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PRELIMINARY RESULTS OF AERIAL SURVEYS OF BLUEFIN TUNA IN THE WESTERN MEDITERRANEAN SEA

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SUMMARY

One of the aims of the EU project STROMBOLI (2000-2002) was to conduct an aerial survey for bluefin tuna in the western Mediterranean Sea to test the feasibility of computing an index of abundance from direct observation. This approach has at least two advantages: (i) to provide fishery-independent information and observation, and (ii) to compensate for the lack of Mediterranean purse seine CPUE indices. The first surveys were done in June-July 2000 over the Balearic and Sicilian areas, where and when adult bluefin tuna used to concentrate for spawning, but the results were disappointing (spawners can hardly be detected from a plane). In contrast, the results obtained from the surveys for juveniles of BFT in the Gulf of Lions and in the Ligurian and Tyrrhenian seas are positive and encouraging. The number of BFT schools being detected was, on average, rather high and the variance between transects appeared satisfactory. Furthermore, the main characteristics, e.g., location and size of schools, fish behaviour, perpendicular distance of the detection, were consistent between the 2000 and 2001 surveys. This study will be pursued and extended in 2002.

RÉSUMÉ

L'un des objectifs du projet européen STROMBOLI (2000-2002) était de mener des survols aériens sur le thon rouge de Méditerranée occidentale pour voir s'il était possible de calculer un indice d'abondance par méthode directe. Cette approche présente au moins deux avantages: (i) fournir des observations et des informations indépendantes de la pêche et (ii) compenser l'absence d'indices de CPUE des thoniers senneurs méditerranéens. Les premières campagnes de survols ont eu lieu en juin, juillet 2000 au dessus des îles Baléares et de la Sicile, date et lieu de la période de reproduction du thon rouge, mais les résultats furent décevants (les thons adultes étant peu détectables d'avion). Cependant, les résultats obtenus lors des survols axés sur les juvéniles du Golfe du Lions et de mer Ligure et Tyrrhénienne se sont avérés positifs et encourageants. Le nombre de bancs de thons détectés était, en moyenne, assez élevé et la variance entre transects satisfaisante. De plus, les principales caractéristiques, e.g., emplacement et taille des bancs, comportement du poisson, distances perpendiculaires des détections, étaient homogènes entre les campagnes 2000 et 2001. Cette étude sera poursuivie et étendue en 2002.

RESUMEN

Uno de los objetivos del proyecto STROMBOLI (2000-2002) de la UE era llevar a cabo expediciones aéreas que sobrevolasen el atún rojo occidental para ver si era posible calcular un índice de abundancia por método directo. Este enfoque presenta por lo menos dos ventajas. (i) proporcionar observaciones e informaciones independientes de la pesca y (ii) compensar la ausencia de índices de CPUE de los cerqueros atuneros mediterráneos. Las primeras campañas de expediciones aéreas tuvieron lugar en junio y julio de 2000 sobrevolando las islas Baleares y Sicilia, fecha y lugar de reproducción del atún rojo, pero los resultados fueron decepcionantes (los atunes adultos no se detectaban bien desde el avión). Sin embargo, los resultados obtenidos en los vuelos centrados en los juveniles del Golfo des Lions y del mar de Liguria y del mar Tirreno fueron positivos y alentadores. El número de bancos de atunes detectados fue, como media, bastante elevado y la varianza entre cortes transversales

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satisfactoria. Además, las principales características, por ejemplo, ubicación y tamaño de los bancos, conducta de los peces, distancias perpendiculares de las detecciones, eran homogéneas en las distintas campañas 2000 y 2001. Este estudio continuará y se ampliará en 2002.

KEYWORDS

Atlantic bluefin tuna, aerial survey, index of abundance, Gulf of Lions, Ligurian and Tyrrhenian Sea

1. INTRODUCTION

Since 1993, aerial spottings are regularly carried out along the Southern Australian coasts to compute an index of abundance of juveniles of Southern bluefin tuna (e.g., Cowling and O'Reilly 1999). Some surveys and a framework for fishery-independent aerial assessment have been also tested on large Atlantic bluefin tuna (BFT) of the West Atlantic (Lutcavage and Kraus 1995, Lutcavage and Newlands 1999). Although encouraging, such a technique had never been investigated on the East Atlantic and Mediterranean BFT. One of the aims of the EU project STROMBOLI (2000-2002) was to conduct aerial surveys for BFT in the Western Mediterranean Sea to test the feasibility of computing an index of abundance from these direct observations. Direct and scientific survey would further provide fishery-independent information, which is, in the current context, a non-negligible advantage (about the question of misreporting, see ICCAT 2001, Fromentin 2002). An index of abundance could also compensate for the lack of Mediterranean purse seine CPUE indices, which can be hardly calculated because of inconsistencies over the fishing period, due to large (but unspecified) changes in technology, tactics, selectivity and fishing area (for more details see Fromentin 2002).

2. METHOD

Aerial survey is based on the theory of the distance sampling (Buckland, et al. 1993). The lines or routes are defined within a given area, along which each object of interest (i.e., a tuna school) is recorded. The route is surveyed several times within a given period. The density of the replicate (i) may be approximated as follow:

$$\hat{D}_i = \frac{n_i}{2wL}$$

where $\hat{D}_i$ is the density estimate (number per unit area) of replicate i, n_i is the number of tuna schools detected in the replicate (i), w, the width of detection from the line of the transect and L, total length of the transect. The mean density, $\hat{D}$, from r replicates may be approximated as follow:

$$\hat{D} = \frac{1}{r}\sum_{i=1}^{k}\hat{D}_i$$

and the variance between replicates as:

$$Var(\hat{D}) = \frac{1}{r(r-1)}\sum_{i=1}^{r}(\hat{D}_i - \hat{D})^2$$

Several constraints must be respected to obtain a reliable index. First, the objects must be detected at their initial position, prior to any movement in response to observers. Second, the detectibility must decrease with the perpendicular distance from the route and the objects directly on the line must be detected with a probability of 1. Finally, the perpendicular distances from the route must be measured accurately (the track of plane and the locations of the detected objects must as precise as possible). The theory allows that some, perhaps many, of the objects are undetected and that variation in detection due to environment or observer could occur, as soon as n, L and w are accurately measured.

According to the line transect theory, *w* is estimated through a detection function, which is a model that fits the histogram of the perpendicular distances of the detections (e.g., Buckland, et al. 1993, Chen 1996). This method, which is currently used for bird surveys, is elegant, but imply a minimum size sample of ~60-80 detections and can be further easily biased in areas of high density. Strip transects are more simple to implement (*w* is fixed and directly determined from the histogram) and more robust than the line transects. They have further several advantages: (i) they do not require a minimum number of observations, (ii) they do not imply to distinguish between primary to secondary detection and (iii) they are easy to poststratify. Note that Cowling and O'Reilly (1999) have recently recommended the implementation of a strip transect method for index of abundance of SBT. Therefore, our first density estimations were calculated using the strip transect method.

3. DATA ACQUISITION

Taking advantage of the experience of the Australian team (see, Cowling and O'Reilly 1999), we could get information to define a precise and efficient protocol, especially regarding the potential biases due to observer, environmental conditions (wind, temperature, sun height and clouds), speed and altitude of the plane. One crucial point of the distance sampling theory is to obtain reliable perpendicular distances, i.e., accurate locations of the route and detected schools. This can be easily obtained with a GPS, which has, however, a limited memory. Therefore, we elaborated a system that couples a GPS with a PC portable. During a survey, the GPS records every 30s the exact position of the plane as well as all the waypoints entered by the operator (i.e. the locations of the spotted BFT schools). All the information is directly sent to the PC, in which the route and the track of the plane are simultaneously plotted. It is so possible to check whether the plane follows the route during the survey and to save automatically the survey track and the waypoints. The team in the plane always included a professional pilot and one or two scientists. When possible, trained spotters also participated to the surveys (information obtained with and without trained spotter has not been mixed to avoid inconsistency). Aerial surveys have been conducted at the same time of day (around noon when the sun is at its highest) and during favourable weather conditions, i.e. sunny sky and low wind speed (<10kt/h), which limits the possibility to conduct aerial survey outside of the summer season.

4. SURVEYS OF BFT SPAWNERS OVER THE BALEARIC AND SICILY

The first surveys have been done in June-July 2000 over the Balearic and Sicilian areas, where and when the adults of BFT used to concentrate for spawning (Mather, et al. 1995). The routes have been defined to optimise the probability of detection, regarding information on previous scientific surveys (i.e., BFT eggs surveys), spatial distribution of the fishing boats and general knowledge (Fig. 1). The Balearic and Sicilian routes were about 1350 nautical miles long each, the former being divided into 3 sub-routes of about 450 nm each that can be easily covered within a day (at a speed of 110knots/hour). Because of windy conditions in June 2000, the 3 Balearic sub-routes have been only covered once, during which we did not detect a single tuna school (Fromentin 2001). The Southern Tyrrhenian Sea survey was done in June 2000 within 4 days (Fig. 1). 6 BFT schools have been detected (2 schools of spawners of ~100 individuals > 50kg and 4 schools of ~100 to 400 juveniles < 10kg). In June 2001, the Tyrrhenian Sea survey was partially covered over 4 days, but interrupted because of bad weather conditions. 11 BFT schools have been detected in 2001 (5 schools of ~100 to 500 spawners of 50 to 200kg and 6 schools of ~200 to 4000 juveniles of 5 to 20kg). The results of these 3 surveys clearly indicated that the BFT spawners are rarely and sporadically spotted from a plane, probably because they mainly remain at the sub-surface (below than 1m depth).

5. SURVEYS OF BFT JUVENILES

5.1 The Gulf of Lions survey

Juveniles BFT are, however, supposed to be more easily spotted from a plane because they often swim at the surface to search food. Furthermore, we knew that the Australian aerial surveys, that target young SBT, are successful. Therefore, some aerial spotting were first realised in September 2000 in the Gulf of Lions, which is a time and place where young BFT are traditionally caught by the French purse seiners. The survey has been divided in a West route (370 nm) and an East route (350 nm), so that each route can be surveyed within 4h30 (including distance between airport and transect, Fig. 2). The two routes have been surveyed two times each, between the 06/09/2000 and the 23/09/2000 and 78 juveniles BFT schools have been detected (Fig. 2). The size of the schools appeared rather small and estimated about 20 to 100 individuals of weight < 30kg (note that the estimates of the school size and fish size are based on direct observation and information given by fishermen, but it remains crude since no professional spotter took part of these surveys). The great majority of the juvenile schools being spotted were easy to detect because fish used to jump and/or swim rapidly at the surface, probably in relation to feeding and/or foraging activity.

As expected with the distance sampling theory, the number of detected schools decreased exponentially with the perpendicular distance (Fig. 3) and 75% of the shoals were detected at a perpendicular distance < 2nm. The survey in the Gulf of Lions was repeated in 2001, between the 28th of August and the 09th of October. The spotting effort was higher, the West and East routes being spotted 4 and 3 times, respectively. However, the number of BFT schools being detected was slightly lower: 77 (Fig. 2). The size of schools, the behaviour of the fish at the surface, the general location of the schools and the perpendicular distances were similar between 2000 and 2001 (in 2001, 80% of the shoals were detected at a perpendicular distance < 2nm, see Figs. 2 and 3). Considering a strip transect with a bandwidth of 2nm, densities of juveniles BFT in the Gulf of Lions could be estimated at:

$\hat{D}_{2000}$ = 0.0147 shoal/nm² (std=0.004, CV=27%)

$\hat{D}_{2001}$ = 0.0089 shoal/nm² (std=0.0036, CV=40%)

5.2 The Ligurian and Tyrrhenian Sea survey

The success of the Gulf of Lions survey in 2000 lead us to investigate another survey for juveniles of BFT in September/October in the Ligurian and Tyrrhenian Sea, which is also a time and place where young BFT are traditionally caught by the Italian and French purse seiners. The survey, that is 1162nm long, has been covered two times in early October 2001, but the route has been only completed once because of bad weather conditions. 18 schools of juveniles BFT have been detected (Fig. 4). The size of the schools appeared larger and more contrasted than in the Gulf of Lions, going from 50 to 1000 individuals (with a mean range of about 100-200 individuals). The size of the fish was comparable, mainly between 7kg and 30 kg. The schools of juvenile BFT being detected also fed or swam at the surface (especially on highly dense patches of small pelagics; a feature being also observed in the Gulf of Lions). The number of schools decreased exponentially with the perpendicular distance, but a few schools have been detected farther than expected by the sampling theory (Fig. 4). The number of detections was, however, insufficient to compute an index of abundance.

6. DISCUSSION-CONCLUSION

Information from observers and recent literature (e.g. Lutcavage, et al. 2000) confirm that adult of BFT spent most of their time within the 10 first meters depth, but they can hardly be detected from a plane when they are deeper than 2 m. During the survey, we saw several cages including big tuna caught by purse seiners, but it was often impossible to spot them. Discussion with different trained observers and fishermen would indicate that a school of BFT spawner is detected, in average, every 50 to 100 hours of aerial survey. Consequently, the information provided by aerial spotting for spawners in the West Mediterranean appears to be unsuitable to compute a fishery-independent index of abundance (Fromentin 2001).

However, the results obtained on surveys for juvenile of BFT are positive and encouraging. The number of BFT schools being detected during each Gulf of Lions survey (~9 hours of plane) was, in average, rather high (39 schools in 2000 and 22 in 2001) and the variance between replicates appears satisfactory. Furthermore, the main characteristics, i.e., general location and size of schools, fish behaviour, perpendicular distances of the detections, were highly consistent between the 2000 and 2001 surveys. The results of the Ligurian and Tyrrhenian Sea survey are also encouraging, but the number of replicates was, unfortunately, too low in 2001. It appears that each route should be repeated 4 times within the survey period to allow the computation of an index of abundance.

In 2002 (the last year of the STROMBOLI project), the Italian survey will only focus on juvenile of BFT in the Ligurian and Tyrrhenian Sea. We planned to repeat this survey 3 to 4 times in September. The Gulf of Lions survey will be extended from June to September; each route being planned to be surveyed about 10 times during the 4 months. We also plan to contract a professional spotter during the main period (end-August to end-September) to get more precise information on the size of the fish and size of the school. This information, together with log-book data, should allow the design of a more sophisticated modelling that would compute an index of abundance in biomass density (see e.g. Buckland et al. 1993).

Depending on the results of 2002 surveys, we might carry out routinely aerial surveys (at least over the Gulf of Lions). This would imply to conduct further research on migration patterns and vertical dynamics of juvenile of BFT in this area, through e.g. pop-up tagging, as well as studies on oceanographic conditions that may affect spatial distribution and spatial dynamics of BFT.

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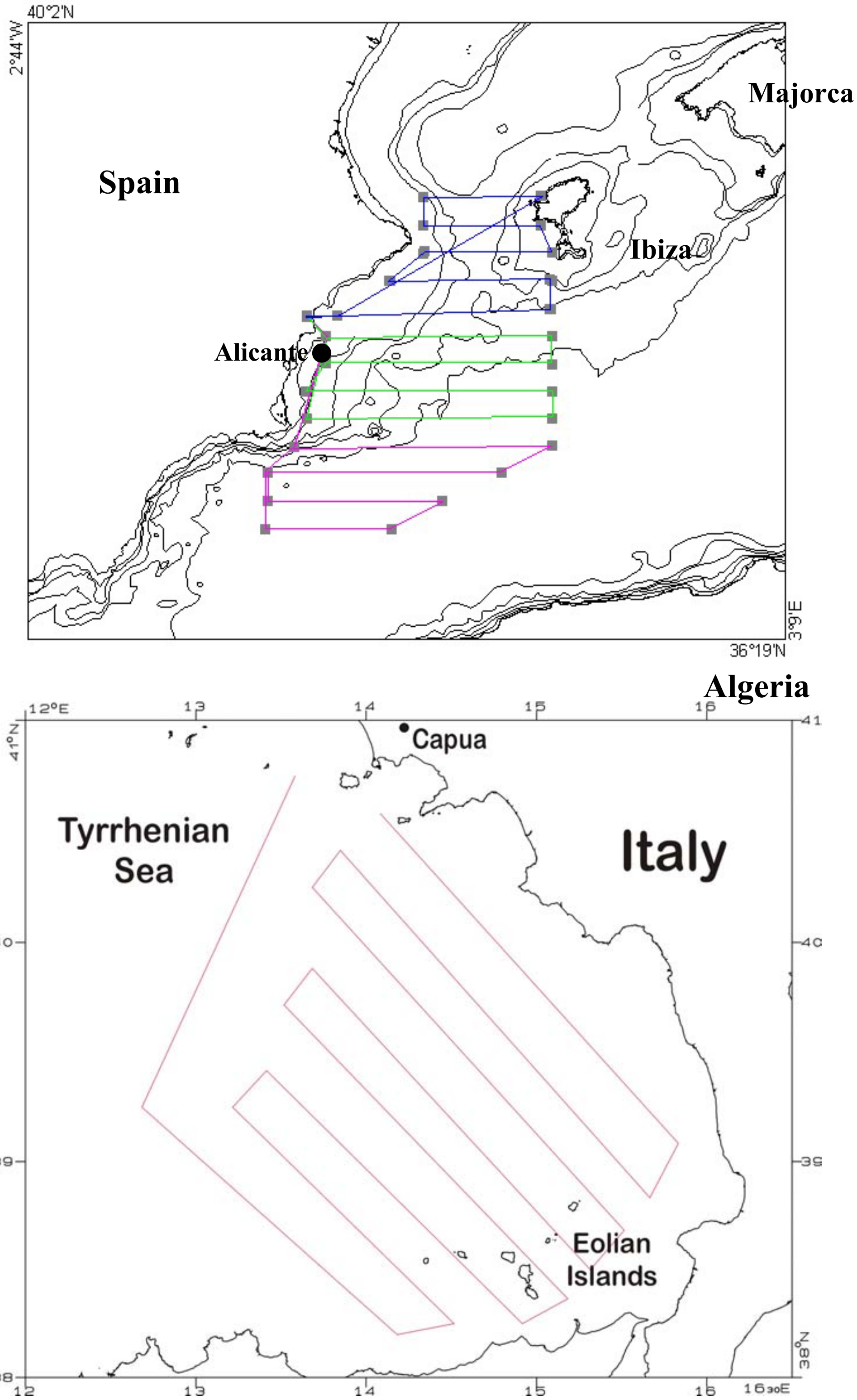

Figure 1. Top: Routes of the aerial survey over the Balearic Islands (the total route being divided into 3 sub-routes of about 450 nm each). Bottom: Route over the southern Tyrrhenean Sea (about 1300 nm)

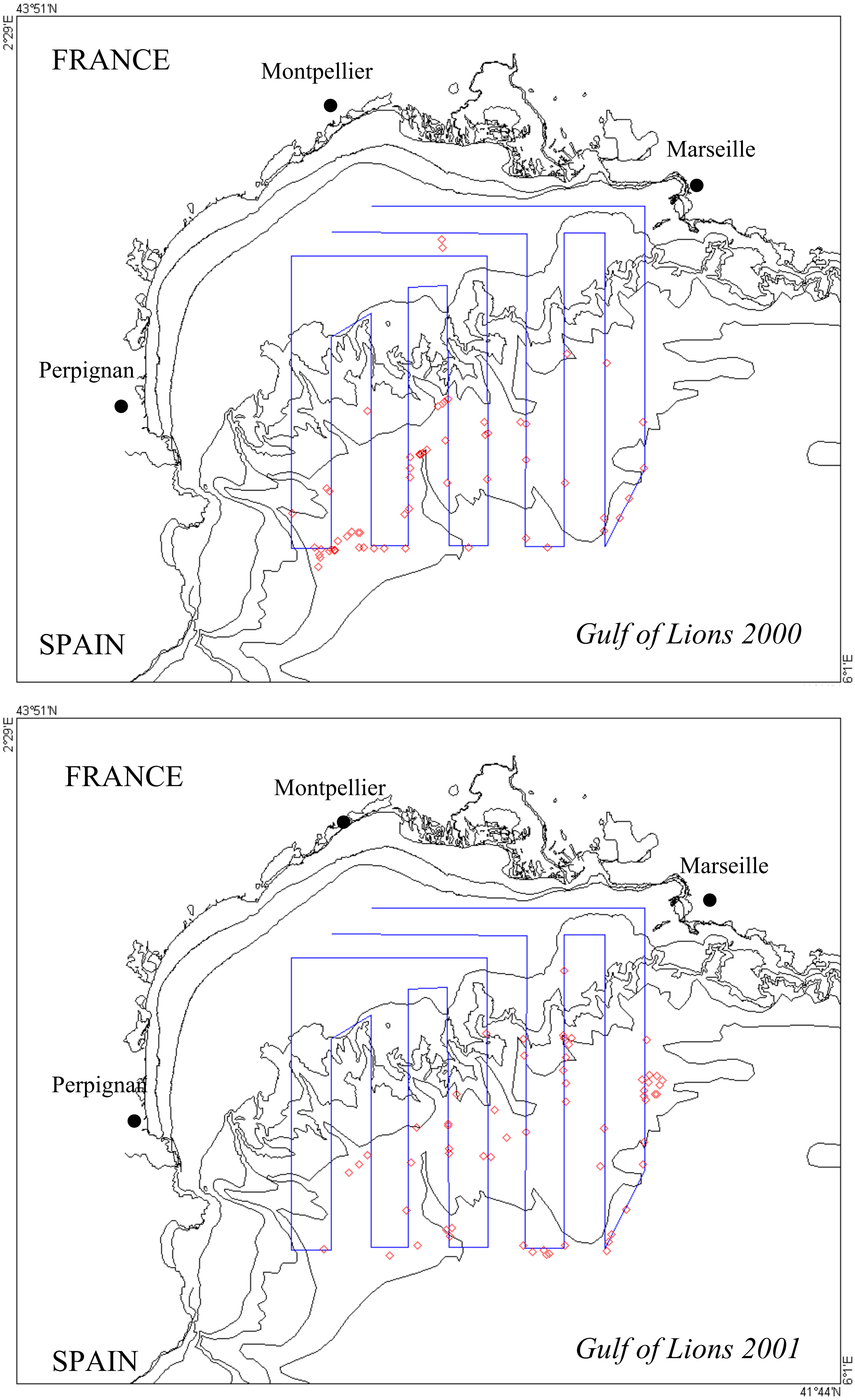

Figure 2. Routes and BFT schools (◊) detected during the 2000 and 2001 aerial surveys in the Gulf of Lions

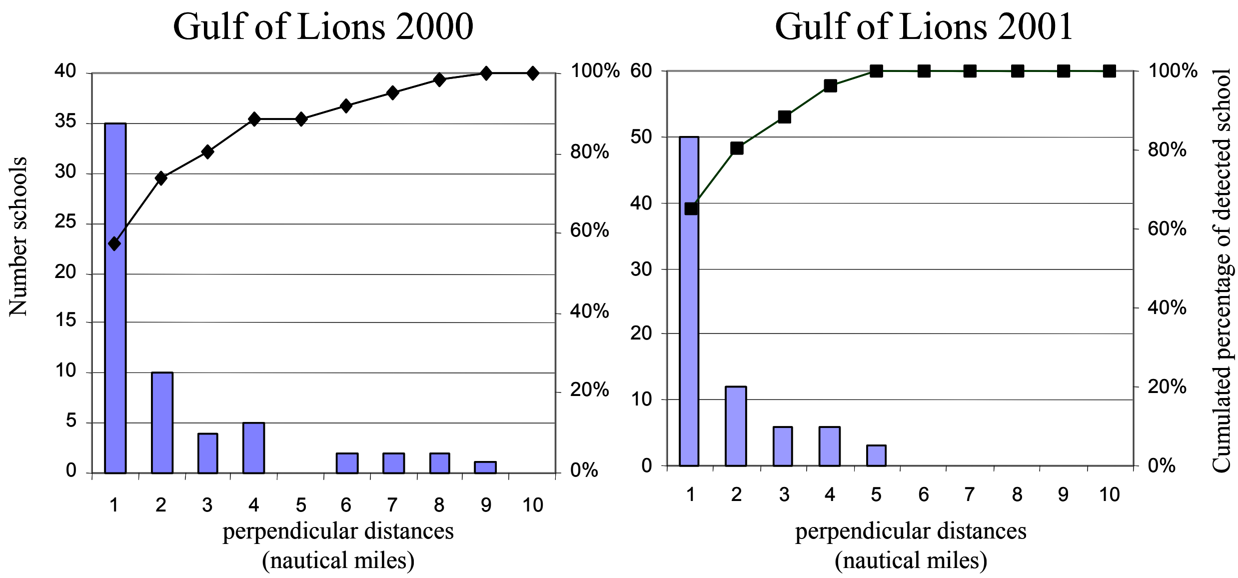

Figure 3. Histograms and cumulated percentage of the number of schools being detected for each class of perpendicular distances to the route

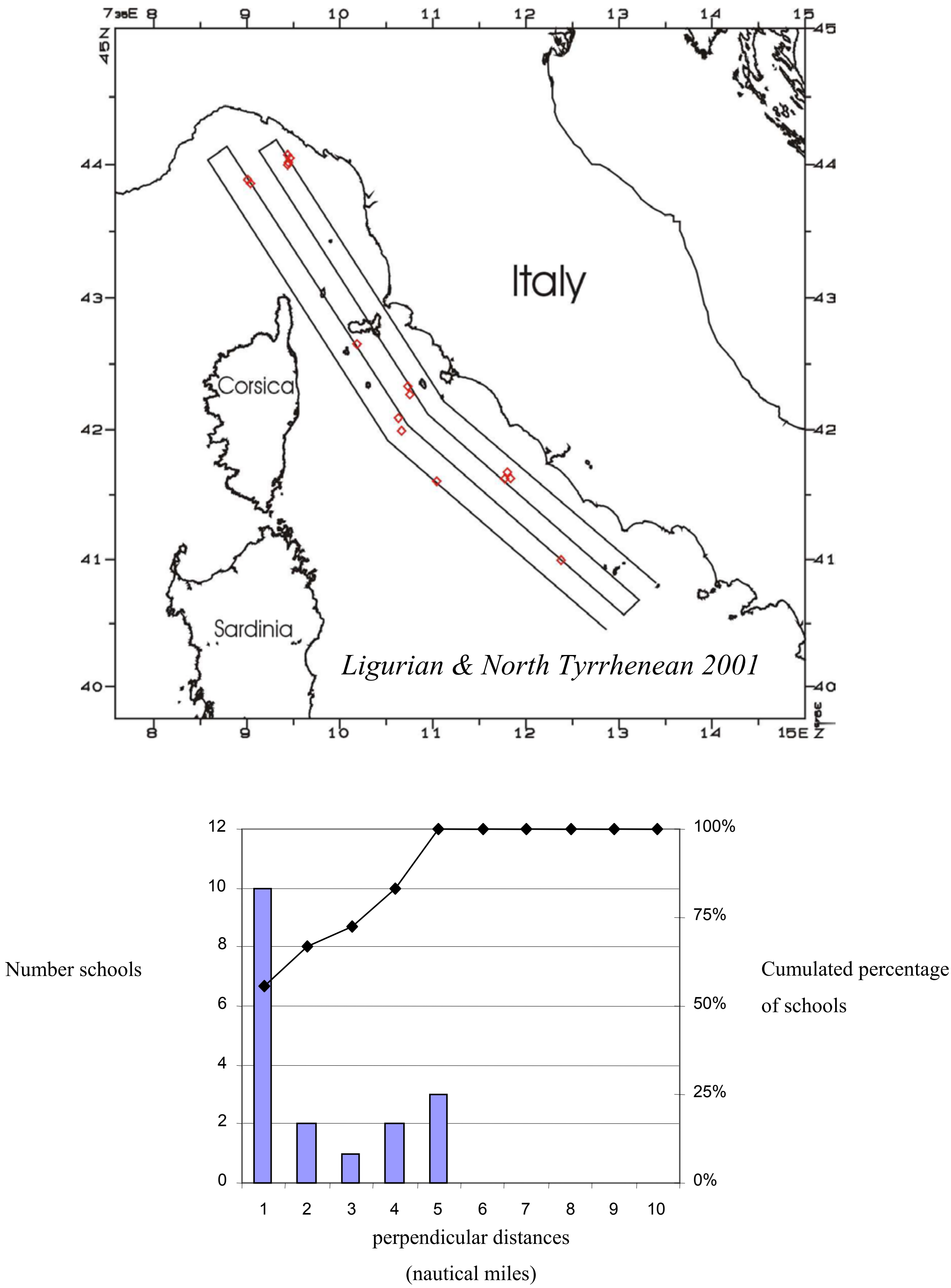

Figure 4. Top: Route and BFT schools (◊) detected during the 2001 aerial survey in the Ligurian and northern Tyrrhenean Sea in 2001 Bottom: histogram and cumulated percentage of the number of schools being detected for each class of perpendicular distances to the route