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EXPLORATORY ANALYSIS OF TAGGING DATA TO EVALUATE THE BENEFITS OF A TIME-CLOSURE AREA FOR TROPICAL TUNAS

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SUMMARY

Movements of juveniles of tropical tunas were investigated to evaluate the effectiveness of the time-area closures using tag-recapture data. The results show that the apparent movements of juveniles are moderate. Nevertheless, due to the spatial heterogeneity of the tagging operations conducted over time and the different objectives of the previous tagging programs, it was difficult to quantify the exchange rates between the protected areas and the surrounding fishing grounds as well as the resident time spent by juveniles within the protected areas. Consequently, based on the limited tagging information available, there is no evidence that the time-area closures used in the past or proposed recently contribute effectively to the reduction of the fishing mortality for the juveniles of tropical tuna. However, since conventional tagging data may provide critical information useful to evaluate the performance of time-closure areas, we suggest that multispecies tagging program in the future take into account in its objective the study of protected areas for migrating fish and be coordinated by a scientific team in charge of the tagging experiments and in the collect and validation of the tagging information.

RÉSUMÉ

Les mouvements des thonidés tropicaux juvéniles ont été analysés afin d'évaluer l'efficacité des fermetures spatio-temporelles en utilisant des données de marquage-recapture. Les résultats font apparaître que les mouvements apparents des juvéniles sont modérés. Néanmoins, en raison de l'hétérogénéité spatiale des opérations de marquage effectuées au fil du temps et des différents objectifs des programmes de marquage précédents, il est difficile de quantifier le taux des échanges entre les zones protégées et les zones de pêche environnantes ainsi que le temps passé par les juvéniles dans les zones protégées. Par conséquent, sur la base des informations limitées de marquage, aucun élément n'atteste que les fermetures spatio-temporelles utilisées dans le passé ou proposées récemment contribuent à réduire efficacement la mortalité par pêche des thonidés tropicaux juvéniles. Toutefois, étant donné que les données de marquage conventionnel peuvent fournir des informations critiques utiles afin d'évaluer les résultats des fermetures spatio-temporelles, nous suggérons qu'un programme de marquage plurispécifique dans le futur prenne en compte l'étude des zones protégées de migration des poissons et soit coordonnée par une équipe scientifique en charge des expériences de marquage et de la collecte et de la validation des données de marquage.

RESUMEN

Se investigaron los movimientos de los juveniles de túnidos tropicales para evaluar la eficacia de las vedas espaciotemporales utilizando datos de colocación-recuperación de marcas. Los resultados muestran que los movimientos aparentes de los juveniles son moderados. Sin embargo, debido a la heterogeneidad espacial de las operaciones de marcado realizadas en el tiempo y los diferentes objetivos de los anteriores programas de marcado, resultó difícil cuantificar las tasas de intercambio entre las zonas protegidas y los caladeros que las rodean, así como el tiempo de estancia de los juveniles en las zonas protegidas. Por consiguiente, basándose en la información disponible sobre marcado limitada, no hay evidencia de que las vedas espaciotemporales utilizadas en el pasado o propuestas recientemente contribuyan de un modo eficaz a la reducción de la mortalidad por pesca de juveniles de túnidos tropicales. Sin embargo, dado que los datos de marcado convencional podrían proporcionar información

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clave útil para evaluar los efectos de las vedas espaciotemporales, sugerimos que el programa de marcado pluriespecífico tenga en cuenta en el futuro, en el marco de sus objetivos, el estudio de zonas protegidas para peces migratorios y que sea coordinado por un equipo científico responsable de los experimentos de marcado y de la recopilación y validación de la información sobre marcado.

KEYWORDS

Tropical tunas, tagging

1. Introduction

In the last meeting of ICCAT it was suggested to review the recommendations concerning the time-area closure [Rec. 09-01]. The main objective of this recommendation was to reduce the fishing mortality exerted on juveniles of bigeye tune (*Thunnus obesus*), and specifically to mitigate the effect of the Fishing Aggregative Devices (hereafter, FADs) operations. Defining a time-area closure, in terms of no-catch or prohibiting a specific fishing practice (e.g., the recent moratorium for FADs fishing) is not trivial, since the effectiveness of TAC for migratory fish depends on different factors as: (1) the state of the stock, (2) some biological parameters (e.g., natural mortality of juveniles and exchange rates among fishing grounds) and (3) fishery characteristics (e.g., the multispecies nature of the tropical purse seine fishery). In addition it has been showed that in presence of catch quotas, as recently adopted for bigeye, seasonal or permanent closure area may have unwanted effect of increasing effort in adjacent areas open to fishing (Hilborn *et al*., 2004) and consequently a such regulation should be implemented in conjunction with other control measures (Stefansson and Rosenberg, 2005).

With the exception of the first moratorium of ban in FADs fishing operations, initiated on a voluntary basis by European Union tuna purse seiner companies (Goujon and Labaisse-Bodilis, 2001) in November 1997 and adopted by ICCAT in 1999, the no-take "Picolo" strata and the recent time-closure proposal never resulted from previous scientific studies analyzed during SCRS by ICCAT scientists.

However, in the lack of important knowledge on some biological-keys parameters, the scientific community raised some concerns to the increase in fishing mortality of juveniles of tropical tunas due to the massive use of FADs since the early 1990s, as well as on some indirect effect such as changes in migration patterns and in health indicators (*i,e*., concept of ecological trap; Hallier and Gaertner, 2008) or on unexpected consequences on non-target species. In addition to several types of useful information for stock assessment studies, such as natural mortality, growth rate, gear selectivity, etc., tag-recovery studies can be helpful to investigate the potential of a spatio-temporal stratum where the fishing mortality on juveniles should be reduced. Consequently, the aim of this paper is to present the spatial distribution of apparent migrations of the juveniles of the 3 main species of tropical tuna in the Eastern Atlantic and to compare the recaptures within the different time-area closures to those from fishing areas without restrictions on fishing.

2. Material and methods

From the beginning of the 1960s a total of 36206 skipjacks, 18216 yellowfins and 11,085 bigeye were tagged with conventional "spaghetti" tags within the framework of different tagging programs conducted by ICCAT scientists with the collaboration of tuna fishermen. However, even if some progress has been registered in the revision of the ICCAT tropical tuna tagging data base (Gaertner *et al*., 2007), for structural reasons (fish tagged but not recaptured) or lack of relevant information (location, date, size at release and at recapture) a small amount of the tagging data base can only be used in this analysis.

Since we focus on information useful to establish advices to reduce the mortality of juveniles exerted by the surface fleets (purse seiners and baitboats), only fish less than 3.2 kg at recapture, i.e., 54 cm fork length (FL) for bigeye and skipjack and 55 cm for yellowfin were considered. Apparent movements between release and recapture locations are represented with regard to the spatio-temporal strata where regulation measures were/or will be exerted. The 3 time-closure areas (TCA, hereafter) considered in this study were:

1) the moratorium on FADs fishing (1997-2005) established from November 1 to January 31, from 5°N latitude to 4°S latitude and from 20°W longitude to the African coasts in the east;

2) the Picolo area (2005-2008), equivalent to a non-take MPA (nMPA) in which surface catches were prohibited whatever the fishing mode used (ie., non-associated school sets and FADs sets) during the month of November, from 5°N latitude to 0°N latitude and from 20°W longitude to 10°W longitude; and (3), the new space and time strata proposed by the Commission in 2009, termed hereafter: “NewZ”, whose effect should be limited to a ban of setting on drifting floating objects (i.e., natural and FADs) should take place from January 1 to February 28/29, from the African coats in the north to 10°S latitude and from 5°W longitude to 5°E longitude.

To analyze the spatial distribution of historic recaptures we need to account for changes in fishing practices resulting from regulations fishing, because the probability of recapturing juveniles is likely linked to FADs setting. So, to prevent for a potential effect of the FADs moratorium on the apparent distribution of recaptures, the tagging data were divided between two periods: before 1997 (year of the first moratorium) and after 1997. In addition to periods, the recapture were also divided seasonally between months inside and months outside the FADs regulation. Since we focus first on spatial movements only individuals either released and recaptured during moratorium months or either released and recaptured outside these months were considered.

To explore how the spatial distribution of the recaptures may be influenced by the spatial distribution of the fishing intensity, we compare for all sizes the observed number of recaptures and a standardized value. Many studies on recapture rates claim that recaptures should be standardized by the fishing effort exerted in the same strata. However, fishing effort remains problematic since it must be standardized to allow the comparison of the effect of different fishing gears and, in addition there is no evidence that it is linearly related with the number of recoveries. In contrast, the catch in number reflects the population from which tagged fish are sampled. For the sake of simplicity we used catch in weight as a proxy for catch in number to standardize the observed recaptures.

The standardized recaptures P_{ij} for the area i and the period-season j are:

$P_{ij} = R_{ij} / C_{ij} / \sum [R_{ij} / C_{ij}]$

With R_{ij} and C_{ij} = observed recaptures and associated catch, respectively.

For the Moratorium and the Picolo areas we compared standardized recaptures between the TAC and for the strata with the same months but outside the TAC area then between the TAC and for the same area than TAC but during the other months of the year.

3. Results

Based on the recaptures reported by purse seiners and baitboats (both fishing gears capture juvenile of tunas and consequently their activities are directly related with the evaluation of a TAC regulation), the apparent migrations for juveniles of the 3 main species of tropical tuna are showed in **Figures 1-3**. Since no recapture of juveniles has been recorded after 2003, only the spatial location of the first moratorium on FADs is depicted on the figures.

In the lack of any tagging program specifically designed to evaluate movements between protected and fished areas or residence times within the TCA, it is not easy to conclude whether this type of regulation reduces growth overfishing by protecting juveniles. Tagging information was scarce for juveniles of yellowfin and bigeye during the moratorium months all over the historic period and recaptures decreased logically after the regulation on FADs since November 1997 **(Figures 1 and 2)**. As expected, this trend is more pronounced for skipjack whose catch are predominant in FADs sets **(Figure 3)**. From these figures, it appears however that the apparent movements of juveniles are relatively moderate.

The observed recaptures of juveniles (i.e., recaptures not standardized by effort or by catch per area) moving into, out of, or remaining within the different TAC (including here the Picolo area and the new potential area) are showed in **Table 1** The different percentages are related to the number of juveniles recaptured (i.e., the “number at risk” in last column of **Table 1**). For instance in the period before 1997 on the 16 bigeye less than 3.2 kg at recapture (for which: size, date and location at release and at recapture were correctly reported), 2 fish were tagged in the moratorium strata and recaptured outside, 2 were released outside and moved to the TCA and there was no recaptures within the TAC. Once again, except for skipjack, due to the small sample size of recoveries, the movement rates must be interpreted with caution. Not surprisingly due to the small spatial and temporal size the Picolo area seems the less effective option. Compared with the moratorium strata, for which 12.5%-14.5% of recaptures concerned fish moving into the protected area, there was not clear evidence that the new TAC (i.e., newZ) may provide some benefits in terms of protection for juveniles of tunas. It should be stressed than standardizing the recaptures by the associated catch did not modify significantly the migration rates (here for all sizes) between large strata considered in this analysis. For the years with significant recaptures, 98% of bigeye and 100% of skipjack were recaptured during the same months than the seasonal TAC on FADs fishing but outside the protected area. In the same way of ideas, 94% of bigeye, 100% of yellowfin and around 96-99% of skipjack were recaptured within the moratorium area but during the other part of the year. However, additional studies are required to quantify the impact of time-closure area on the tropical tuna fishery more reliably.

4. Discussion and conclusion

Considering the limits of the tagging information available, there is limited evidence from this study to verify the effectiveness of the different time-area closures. To date, there is a lack of information on migration of juveniles between the free-access areas of the eastern Atlantic and the TAC as well as if there is a resident component within the TAC. Tunas are large migratory species and area closures may be of little interest if the juveniles migrate seasonally out of these areas. Furthermore, to gauge the performance of a TAC it makes sense to perform tagging operations within and outside the future area closure (see for instance, Schopka *et al.,* 2009).

In spite of the large number of tagging operations conducted in the Tropical Eastern Atlantic since the early 1960s, the amount of suitable information provided by the tagging data to analyze the performance of protected areas is relatively weak. There are many explanations for this: lack of appropriate checking and potential correction of the tag information at the time of recovery, non-reports by local scientists of some tagging experiments, heterogeneity in the information and in the units used in different countries (eg., cm vs inches, Kg vs pounds), few publicity for recovery in some landing places or for some fisheries, tagging conducted during different international year program focused in general on one species, etc.

For all of these reasons, and considering the financial cost and energy devoted to tagging experiments, ICCAT should investigate the possibility to conduct a large multispecies tagging program in the tropical Atlantic Ocean in which the question of time-closure area be one of the objectives. In addition to be fully effective such program should be coordinated by a unique scientific team in charge of the organization and the technical aspects in relation with the project. The great success of the tagging program conducted recently in the Indian Ocean (RTTP-IO) gives some insight on the interest of such coordinated approach (Hallier and Millon, 2009).

References

Gaertner, D., Kebe, P., and Palma, C. 2007, Some clues for correcting the tagging data base of tropical tunas. Collect. Vol. Sci. Pap. ICCAT, 60(1): 185-189.

Goujon M., Labaisse-Bodilis C. 2001, Effets des plans de protection des thonidés de l'Atlantique depuis 1997 d'après les observations faites sur les thoniers senneurs gérés par les armements Français. Collect. Vol. Sci. Pap. ICCAT, 52(2): 575-589.

Hallier, J.-P., Gaertner, D. 2008, Drifting fish aggregation devices could act as an ecological trap for tropical tunas. *Mar. Ecol. Prog. Ser.* 353: 255-264.

Hallier J.-P., Millon J. 2009, The contribution of the regional tuna tagging project-Indian Ocean to IOTC stock assessment. *IOTC-2009-WPTT-24*

Hilborn, R., Stokes, K., Maguire, J.J., Smith, A., Botsford, L.W., Mangel, M., Orensanz, J., Parma, A., Rice, J., Bell, J., Cochrane, K.L., Garcia, S., Hall, S.J., Kirkwood, G.P., Sainsbury, K. 2004, When can marine reserves improve fisheries management? Ocean and Coastal Management, 47: 197-205.

Schopka, S.A., Solmundsson, J., Ragnarsson, S.A., Thorsteinsson, V. 2010, Using tagging experiments to evaluate the potential of closed areas in protecting migratory Atlantic cod *(Gadus morhua)* ICES Journal of Marine Science, 67: 1024-1035.

Stefansson, G., Rosenberg, A.A. 2005, Combining control measures for more effective management of fisheries under uncertainty: quotas, effort limitation and protected areas. Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences, 360: 133-146.

Table 1. Number of observed recaptures by the surface fisheries for juveniles (<=3.2 kg) of tropical tunas in the Atlantic before and after the implementation of the first moratorium on FADs in relation with different time-closure areas.

Time-Closure Area (TCA)	*Species*	*Period*	*No. tagged in TCA*	*No. moving out of TCA*	*No. moving into TCA*	*No. remaining in TCA*	*Total recapt*
Moratoria	BET	before 1997	2	2 (12.5%)	2 (12.5%)	0 (0.0%)	16
on FADs	BET	after 1997	5	0 (0.0%)	0 (0.0%)	5 (1.8%)	279
Moratoria	YFT	before 1997	16	7 (5.1%)	20 (14.5%)	9 (6.5%)	138
on FADs	YFT	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	195
Moratoria	SKJ	before 1997 3	2 (0.1%)	176 (12.2%) 1 (0.1%)		1440	
on FADs	SKJ	after 1997	1	0 (0.0%)	2 (0.3%)	1 (0.1%)	681
Picolo	BET	before 1997	2	2 (12.5%)	0 (0.0%)	0 (0.0%)	16
	BET	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	279
Picolo	YFT	before 1997	4	1 (0.7%)	3 (2.2%)	3 (2.2%)	138
	YFT	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	195
Picolo	SKJ	before 1997	0	0 (0.0%)	43 (3.0%)	0 (0.0%)	1440
	SKJ	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	681
New	BET	before 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	16
proposal	BET	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	279
New	YFT	before 1997	2	1 (0.7%)	6 (4.3%)	1 (0.7%)	138
proposal	YFT	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	195
New	SKJ	before 1997	1	0 (0.0%)	50 (3.4%)	1 (0.1%)	1440
proposal	SKJ	after 1997	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	681

Table 2. Standardized and observed recaptures (within brackets), for all size, by the Eastern Atlantic surface fisheries (only FADs moratorium and Picolo areas were considered).

			Bigeye			***Yellowfin***			***Skipjack***
Year	*Tags*	*Moratoria*	*Same months outside*	*Tags*	*Moratoria*	*Same months outside*	*Tags*	*Moratoria*	*Same months outside*
1994	1	0 (0)	1 (1)	0	NA	NA	5	0 (0)	1 (1)
1995	0	NA	NA	0	NA	NA	0	NA	NA
1996	0	NA	NA	3	0.14 (0.67)	0.86 (0.33)	1	0 (0)	1 (1)
1997	3	0 (0)	1 (1)	7	0 (0)	1 (1)	29	0 (0)	1 (1)
1998	3	0 (0)	1 (1)	0	NA	NA	3	0 (0)	1 (1)
1999	583	0.02 (0.01)	0.98 (0.99)	16	0 (0)	1 (1)	108	0 (0)	1 (1)
2000	9	0 (0)	1 (1)	0	NA	NA	2	0.32 (0.5)	0.68 (0.5)
2001	5	0 (0)	1 (1)	0	NA	NA	6	0.54 (0.67)	0.46 (0.33)
2002	4	0.44 (0.50)	0.56 (0.50)	0	NA	NA	3	0.46 (0.67)	0.54 (0.33)
2003	0	NA	NA	0	NA	NA	0	NA	NA
Year	Tags	Moratoria	Same area other months	Tags	Moratoria	Same area other months	Tags	Moratoria	Same area other months
1994	0	NA	NA	3	0 (0)	1 (1)	10	0 (0)	1 (1)
1995	0	NA	NA	0	NA	NA	1	0 (0)	1 (1)
1996	0	NA	NA	5	0.52 (0.4)	0.48 (0.6)	0	NA	NA
1997	0	NA	NA	2	0 (0)	1 (1)	0	NA	NA
1998	0	NA	NA	3	0 (0)	1 (1)	0	NA	NA
1999	6	0.93 (0.83)	0.17 (0.07)	0	NA	NA 0	0	NA	NA
2000	0	NA	NA	0	NA	NA	1	1 (1)	0 (0)
2001	6	0 (0)	1 (1)	22	0 (0)	1 (1)	110	0.04 (0.04)	0.96 (0.96)
2002	58	0.06 (0.03)	0.94 (0.97)	202	0 (0)	1 (1)	764	0.01 (0)	0.99 (1)
2003	0	NA	NA	1	0 (0)	1 (1)	1	0 (0)	1 (1)
Year	Tags	Picolo	Same months outside	Tags	Picolo	Same months outside	Tags	Picolo	Same months outside
1994	1	0 (0)	1 (1)	0	NA	NA	2	0 (0)	1 (1)
1995	0	NA	NA	0	NA	NA	0	NA	NA
1996	0	NA	NA	0	NA	NA	0	NA	NA
1997	2	0 (0)	1 (1)	1	0 (0)	1 (1)	10	0 (0)	1 (1)
1998	2	0 (0)	1 (1)	0	NA	NA	2	0 (0)	1 (1)
1999	122	0 (0)	1 (1)	14	0 (0)	1 (1)	46	0 (0)	1 (1)
2000	7	0 (0)	1 (1)	0	NA	NA	0	NA	NA
2001	3	0 (0)	1 (1)	0	NA	NA	0	NA	NA)
2002	0	NA	NA	0	NA	NA	0	NA	NA
2003	0	NA	NA	0	NA	NA	0	NA	NA
Year	Tags	Picolo	Same area other months	Tags	Picolo	Same area other months	Tags	Picolo	Same area other months
1994	0	NA	NA	0	NA	NA	0	NA	NA
1995	0	NA	NA	0	NA	NA	0	NA	NA
1996	0	NA	NA	0	NA	NA	0	NA	NA
1997	0	NA	NA	0	NA	NA	0	NA	NA
1998	0	NA	NA	0	NA	NA	0	NA	NA
1999	0	NA	NA	0	NA	NA 0	0	NA	NA
2000	0	NA	NA	0	NA	NA	0	NA	NA
2001	0	NA	NA	0	NA	NA	0	NA	NA
2002	1	0 (0)	1 (1)	0	NA	NA	0	0 (0)	1 (1)
2003	0	NA	NA	0	NA	NA	0	0 (0)	1 (1)

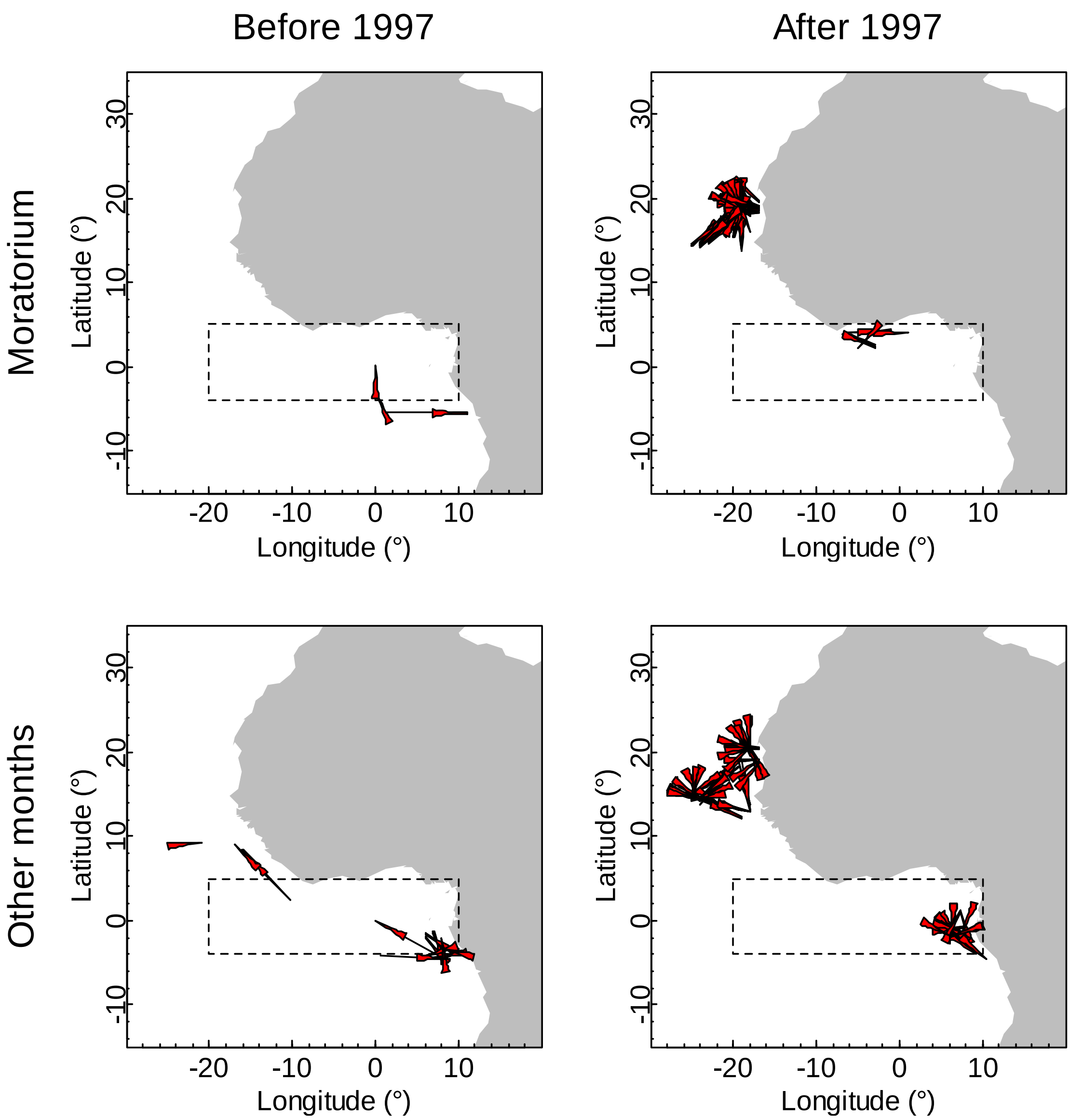

Figure 1. Bigeye less than 3.2 kg (54 cm), recaptured by the surface fisheries by periods and according to the months of the first moratorium on FADs (the limits of the time-closure area are indicated by a dotted line). Only fish released and recaptured during the same season (moratorium months *vs.* other months) are represented.

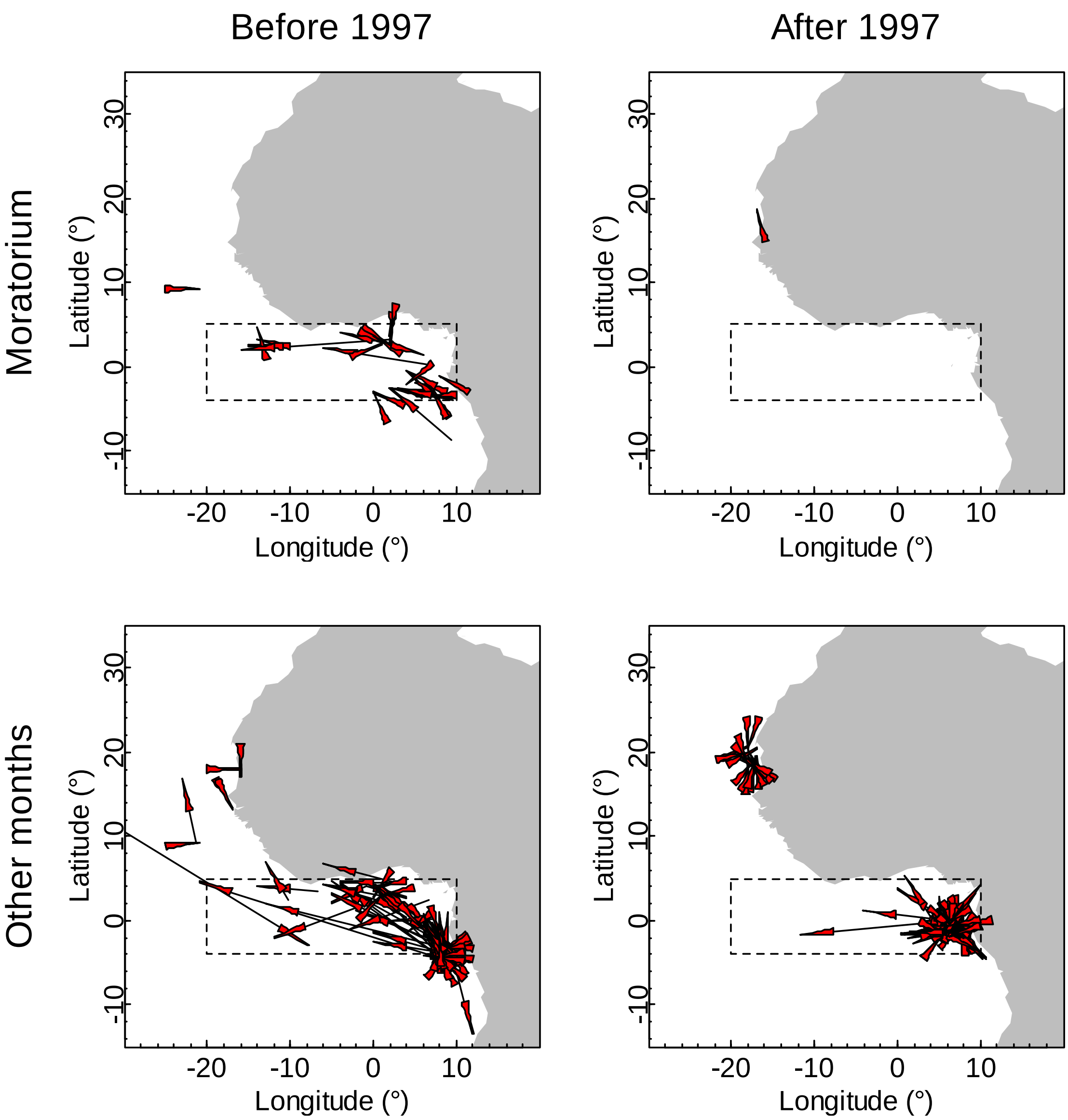

Figure 2. Yellowfin less than 3.2 kg (54 cm), recaptured by the surface fisheries by periods and according to the months of the first moratorium on FADs (the limits of the time-closure area are indicated by a dotted line). Only fish released and recaptured during the same season (moratorium months vs. other months) are represented.

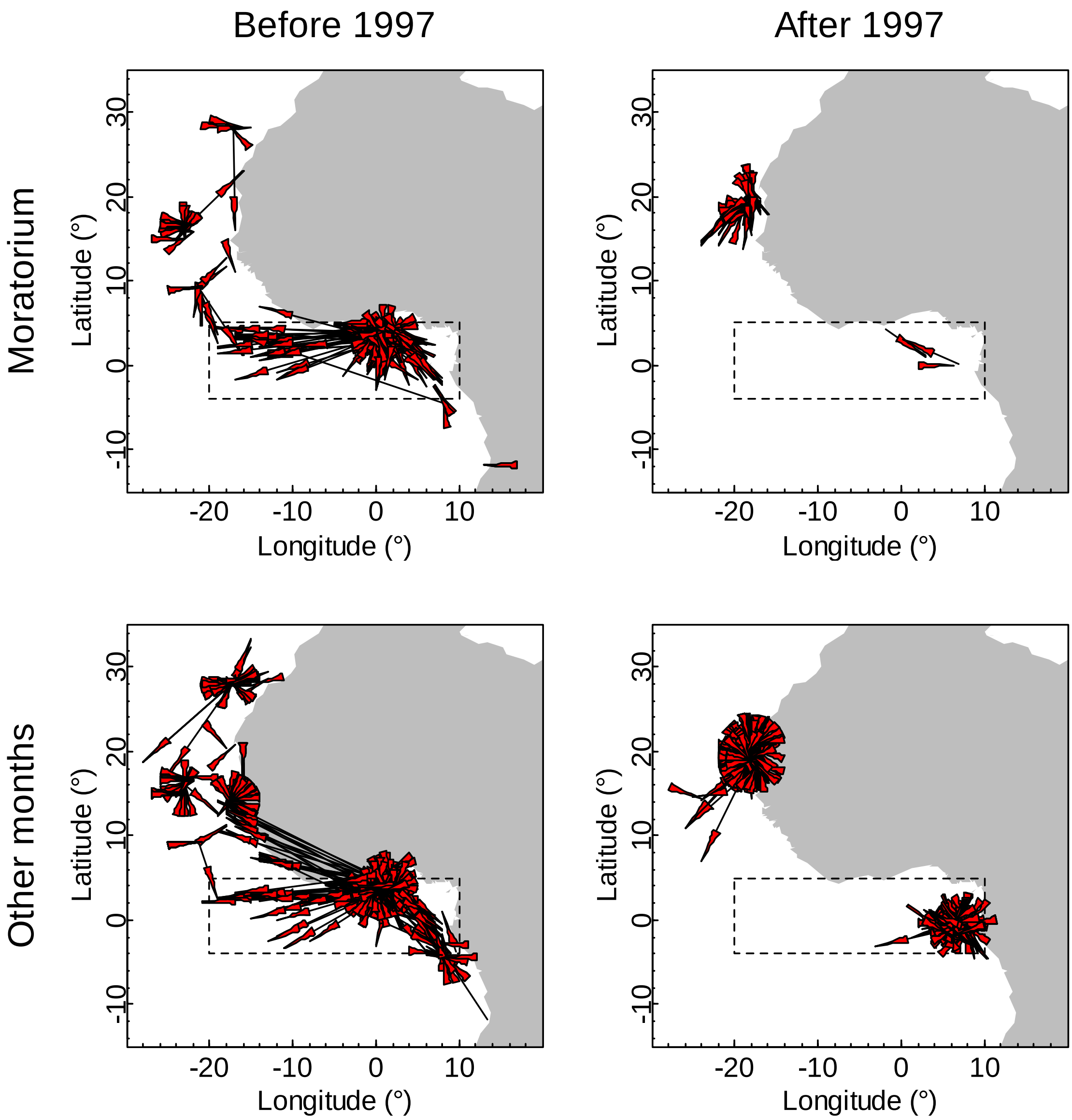

Figure 3. Skipjack less than 3.2 kg (54 cm), recaptured by the surface fisheries by periods and according to the months of the first moratorium on FADs (the limits of the time-closure area are indicated by a dotted line). Only fish released and recaptured during the same season (moratorium months vs. other months) are represented.