearly

constant recruitment at a level corresponding to a full exploitation of the Atlantic stock. In order to choose this level, a table of average F calculated for each cohort under various levels of recruitments has been calculated (table 2). This result allows to estimate that an average level of 70 millions of fishes could well explain the observed catches (under the present hypothesis of M). This level of recruitment has been used for all cohorts, with the exception of the 1981 and 1983 cohorts which has shown higher catches, and which are estimated at 80 millions.

The global fishing mortalities calculated under those hypothesis are given in table 2. The age specific F by gear and area have also been calculated from this table. This result is shown by gear for the eastern, the western and the total Atlantic on the figure 11.

#### 5.2-FIRST RUN OF SIMULATION: EQUILIBRIUM FOR RECENT FISHERIES AND STOCK

The first step of the simulations is to rebuild the present status of fisheries: using the original assumptions of the VPA (global F, corresponding q, average recruitments), the migratory rates and the recent efforts of fisheries, the simulation allows easily to rebuild the catch at age table of each gear in each area, to calculate an equilibrium population by age and by area, and to calculate the corresponding local fishing mortalities, and the catchabilities of each gear in each area. This equilibrium biomass is given in figure 12. Of course the simulated fisheries are nearly identical to the real ones, which is the minimal result expected.....

#### 5.3-PROJECTIONS OF ALTERNATE FISHING PATTERN:

Using the same migratory scheme under which the catchabilities were calculated and those gear/age catchabilities as being constant parameters, the simulation model will allow easily to evaluate the transition and equilibrium consequences, on the catch, the catch rates and the underlying biomass, of any change of fishing efforts by gear and/or area, or the consequences of any recruitment variability.

Four simulations have been conducted with the following results:

(1) effort of purse seiners in the east with a 25% increase.

The short consequence is a 14% increase of purse seine eastern catches and a stable catch the same year in the west. The equilibrium effect is a 1.7% increase in eastern PS catches, but a 6 % decrease in the western catches.

(2) effort of purse seiners in the west is doubled.

The short consequence is a 85% increase of purse seine eastern catches and a stable catch the same year in the east. The equilibrium effect is a 70% increase in western PS catches, but a 10 % decrease in the eastern catches.

(3) effort of long liners in the west is multiplied by 2.

The short consequence is a 87% increase of Longline western catches, a 3% decrease of western PS catches, and a nearly stable catch the same year in the east. The equilibrium effect is a 70% increase in western LL catches, but a 9 % decrease in the eastern catches.

(4) a large year class, double of the average recruitment, is recruited in the eastern stock.

The effects of such a high recruitment provides 24% increase of catches after 3 and 4 years. Those positive effects appear earlier and remain longer in the east, because of the younger and older fishes exploited in the eastern area.

Those results cannot be interpreted as realistic previsions because of the various limitations in the available data and present hypothesis (Especially the high exploitation rate presently assumed). However, the geographical diffusion of the effects of local events -concerning the stock or the fisheries- is well shown by this type of analysis.

#### VI-CONCLUSION

The present simulation approach is obviously very preliminary because of several reasons, among others:

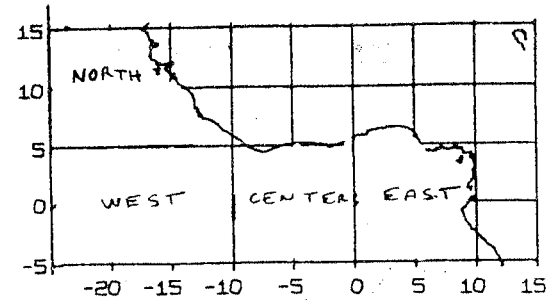
(1) the available data are still provisional.

(2) the migratory scheme should be better analyzed and estimated quantitatively.

(3) the fishing mortalities should be estimated more precisely.

However, the migratory nature of the yellowfin stock leads to the necessity to develop such models and to use them with improved parameters. It is obvious that the present model fits well, at least as a concept, to the hypothetical stock structure. This approach also allows to some VPA analysis which would be difficult for the western fraction of stock because tuning of the terminal F's will depend mostly of the spawning migratory patterns of adults toward the east. Furthermore the existing data available upon the Atlantic yellowfin are now enough detailed and complete to allow (potentially) the use of such models. This type of modelling is also the only one which can provide some realistic estimates of the potential interactions between fisheries operating in different areas. Another potential advantage of this approach would also be to take into account the vertical heterogeneity of the stock, assuming a low mixing between a surface and longline fractions of adult stocks. The results expected from this alternate improved stock assessment will probably be much more realistic than previous ones conducted under the traditional "One Stock" or "two stocks" hypothesis.

However, it is clear that further scientific work is still required in order to improve the data base, to estimate better the biological parameters (especially migratory patterns), to estimate better the fishing mortalities and to develop improved simulation models.



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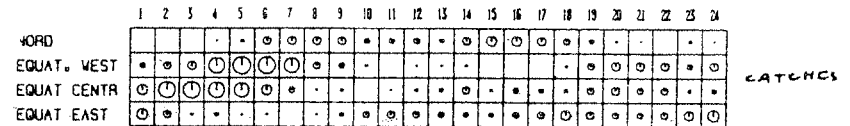
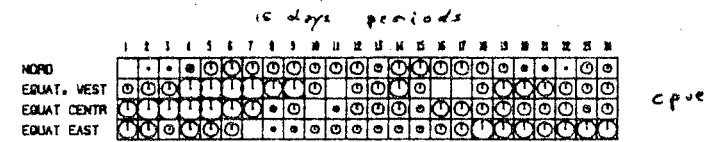


Figure 1 - Average catches and cpue of large yellowfin (more than 40 kg) by area for the french and spanish purse seiners combined in the eastern Atlantic by fishing zones (in tons per 10 fishing hours) (1970-1985)

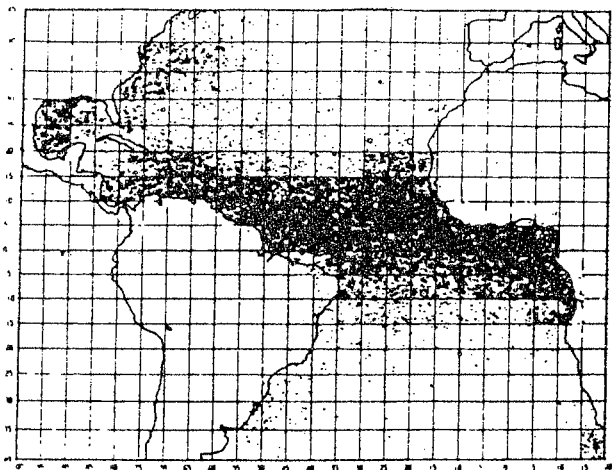


Figure 2 - Monthly spots of Japanese longliners, by 5 degrees west plotted randomly in each area, during the period 1956 to 1980.

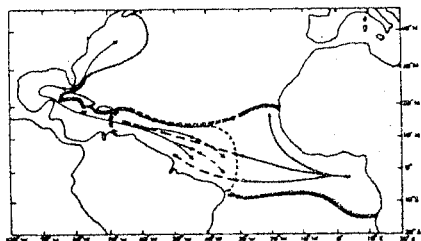
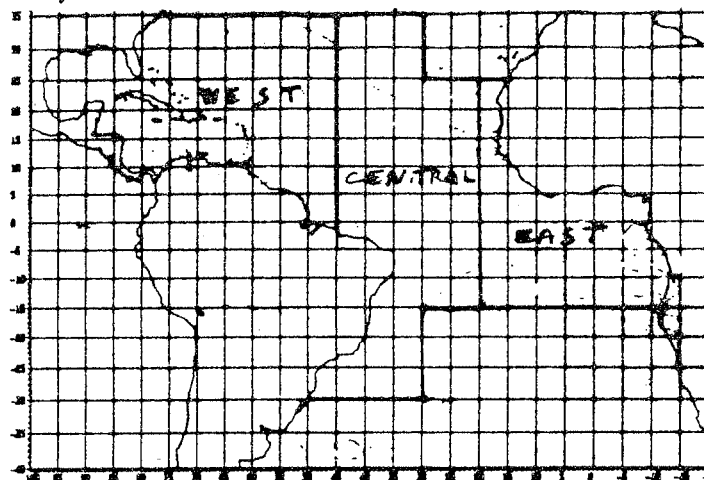
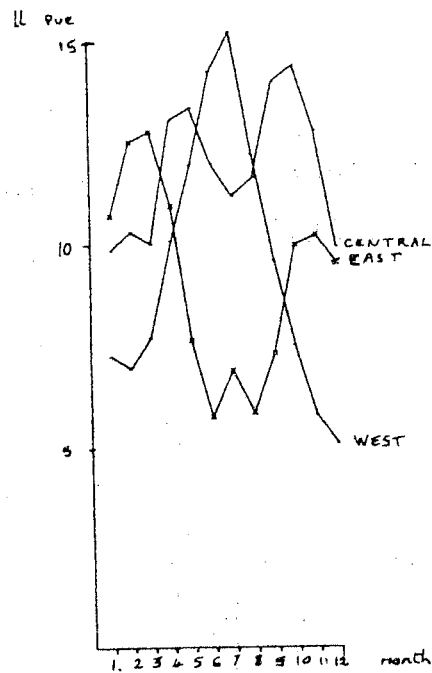


Fig. Schematic representation of migratory routes of adult yellowfin tuna deduced from catch statistics and length composition taken by longline fishery operated on the Atlantic Ocean.  
 - - - - - general distributional range of the eastern group.  
 - - - - - general distributional range of the western group.  
 - - - - - migratory routes of eastern group.  
 - - - - - possible migratory routes of eastern group.  
 - - - - - migratory routes of western group.  
 - - - - - possible migratory routes of western group.

( Honma and Hisada 1971 )



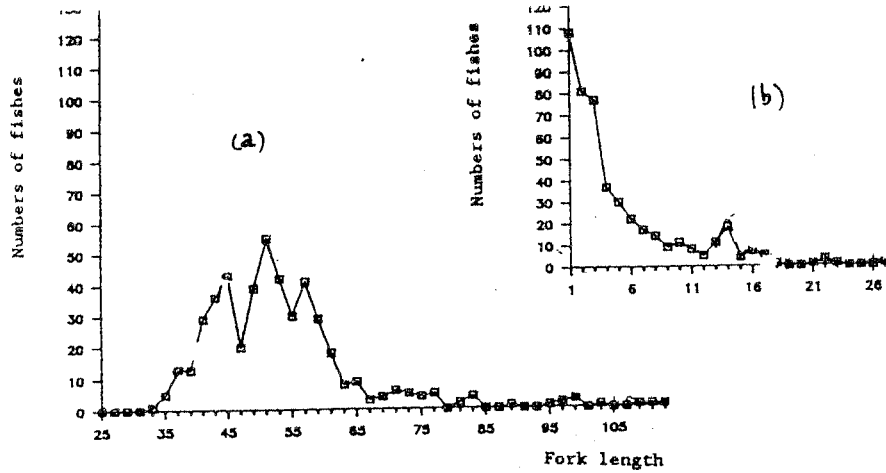


Figure 4 - Sizes of yellowfin tagged until 1986 in the Eastern Atlantic and duration of liberty for those recovered fishes. (a)

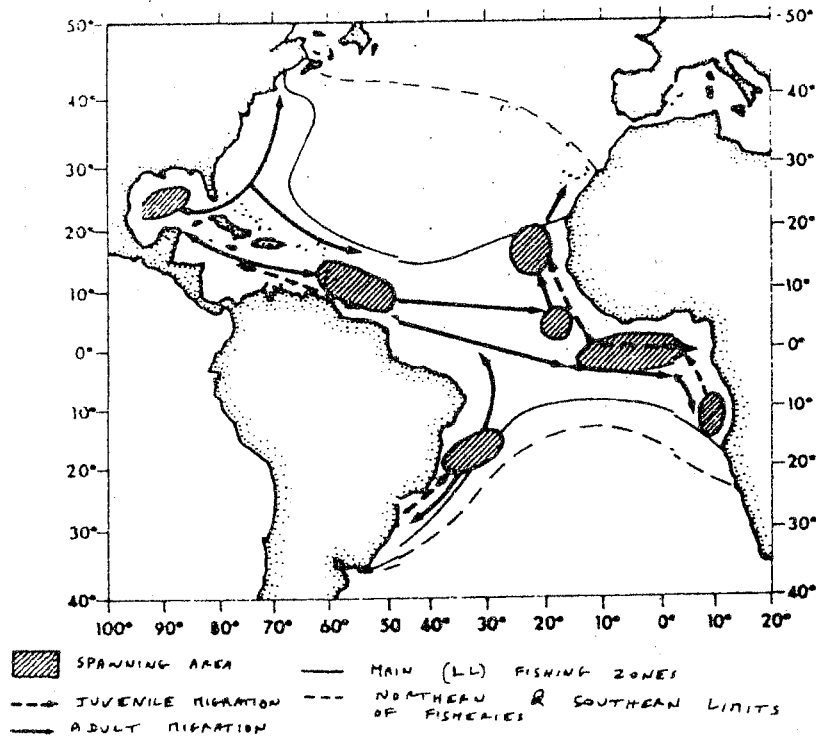


Figure 5 - Conceptual migration model built for yellowfin during the YYP program.

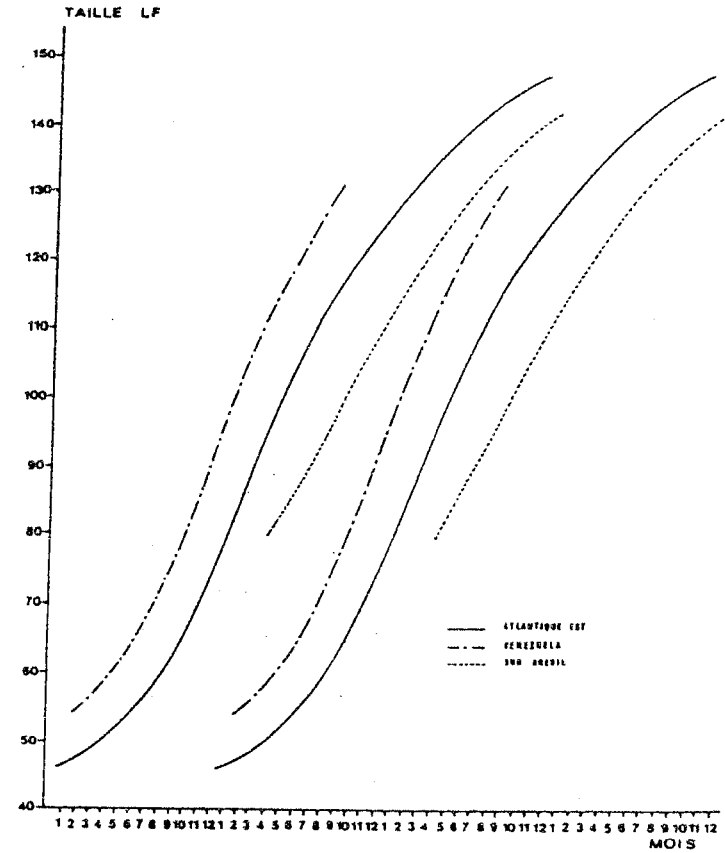


Figure 6 - Monthly average size distribution (modal sizes) taken by areas in the Atlantic (from Capisano and Fonteneau, YYP report).

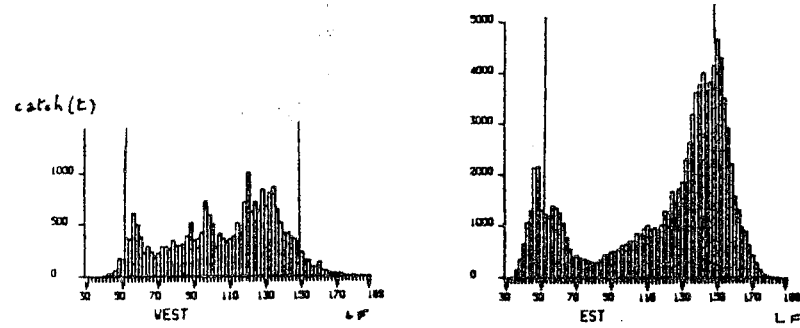


Figure 7 - Size distribution (in weight per 2 cm intervals) of the yellowfin taken in the eastern and in the western Atlantic (all gears).

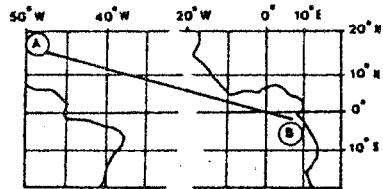
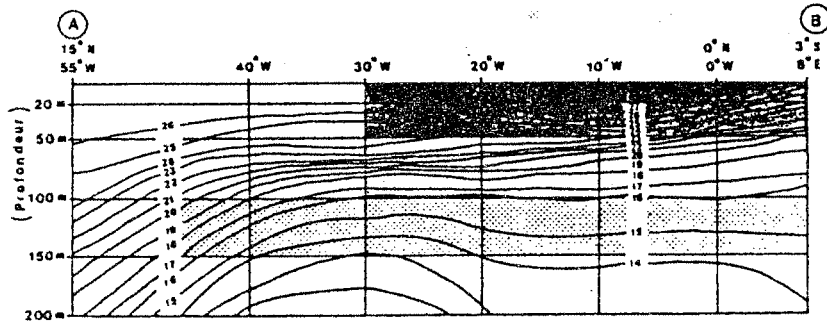


Figure 8 - Thermocline structure between 55° West/15° north and Cape Lopez area.

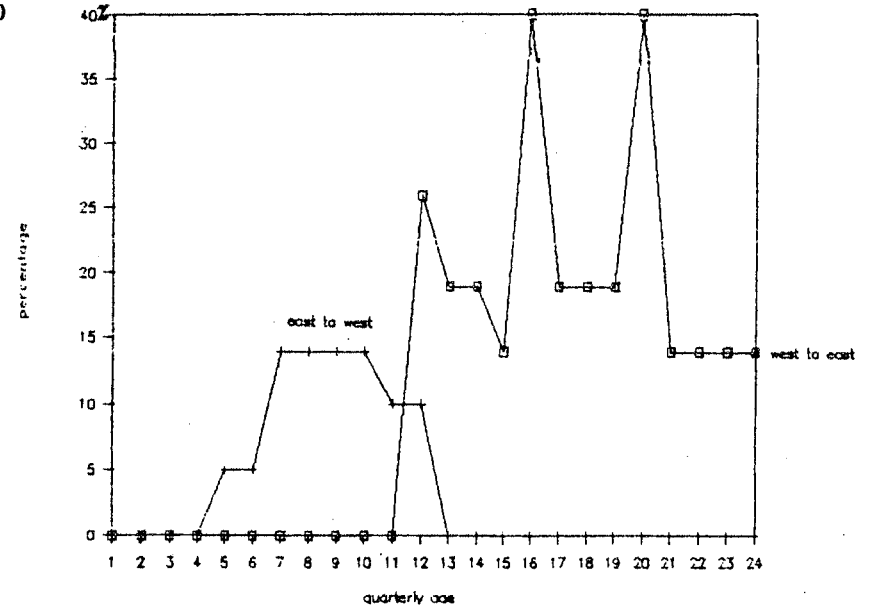


Figure 9 - Mixing rates used as working hypothesis; the percentage given show the fraction of the local population which migrate from an area to the adjacent one.

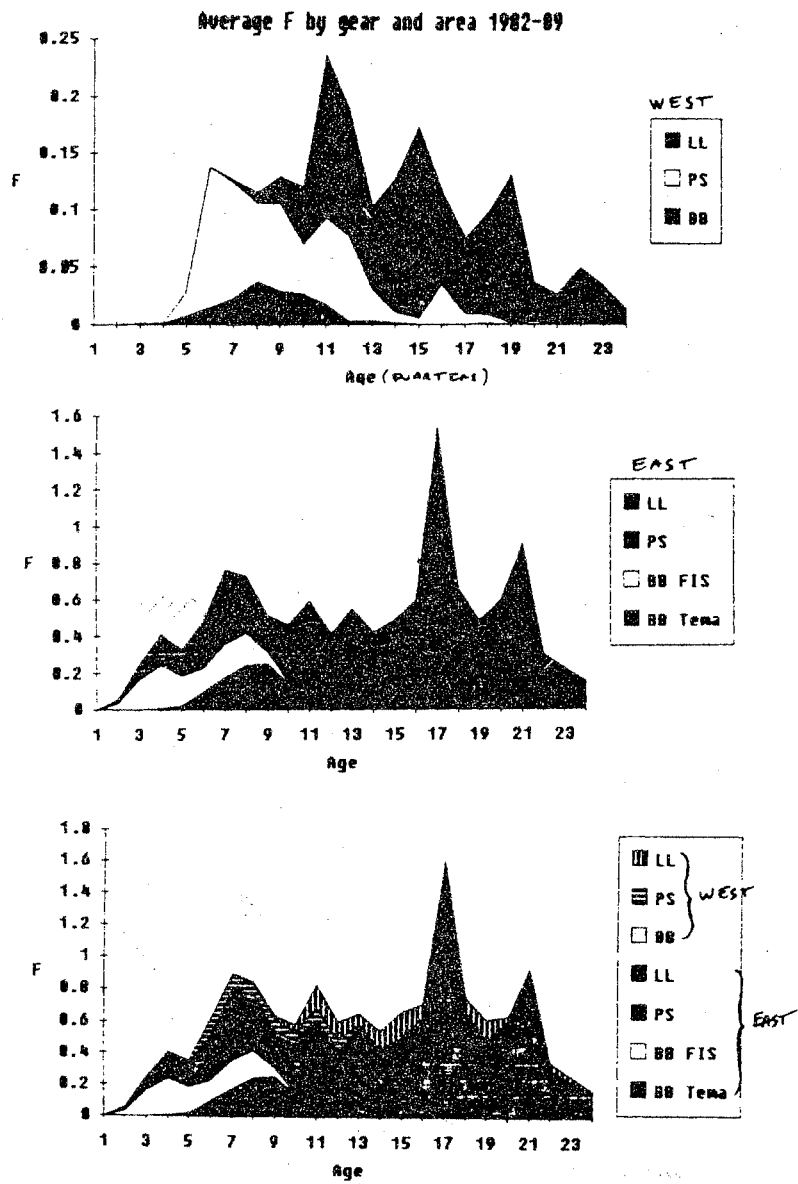


Figure 10: Global fishing mortalities by gear and area average level 1982-1989.

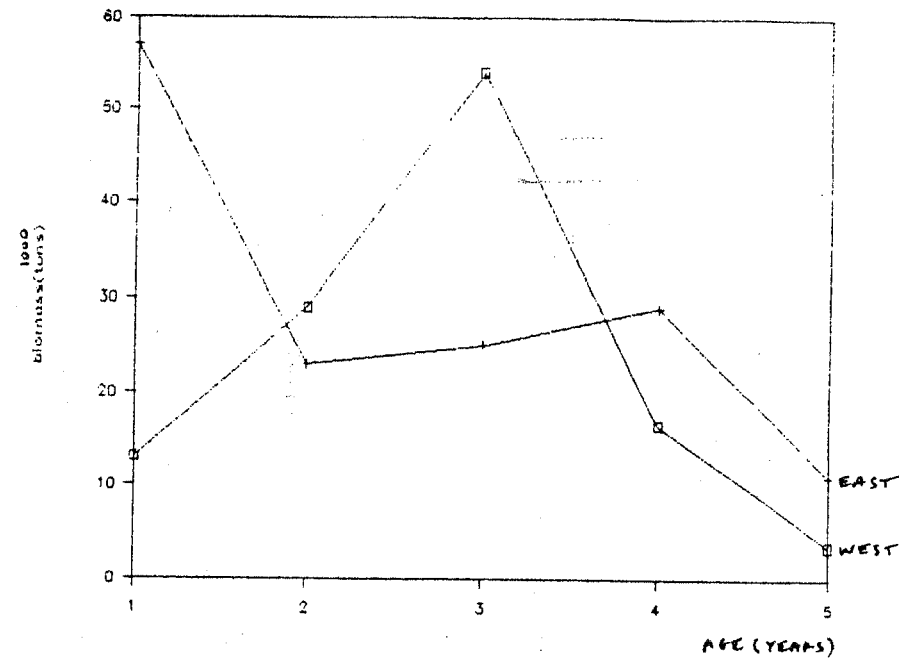
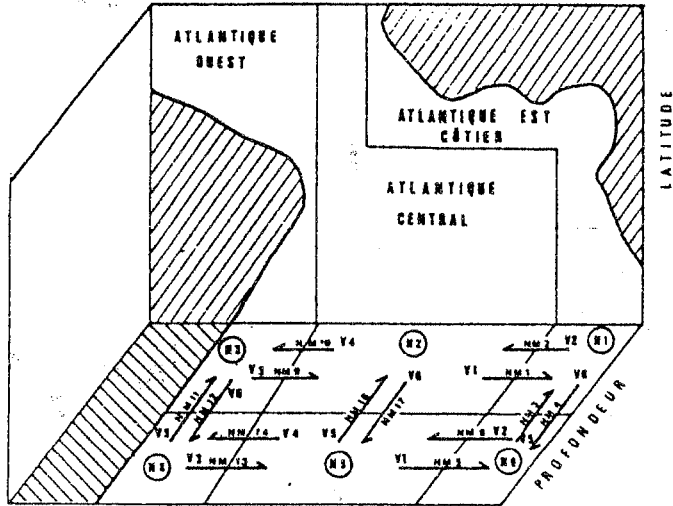


Figure 11: Age specific biomass in each of the 2 areas simulated under the present fishing patterns and present migratory scheme.

The analytical framework of the simulation model used (From FORTENEAU 1981)

1-Geographical and vertical units potentially used in the model



2-Quarterly changes in the underlying populations within each area strata under the exploitation by a multi gear fishery; the fishing takes place during the quarter; and the migration takes place instantaneously at the end of each quarter. The recruitment takes place once a year on the first of January.

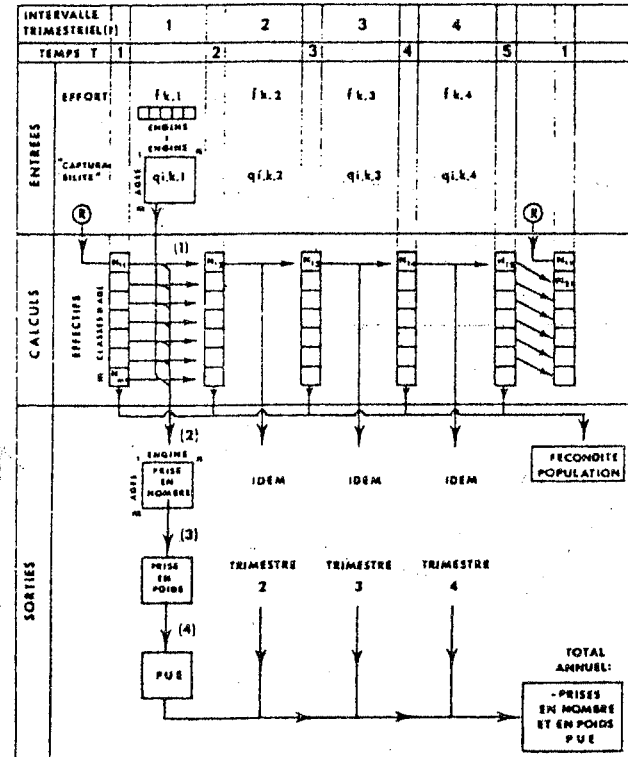


Table 2 - Average fishing mortalities between age 2 and 6 for the entire Atlantic stock under various level of recruitments.

	RECRUITMENT LEVELS (MILLIONS)														
	COHORT	BORN IN													
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
250 *	0.029	0.033	0.032	0.033	0.029	0.038	0.041	0.043	0.038	0.038	0.026	0.039	0.033	0.040	0.030
200 *	0.037	0.043	0.041	0.043	0.037	0.050	0.054	0.055	0.050	0.049	0.034	0.053	0.043	0.054	0.039
150 *	0.053	0.061	0.059	0.063	0.054	0.073	0.080	0.080	0.072	0.072	0.050	0.081	0.064	0.084	0.057
100 *	0.092	0.106	0.103	0.114	0.094	0.134	0.151	0.141	0.128	0.131	0.090	0.177	0.121	0.193	0.102
95 *	0.100	0.114	0.111	0.124	0.102	0.146	0.166	0.153	0.139	0.143	0.098	0.202	0.134	0.222	0.111
90 *	0.108	0.124	0.121	0.137	0.111	0.161	0.184	0.169	0.152	0.158	0.107	0.234	0.148	0.263	0.122
85 *	0.119	0.136	0.133	0.152	0.122	0.172	0.207	0.185	0.168	0.176	0.119	0.291	0.167	0.322	0.135
80 *	0.131	0.150	0.147	0.170	0.136	0.202	0.236	0.206	0.198	0.198	0.133	0.350	0.192	0.423	0.151
75 *	0.147	0.168	0.165	0.195	0.151	0.232	0.277	0.234	0.213	0.227	0.151	0.479	0.225	0.649	0.172
70 *	0.168	0.191	0.189	0.227	0.173	0.274	0.335	0.270	0.247	0.268	0.176	0.858	0.274		0.199
67 *	0.180	0.204	0.202	0.243	0.186	0.301	0.375	0.293	0.268	0.294	0.191		0.308		0.217
65 *	0.194	0.220	0.218	0.273	0.201	0.334	0.429	0.320	0.294	0.326	0.209		0.351		0.238
62 *	0.212	0.240	0.239	0.306	0.220	0.379	0.507	0.355	0.327	0.370	0.232		0.414		0.264
60 *	0.232	0.263	0.263	0.347	0.242	0.437	0.626	0.398	0.367	0.426	0.260		0.507		0.297
57 *	0.257	0.291	0.292	0.402	0.269	0.523	0.877	0.456	0.420	0.507	0.297		0.677		0.340
55 *	0.289	0.327	0.331	0.484	0.305	0.668		0.538	0.497	0.642	0.348		1.348		0.399
52 *	0.330	0.374	0.381	0.621	0.351	1.039		0.570	0.617	0.961	0.421				0.489
50 *	0.388	0.440	0.454	0.971	0.413			0.768	0.873		0.546				0.653
47 *	0.475	0.542	0.573		0.524						0.854				1.253
45 *	0.627	0.732	0.821		0.733										
42 *	1.119														

Table 1 - Catch at age estimated for the total Atlantic

YEAR	QUARTERLY					AGE																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
62	1	94	103	291	367	273	65	433	333	206	89	71	86	210	166	86	118	104	66	14	45	21	3	1
63	1	77	84	291	376	357	95	650	865	275	108	128	100	151	115	93	98	79	45	16	47	17	2	1
64	1	170	156	505	639	484	183	763	863	411	161	226	236	98	128	58	77	34	51	23	10	4	9	2
65	1	111	1	280	378	323	86	374	754	282	225	117	170	86	90	36	203	60	39	10	29	3	5	2
66	1	43	47	171	222	309	205	489	661	359	187	148	63	57	156	22	76	41	92	35	19	9	4	1
67	1	113	27	172	253	144	264	200	330	212	492	261	88	62	87	94	64	39	30	19	23	20	8	2
68	1	191	14	243	445	370	877	474	377	361	228	186	208	103	152	103	122	32	128	17	30	6	44	1
69	1	143	88	301	207	187	474	393	624	498	617	200	201	133	144	110	74	53	56	50	20	16	21	3
70	1	41	77	410	186	889	898	1099	124	164	241	109	162	180	147	38	81	55	92	18	40	11	25	4
71	1	96	329	497	399	386	1839	855	343	430	595	286	43	49	79	21	80	51	59	22	32	12	18	4
72	1	8	650	669	582	380	997	896	441	386	812	283	150	131	113	80	57	54	14	35	49	22	4	9
73	1	455	1447	725	583	787	1168	578	365	296	417	173	160	153	146	76	89	83	29	34	50	16	6	8
74	1	67	611	2474	829	985	941	1015	233	411	610	188	95	135	166	93	113	52	44	39	62	19	10	7
75	1	32	213	419	943	487	727	646	436	294	643	313	178	92	134	154	213	93	79	47	105	31	21	18
76	1	24	1120	998	938	487	1576	1140	545	229	416	144	164	236	174	138	133	198	58	63	77	51	15	15
77	1	27	331	466	951	572	1432	891	257	584	546	337	131	224	170	128	226	109	64	53	79	26	20	9
78	1	59	623	554	743	905	1217	481	553	514	645	285	256	221	202	215	203	47	39	50	41	15	5	6
79	1	14	316	623	617	847	1537	484	293	261	432	216	172	170	170	251	225	123	47	63	46	24	13	5
80	1	59	899	1395	1185	843	1619	860	395	340	417	280	152	141	209	213	159	71	96	107	38	12	21	14
81	1	908	1870	3141	1243	1415	1254	882	626	420	360	250	239	123	170	116	334	162	30	47	98	37	18	11
82	2	187	797	1995	2211	2372	1452	1023	377	401	475	299	332	204	189	197	301	163	49	46	91	47	9	6
83	12	561	1297	2479	1409	3195	889	753	484	378	719	439	238	170	203	145	413	75	74	39	110	23	15	6
84	14	192	1065	949	1206	2517	2929	1857	682	255	362	314	188	114	114	72	87	34	41	16	24	6	6	2
85	3	496	1411	1606	340	1716	1827	1050	322	665	523	288	331	134	96	141	456	76	34	52	71	7	6	3
86	12	332	931	1752	1345	1223	1500	674	210	218	312	198	397	152	159	224	276	52	43	66	75	7	7	7
87	3	335	2629	2120	990	685	1468	1178	466	374	320	240	225	102	129	142	315	72	37	46	49	7	5	4
88	5	181	1627	2222	1767	1278	1450	719	407	224	216	207	390	206	144	98	229	78	34	15	41	13	4	1
89	13	834	1764	2239	1361	1262	1019	720	444	241	275	159	416	133	194	148	535	47	91	45	106	17	11	8

Table 3 - Quarterly global fishing mortalities estimated for the entire Atlantic stock.

YEAR	AGE	REC	QUARTERLY																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
62	700531	0.000	0.007	0.010	0.034	0.052	0.049	0.014	0.116	0.109	0.080	0.041	0.038	0.055	0.162	0.154	0.096	0.150	0.166	0.127	0.032	0.129	0.072	0.012	0.005	
63	700531	0.000	0.004	0.009	0.034	0.054	0.063	0.021	0.179	0.251	0.113	0.053	0.074	0.063	0.114	0.103	0.100	0.117	0.126	0.086	0.036	0.127	0.055	0.008	0.004	
64	700531	0.000	0.013	0.014	0.059	0.092	0.087	0.041	0.214	0.299	0.175	0.063	0.139	0.163	0.081	0.126	0.068	0.093	0.051	0.091	0.049	0.026	0.032	0.032	0.008	
65	700531	0.000	0.000	0.000	0.032	0.055	0.058	0.019	0.158	0.267	0.122	0.117	0.072	0.125	0.075	0.094	0.044	0.299	0.104	0.081	0.073	0.072	0.009	0.017	0.002	
66	700531	0.000	0.003	0.004	0.028	0.032	0.054	0.044	0.132	0.227	0.151	0.094	0.099	0.046	0.049	0.159	0.027	0.111	0.071	0.191	0.044	0.055	0.031	0.016	0.005	
67	700531	0.000	0.009	0.003	0.028	0.036	0.025	0.061	0.053	0.110	0.084	0.231	0.152	0.062	0.035	0.085	0.110	0.091	0.060	0.060	0.045	0.068	0.070	0.033	0.010	
68	700531	0.000	0.015	0.001	0.028	0.063	0.065	0.195	0.135	0.123	0.141	0.107	0.104	0.146	0.087	0.153	0.125	0.171	0.054	0.259	0.042	0.083	0.020	0.171	0.005	
69	700531	0.000	0.011	0.008	0.035	0.029	0.029	0.167	0.107	0.221	0.216	0.333	0.133	0.134	0.106	0.138	0.127	0.197	0.100	0.116	0.124	0.058	0.054	0.044	0.014	
70	700531	0.000	0.003	0.007	0.047	0.027	0.119	0.186	0.321	0.041	0.064	0.111	0.060	0.129	0.173	0.172	0.053	0.112	0.090	0.181	0.042	0.118	0.039	0.104	0.020	
71	700531	0.000	0.007	0.031	0.059	0.057	0.053	0.277	0.252	0.127	0.192	0.329	0.196	0.028	0.037	0.070	0.022	0.133	0.101	0.140	0.042	0.089	0.039	0.070	0.018	
72	700531	0.000	0.001	0.067	0.079	0.084	0.101	0.230	0.289	0.163	0.173	0.457	0.201	0.125	0.130	0.135	0.115	0.070	0.079	0.024	0.070	0.165	0.099	0.019	0.051	
73	700531	0.000	0.035	0.140	0.088	0.086	0.130	0.276	0.177	0.139	0.138	0.229	0.115	0.130	0.159	0.184	0.115	0.153	0.173	0.072	0.101	0.120	0.051	0.020	0.031	
74	700531	0.000	0.005	0.054	0.294	0.126	0.190	0.234	0.331	0.088	0.188	0.343	0.130	0.075	0.129	0.190	0.129	0.209	0.116	0.117	0.121	0.222	0.092	0.051	0.042	
75	700531	0.000	0.002	0.087	0.073	0.147	0.056	0.181	0.206	0.181	0.147	0.401	0.246	0.148	0.092	0.160	0.225	0.373	0.210	0.207	0.291	0.415	0.153	0.125	0.128	
76	700531	0.000	0.002	0.107	0.119	0.079	0.086	0.374	0.363	0.210	0.111	0.247	0.103	0.158	0.278	0.255	0.250	0.239	0.426	0.165	0.219	0.311	0.257	0.042	0.109	
77	700531	0.000	0.002	0.031	0.054	0.144	0.109	0.352	0.290	0.103	0.286	0.336	0.260	0.112	0.232	0.216	0.199	0.523	0.326	0.239	0.244	0.340	0.106	0.127	0.068	
78	700531	0.000	0.005	0.059	0.065	0.109	0.186	0.288	0.147	0.229	0.263	0.418	0.233	0.244	0.261	0.297	0.401	0.395	0.212	0.115	0.214	0.233	0.103	0.041	0.057	
79	700531	0.000	0.003	0.030	0.073	0.090	0.156	0.389	0.190	0.187	0.117	0.236	0.144	0.172	0.207	0.254	0.478	0.548	0.192	0.197	0.310	0.271	0.127	0.042	0.037	
80	700531	0.000	0.005	0.045	0.166	0.174	0.182	0.397	0.280	0.156	0.161	0.241	0.199	0.172	0.135	0.244	0.310	0.471	0.224	0.390	0.552	0.233	0.099	0.147	0.151	
81	900771	0.000	0.062	0.159	0.147	0.193	0.280	0.327	0.304	0.280	0.215	0.227	0.193	0.208	0.130	0.327	0.181	0.745	0.419	0.236	0.191	0.095	0.142	0.207	0.154	
82	700541	0.000	0.014	0.075	0.241	0.125	0.470	0.444	0.376	0.165	0.213	0.315	0.244	0.317	0.242	0.265	0.364	0.600	0.444	0.162	0.195	0.456	0.104	0.072	0.057	
83	700061	0.001	0.018	0.107	0.267	0.220	0.481	0.261	0.289	0.229	0.232	0.535	0.428	0.242	0.212	0.315	0.281	1.069	0.265	0.325	0.154	0.564	0.150	0.118	0.056	
84	700031	0.001	0.015	0.102	0.114	0.164	0.461	0.762	0.710	0.338	0.156	0.272	0.294	0.231	0.172	0.209	0.161	0.203	0.093	0.142	0.059	0.154	0.047	0.055	0.022	
85	700171	0.000	0.034	0.136	0.127	0.041	0.331	0.475	0.371	0.164	0.424	0.431	0.302	0.392	0.199	0.173	0.314	1.421	0.348	0.194	0.159	0.154	0.041	0.044	0.076	
86	700041	0.001	0.026	0.089	0.213	0.213	0.250	0.407	0.355	0.094	0.116	0.201	0.155	0.537	0.265	0.347	0.641	0.821	0.205	0.207	0.198	0.706	0.045	0.101	0.120	
87	700171	0.000	0.024	0.257	0.270	0.154	0.134	0.375	0.405	0.218	0.191	0.224	0.206	0.214	0.118	0.180	0.242	1.134	0.445	0.272	0.451	0.379	0.067	0.056	0.053	
88	700001	0.000	0.030	0.157	0.277	0.295	0.320	0.426	0.280	0.180	0.121	0.139	0.160	0.419	0.281	0.244	0.204	0.437	0.215	0.114	0.051	0.343	0.221	0.042	0.024	
89	700041	0.001	0.065	0.173	0.249	0.220	0.265	0.280	0.258	0.220	0.170	0.202	0.142	0.399	0.159	0.285	0.271	1.506	0.393	0.473	0.498	0.516	0.106	0.042	0.070	