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ESTIMATES OF INCIDENTAL CATCHES OF BILLFISHES TAKEN BY THE EUROPEAN TUNA PURSE SEINE FISHERY IN THE ATLANTIC OCEAN (1991-2000).

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SUMMARY

Billfishes are not targeted by tuna purse seiners, but they can be taken incidentally during the setting operation. Because by-catch information is not recorded in the commercial logbooks, it is important to quantify by-catches taken by the purse seine fishery in the Atlantic Ocean. In this paper, we attempted to estimate the total by-catch of billfishes generated by the European tropical tuna purse seine fishery in the eastern Atlantic Ocean from 1991 to 2000. Information on the by-catch of billfish was collected by scientific observers at sea during the European Union Bigeye Program. A Monte Carlo simulation was performed to account for some uncertainties in the changes over time of the fishing strategies adopted by the purse seine fishermen operating in this ocean. This study indicates that the temporary moratorium on fishing with FADs adopted by the European purse seiners, combined with a decrease in the number of fishing operations, produced a substantial decrease in incidental catches of marlins from 450 - 520t/year to less than 300t/year. For the sailfishes, the by-catch was very low (between 40t and 70t per year).

RÉSUMÉ

Les istiophoridés ne sont pas visés par les senneurs, mais ils peuvent être capturés accidentellement lors des opérations de pêche. Comme l'information sur les prises accessoires n'est pas consignée dans les livres de pêche commerciaux, il est important de quantifier les prises accessoires réalisées par les senneurs dans l'océan Atlantique. Dans le présent document, nous avons tenté d'estimer le volume total des prises accessoires d'istiophoridés effectuées par la pêcherie tropicale européenne de senneurs thoniers qui ont opéré dans l'Atlantique est de 1991 à 2000. L'information sur les prises accessoires d'istiophoridés a été recueillie en mer par des observateurs scientifiques au cours du programme sur le Thon obèse de l'Union européenne. Une simulation Monte Carlo a été réalisée pour tenir compte de certaines incertitudes dans les changements intervenus au fil des ans dans les stratégies de pêche adoptées par les senneurs qui opèrent dans cet océan. La présente étude indique que le moratoire temporaire à la pêche avec DCP adopté par les senneurs européens, associé à une diminution du nombre d'opérations de pêche, a entraîné une baisse considérable des prises accessoires de makaires, qui ont été ramenées de 450-520 t/an à moins de 300 t/an. Pour les voiliers, les prises accessoires étaient très faibles (entre 40 t et 70 t/an).

RESUMEN

Los peces de pico no son la especie objetivo de los cerqueros atuneros, pero pueden ser capturados de forma fortuita durante la operación de lance. Dado que la información sobre capturas fortuitas no se registra en los cuadernos de pesca comerciales, es importante que se cuantifiquen las capturas fortuitas de la pesquería de palangre en el océano Atlántico. En este documento, intentamos realizar una estimación de la captura fortuita total de peces de pico de la pesquería europea de cerco de túnidos tropicales en el océano Pacífico oriental desde 1991

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hasta 2000. La información sobre la captura fortuita de peces de pico fue recopilada por observadores científicos en el mar durante el Programa de Patudo de la Unión Europea. Se realizó un simulación Monte Carlo para considerar algunas incertidumbres en los cambios de las estrategias de pesca adoptadas por los pescadores de cerco que operan en este océano que se han producido en el tiempo. Este estudio indica que la moratoria temporal para la pesca sobre DCPs adoptada por los cerqueros europeos, combinada con un descenso en el número de operaciones pesqueras produjo un descenso sustancial de las capturas fortuitas de marlines desde 450-520 t/año hasta menos de 300 t/año. Para los peces vela, la captura fortuita fue muy escasa (entre 40 y 70 t por año).

KEY WORDS

Billfishes, by-catch, purse seining, catch statistics, simulation, ecosystem management

1. INTRODUCTION

Despite recommendations made by fishery agencies, such as ICCAT, information on discards and on by-catches is rarely reported by skippers in their commercial logbooks. As a consequence, the level of catches of billfishes taken incidentally by the tropical tuna purse seine fishery is not well-known. In contrast to the recreational fishery, or to some specific small-scale fisheries, billfishes are not targeted by purse seiners but they can be taken incidentally during the setting operation and sold in the local African market fish (Romany *et al.*, 2000). The aim of this study was to quantify the by-catch of billfishes taken by the European purse seiners (i.e., Spain, France and EU NEI) in the Eastern Atlantic Ocean. Because by-catch information is not recorded in the commercial logbooks, we used observations collected by scientific observers aboard purse seiners during the European Union Bigeye Program (Ariz and Gaertner, 1999).

2. MATERIALS AND METHODS

2.1 Data

With a total of 62 observers' trips (44 for the Spanish fleet and 18 for the French fleet) this project is the biggest observer program ever carried out in the European tuna purse seine fishery (a total of 2706 fishing days, corresponding approximately to a coverage rate of 15%). The observers' trips were conducted opportunistically between June 1997 and May 1999, with a break during the second moratorium on the FADs fishing operations (from November 1998 to January 1999 inclusive). The catch of commercial tunas reached 34,693t whereas discards (composed mainly of small tuna species or of juveniles of commercial tuna species) have been estimated at about 737t and total by-catch (billfishes, sharks, other fish, etc) at about 762t (Ariz and Gaertner, 1999).

Because the European Union Bigeye Program was focused on the study of the increase in catch of bigeye (*Thunnus obesus*), the billfish species may not have been correctly identified. For this reason we established groups including the blue marlin (*Makaira nigricans*) and the white marlin (*Tetrapterus albidus*) in one and the sailfishes (*Istiophorus albicans*) and the longbill spearfish (*T. pfluegeri*) in the second.

Based on the ecological provinces in the oceans established by Longhurst (1998), the Eastern tropical Atlantic Ocean (from 25°N to 15°S and from 35°W to the African coasts) was stratified by quarters in two areas:

- the Senegalese area (from latitude 12°N to 25° N),

- the remaining areas, termed as “equatorial” areas.

On the basis of a study made on tuna size classes by set type in this fishery (Pallares and Petit, 1998), the sets made on whales and on whale-sharks were classified as non-associated sets (i.e. school sets) and as FAD sets, respectively. In contrast, we distinguished the sets made on seamounts from the usual tuna fishing modes (i.e., non-associated school sets and FAD sets). Because seamount sets may not always be recorded in the commercial logbooks sets located within a square of 6 miles side, centered on a seamount, were considered as a seamount set (even if it has been previously reported as a non-associated school set or as a log set).

3. METHODS

We used the same methodology described in detail by Gaertner *et al.* (in process). Basically, we considered that the period of 12 months, between October 1997 and September 1998, was representative for the observer program (approximately 66 % of the total purse seine tuna catch is taken by the European purse seiners during this period). Thus, the total by-catch of each group of billfishes was estimated for this standard year. Assuming that billfish by-catch was proportional to the tuna catch, the observed by-catch for each billfish group was raised to the total European purse seine catch with the use of a raising factor RF_{sijk} as in the following equation :

$$TBC_s = \sum_k \sum_j \sum_i RF_{sijk} \; BC_{sijk} \; ,$$

where TBC_s = Total by-catch for the group s during a standard year,
RF_{sijk} = Total purse seine tuna catch $_{ijk}$ / Observed aboard purse seine tuna catch $_{ijk}$
BC_{sijk} = By-catch for the group s, in area i, quarter j and fishing mode k.
and: i = 1,2 ; j = 1,2,3,4 ; k = non-associated set, FAD set, set on seamount.

However, uncertainty in the calculation of the billfish by-catch can be caused by (1) changes in fishing strategies adopted by the fishermen over the year, e.g. change in the probability of choosing the fishing mode k, (2) the occurrence of each billfish species by fishing mode, e.g. the conditional probability for a given group of billfish s to be present in a set of type k, as well as the probability of obtaining x tons of group s in the set.

To account for some of these uncertainties we used computer-intensive methods, such as a Monte Carlo simulation. In the present analysis, the model mimics the fishing operations made by the purse seiners over a standard year **(Figure 1)**. That means that we take into account the probability of setting on the fishing mode k, and the conditional probability that group s is present in this type of set **(Table 1)**. For each group s, the simulated input (i.e., the by-catch generated by one set) is drawn from the observed distribution of the by-catch by set for the fishing mode k. Notice that the calculation of the total by-catch is based on the proportion of total sets (including those made on trips without observers at sea) recorded in commercial logbooks in each strata by fishing mode. That means that the observed by-catch in each set was previously raised by the corresponding raising factor: RF_{ijk}. A single set is then generated by randomly selecting inputs from the distributions of by-catch per set. This is repeated 1272 times (the total number of sets reported by observers aboard) to give the total by-catch of group s during the standard year. 500 Monte Carlo simulations were generated to determine the amount of variation expected in the yearly by-catch estimates. Confidence limits (0.025 and 0.975) for total by-catch by group were performed by the percentile method.

4. RESULTS

Table 2 shows the estimated by-catch of billfishes taken by type of fishing mode during a standard year. The results indicate that 245t marlin and 42t sailfishes were taken as by-catch by the European purse seiners in the Eastern Atlantic Ocean. Changes in fishing strategies over the 1990s are represented in **Table 3**. The proportion of FADs sets increased from the beginning of the nineties to 1996 (with a maximum at 50.1 %). Due to the moratorium on FADs fishing adopted by the French and the Spanish tuna purse seiner companies in the Eastern Atlantic Ocean in 1997, this percentage decreased progressively. This temporary ban was adopted over a large area from the African coast to 20°W and from 5°N to 4°S, between November 1 and January 31, in 1997-98 and in 1998-99 respectively. Notice that the percentage of seamount sets remained very low (less than 1%) over the years. During the period considered the total number of sets and, as a consequence, the total of tuna catch decreased.

Theses changes in fishing modes over the years were taken into account in the Monte Carlo simulation. However, we used the same conditional probability about the presence of each billfish group by fishing mode **(Table 1)**, as well as for the observed distribution of the by-catch per set by fishing mode. In order to obtain the total by-catch of billfishes, the ratio of the billfish by-catch per tons of tunas (obtained from the simulation) was raised to the total tuna catch taken by the European purse seine fishery **(Table 4)**. Introducing some elements of uncertainty in the inputs highlighted the large variability of the by-catch estimates (see the values obtained for the lower and upper C.I; **Table 4**). However, even including uncertainty in the inputs, these values remain very low compared with by-catches reported from other fisheries. The simulated by-catch of marlin generated by the European fleets increased from 450t in 1991 to 530t in 1995, then decreased to 288t in 2000 **(Figure 2)**. This pattern reflects the decrease in fishing activities of the purse seine fishery, as mentioned above, but also the effect caused by the moratorium on FADs fishing. For instance, assuming a constant level of tuna catch, a comparative analysis conducted between 1996 (when FADs sets reached a maximum at 50.1 %) and 1998 (with only 31.38 % of FADs sets) leads to the conclusion that the simulated ratio of the billfish by-catch per tons of tunas decreases by 31% (from 2.63 E-03 to 1.82 E-03, respectively). This result is a consequence of the larger association of marlins with floating objects than with non-associated schools. In looking at **Table 1**, we can see that the occurrence of marlin was around 35% for FAD fishing operations compared to only 4% in school sets. Marlin were also present in 25% of the seamount sets but with such a small quantity of sets made on seamounts that there was no apparent effect on the change of the total by-catch of this group. Sailfishes were more commonly observed in non-associated sets than in FAD sets **(Table 1)**. Thus, it appears that the by-catch of sailfish remained low and relatively stable in the 1990s **(Figure 3)**.

5. DISCUSSION

A purse seine fishery cannot be assessed purely in terms of the tuna catch. In the Eastern Atlantic Ocean, it can be assumed that the large catches of tunas taken by the purse seiners (around 200,000t by year in the last decade; **Table 4**) affect the abundance of billfishes (1) directly, by generating by-catch and (2) indirectly, by increasing or decreasing the abundance of predators or competitors thereby changing in the food webs of the ecosystem. The by-catch of Istiophoridae represents less than 0.021% of the total tuna catch and less than 10% of the total catches of billfishes currently reported (assumed to fluctuate around 7,000-8,000t per year), suggesting that the direct impact of the purse seine fishery on these stocks is rather weak. Our analysis suggests that the moratorium led to a decrease in incidental catch of marlin by the European purse seiners from 450-520t/year to less than 300t/year. Based on the simulated ratio of the billfish by-catch per tons of tunas obtained from the European fleets **(Table 5)** the total by-catch for the entire purse seine fishery could be estimated (bearing in mind that the purse seiners based in Ghana have not the same fishing strategy than the EU fleet). It could be argued that this method leads only to a partial exploration of the uncertainty because we assumed that spatial and temporal effects did not affect these latter probabilities and the by-catch per set distribution. In this analysis, the relative low number of samples in some strata made it impossible to account for the uncertainty within area and quarter strata (excepted for the raising factor: RF_{ijk}). However, it would be interesting to consider this source of uncertainty in the future. Consequently, the potential for possible regulations at different spatial and temporal scales needs further exploration.

Large by-catch of billfishes could affect the food web of the epipelagic ecosystem inhabited by other apex predators. However objectively measuring an ecological risk, when it concerns unexploited components of the ecosystem, remains a vague concept. In addition, decision makers need to evaluate management options that are both scientifically credible and economically practical regarding the use of the ecosystems. Because billfishes are sold on the local African fish market (Romany *et al*, 2000), the effects of the fishing on the ecological processes as well as on human activities must be evaluated.

6. CONCLUSION

This study examined the by-catch taken by the European tuna purse seine fishery in the Eastern Atlantic Ocean. The main conclusion of this paper is that the direct impact of the purse seine fishery on the billfish component of the epipelagic ecosystem is weak. Results of this study provide additional information on the effect of the moratorium on FAD fishing. Although some caution is required at this stage, due to limitations of the spatial and temporal sampling coverage, it was found that the ban on FAD fishing operations led to a substantial decrease of marlin by-catch.

7. ACKNOWLEDGMENTS

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Table 1. Observed conditional probabilities that a specific group of billfish *s* is associated with a specific fishing mode (information obtained from data collected by scientific observers at sea during the European Union Bigeye Program). These values have been used to perform the Monte Carlo simulation.

Fishing mode	Number of observed sets	Prob. { s present | k }	
		Marlins	Sailfishes
FAD sets	373	0.3539	0.0134
School sets	859	0.0408	0.1036
Seamount sets	40	0.2500	0.0750

Table 2. Estimated by-catches of billfishes (t) and observed commercial tuna catches (t) taken by fishing modes by the European purse seiners in the Eastern Atlantic Ocean for a standard year (October 1997 -September 1998).

Fishing mode	Marlins (t)	Sailfish (t)	Tuna catches (t)
FAD sets	200.8	7.6	49,214
School sets	42.8	34.7	88,456
Seamount sets	1.5	0.1	1,285
Total	245.1	42.4	138,955

Table 3 Changes in tuna catches (t), in total number of sets and in proportion of fishing modes for the European purse seiners in the Eastern Atlantic Ocean from 1991 to 2000.

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tuna catch(t)	241 812	210 725	249 635	229 390	211 604	195 466	147 284	145 906	154 887	152 101
Total sets	10 585	8 969	9 802	9 360	10 016	9 510	7 037	7 520	6 323	6 195
P (non ass.)	0.6589	0.6380	0.6608	0.6257	0.5228	0.4906	0.5826	0.6797	0.6753	0.6644
P (FADs)	0.3255	0.3512	0.3350	0.3693	0.4731	0.5010	0.4125	0.3138	0.3182	0.3318
P (seamount)	0.0156	0.0108	0.0042	0.0050	0.0041	0.0084	0.0050	0.0065	0.0065	0.0039

Table 4. Estimates of the total by-catch (t) taken by the French, Spanish and NEI purse seine fishery in the Eastern Atlantic Ocean based on the results of the Monte Carlo simulation (see text).

		Marlins			Sailfishes		
Year	Tot. tunas catch (t)	Estim. By -catch (t)	L.C.I. 0.025	U.C.I. 0.975	Estim. By -catch (t)	L.C.I. 0.025	U.C.I. 0.975
1991	241,812	448.71	371.31	527.72	67.52	41.63	98.49
1992	210,725	415.00	339.75	485.64	58.63	37.53	85.74
1993	249,635	473.80	394.16	558.56	70.27	45.63	106.36
1994	229,390	472.84	387.47	551.32	64.18	39.54	96.63
1995	211,604	529.73	451.79	607.59	54.87	31.85	82.55
1996	195,466	513.54	440.57	594.84	50.17	27.23	77.96
1997	147,284	329.34	275.54	384.44	40.06	23.46	60.95
1998	145,906	265.67	216.46	317.63	41.86	26.55	60.15
1999	154,887	282.13	234.66	333.60	44.46	28.22	63.33
2000	152,101	287.97	236.47	348.05	42.96	26.27	62.28

Table 5. Estimated ratio of the billfish by-catch per 1000 tons of tunas for the European purse seiners in the Eastern Atlantic Ocean obtained from the Monte Carlo simulation.

	Marlins			Sailfishes		
Year	R.. Marlins / tunas	L.C.I. 0.025	U.C.I. 0.975	R. Sailfishes / tunas	L.C.I. 0.025	U.C.I. 0.975
1991	1.8556	1.5355	2.1824	0.2792	0.1722	0.4073
1992	1.9694	1.6123	2.3046	0.2782	0.1781	0.4069
1993	1.8980	1.5789	2.2375	0.2815	0.1828	0.4261
1994	2.0613	1.6891	2.4034	0.2798	0.1724	0.4212
1995	2.5034	2.1351	2.8714	0.2593	0.1505	0.3901
1996	2.6273	2.2540	3.0432	0.2567	0.1393	0.3988
1997	2.2361	1.8708	2.6102	0.2720	0.1593	0.4138
1998	1.8208	1.4835	2.1770	0.2869	0.1820	0.4123
1999	1.8215	1.5150	2.1538	0.2871	0.1822	0.4089
2000	1.8933	1.5547	2.2883	0.2824	0.1727	0.4095

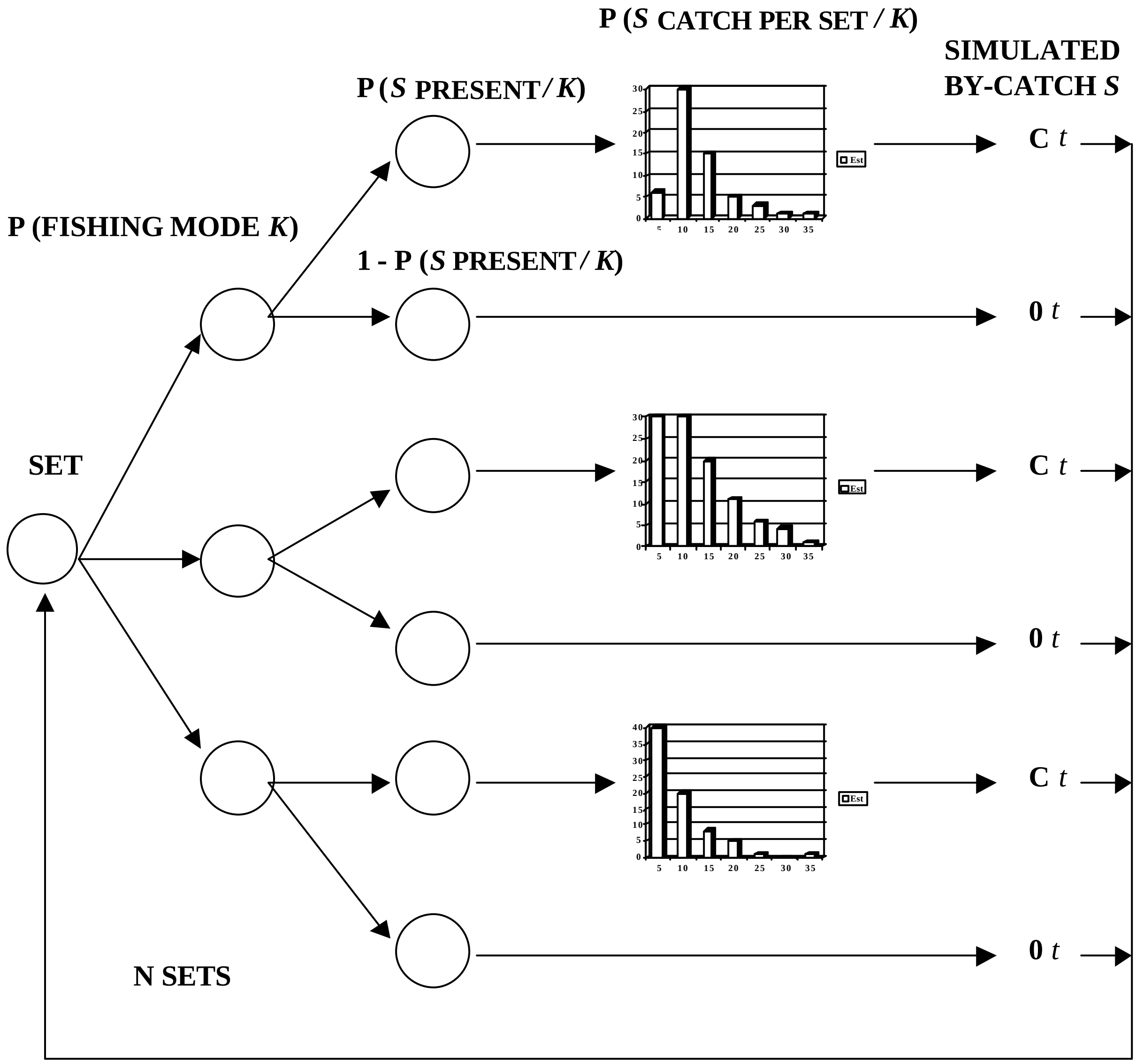

Figure 1. Representation of the Monte Carlo simulation used to estimate the by-catch of billfishes by the European purse seine fishery in the Eastern Atlantic Ocean. The fishing modes considered in this study (see text) were non-associated schools sets (including whale sets), FADSs sets (including natural log sets and shark-whale sets) and seamount sets.

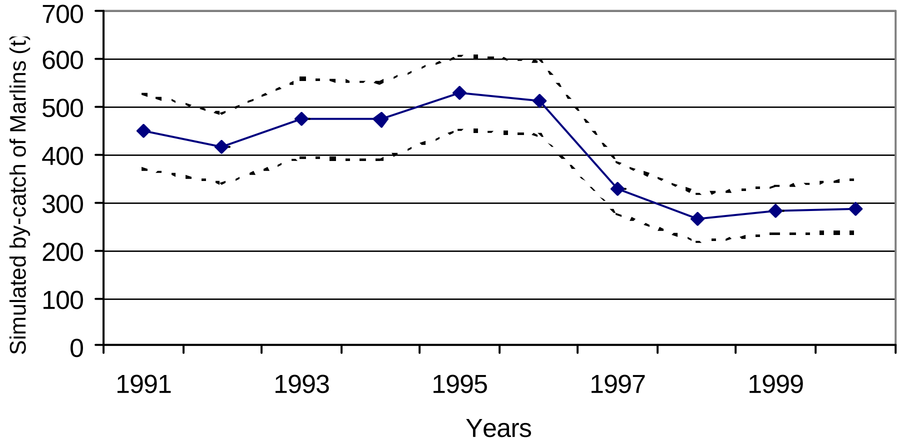

Figure 2. Simulated by-catch of Marlins by the European purse seiners in the Eastern Atlantic Ocean. The seasonal ban on FAD fishing operations adopted by the European purse seiners has been implemented in 1997.

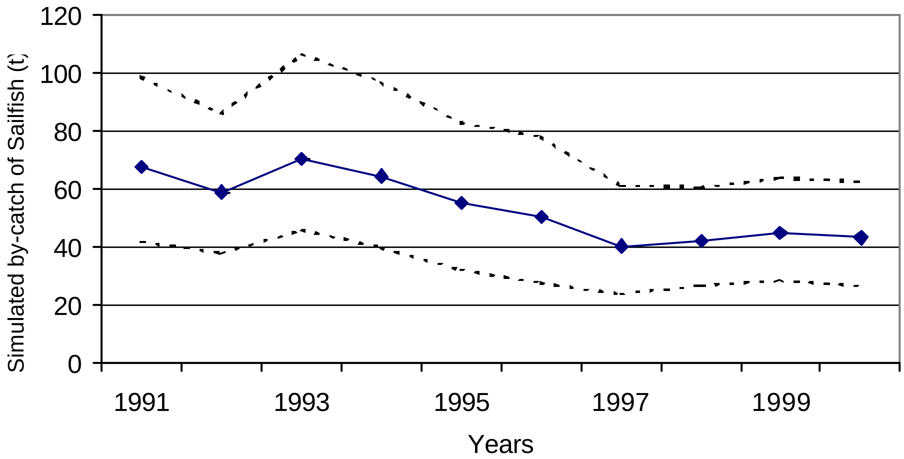

Figure 3. Simulated by-catch of Sailfishes by the European purse seiners in the Eastern Atlantic Ocean. The seasonal ban on FAD fishing operations adopted by the European purse seiners has been implemented in 1997.