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Electronic tagging data and habitat envelope modeling used to monitor spatial persistency and possible relocation of spawning grounds for the bluefin tuna in the East Atlantic and the Mediterranean.

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ABSTRACT

A spawning habitat envelope has been created for bluefin tuna in its traditional spawning ground in the Mediterranean Sea by combining environmental variables and species behavior. We used logistic regressions through a generalized linear model (GLM) approach to determine whether reproduction was affected by spawning habitat characteristics and individual behavior. Results from the implementation of the model predicted a high probability of occurrence of reproductive events associated with 17 tagged tuna. Some of them matched the already well known spawning grounds in the Mediterranean Sea (the area around the Balearic Islands, the Tyrrhenian Sea and the Gulf of Sirte). The model also

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proposed some other areas seldom or not at all mentioned in the bibliography in both, the Mediterranean and the Atlantic Ocean, such as the Alboran Sea, the Catalan Sea, the Gulf of Lions and the Bay of Biscay. This model provides an objective methodology to predict and adapt spawning areas, and to identify other potential but unknown, or even new, spawning areas and periods for the species. Moreover, the application of the present methodology could help the implementation of an adaptive management approach for Atlantic bluefin tuna by predicting areas suitable for spawning and identifying changes in spawning areas and season in the currently highly changing ocean and climate conditions.

INTRODUCTION

The Mediterranean Sea has been widely acknowledged as one of the main spawning grounds of Atlantic bluefin tuna. Its migration from the Atlantic to the Mediterranean was already known since ancient times and has been used by fishermen to set traps along its path near the Strait of Gibraltar for nearly 3,000 years (Desse and Desse-Berset, 1994; Doumenge, 1998). However, the first study making a direct connection between bluefin tuna migration from the Atlantic to the Mediterranean to spawning was the one made by Cetti (1777). Evidence of spawning was later corroborated by the presence of bluefin tuna larvae in the Mediterranean since Ehrembaum (1924) and Sella (1924). Several research surveys targeting bluefin tuna and other species eggs and larvae regionally have been carried out since then (Sanzo, 1929a,b, 1933; Dieuzeide, 1951, Vodianitzki and Kazanova, 1954; Akiüz and Artüz, 1957; Duclerc *et al*., 1973; Dicenta *et al*., 1975, 1979; 1983; Rodriguez-Roda, 1975; Piccinetti *et al*., 1976, 1977a,b; Dicenta, 1977; Piccinetti and Piccinetti-Manfrin, 1978; Dicenta and Piccinetti, 1978; Potoschi *et al*., 1994; Cavallaro *et al*., 1996; Tsuji *et al*., 1997; Nishida *et al*., 1998;

Piccinetti *et al*., 1996a,b; Karakulak *et al*., 2004; Oray and Karakulak, 2005; Alemany, 1997, 2010). Those studies have revealed presence of bluefin tuna larvae in several places around the basin, i.e. Alboran Sea, off Algerian coast, around the Balearic Islands, around Sicily including the Tyrrhenian Sea, the Messina Strait and the Ionian Sea, Adriatic Sea, Gulf of Sirte and south of the Anatolian peninsula. Although its presence has been very scarce in some of them, it has frequently been highlighted in the waters around the Balearic Islands. As reported in Alemany (2008), due to the variety of sampling methodologies and strategies it is difficult to compare the abundances and frequencies of occurrence of bluefin tuna larvae accounted in the available bibliography within the Mediterranean. However, results of basin scale larval surveys (Dicenta, 1977; Dicenta and Piccinetti, 1978; Tsuji *et al*., 1997; Piccineti *et al*., 1996; Nishida *et al*., 1998) corroborate the importance of the Balearic waters spawning grounds since Atlantic bluefin tuna larvae always appeared in this area and larval densities were always among the highest recorded. Spanish purse seiners, taking advantage of the aggregating behavior of the fish during spawning, is exploiting the Balearic fishing ground every spawning season since the early ‘80s.

The Balearic Islands spawning ground is likely the most exhaustively studied and characterized in the Mediterranean (García et al., 2005; Alemany et al. 2010). Larvae survey has been conducted around the islands since the ‘70s, and regularly from 2001 to 2005 along with hydrological data in the framework of the TUNIBAL project (García et al., 2005; Alemany, 2010). This project revealed that Atlantic bluefin tuna spawning peaks in the Balearic Sea from mid-June to mid-July, and is closely related to inflowing surface Atlantic waters mixing with surface

Mediterranean waters and generating mesoscale eddies, in part responsible for larval distribution.

Electronic tagging carried out recently in the Mediterranean has enormously contributed to understand the bluefin tuna population structure, migration routes and habitat use (Fromentin and Lopuszanski, 2013; Cermeño et al., 2015; Quílez-Badia et al., submitted). Combination of data from electronic tagging and satellite derived sea surface temperature, Chlorophyll-a, and sea height anomaly in both sides of the Atlantic and along most of the geographical distribution of the species have provided a deeper insight of bluefin tuna habitat use during both, feeding and spawning (Teo et al. 2007, Druon et al. 2011, 2016). Given its promising results and besides being costly, tagging campaigns will likely increase and expand to the whole Mediterranean and even to other species. It is therefore relevant to ensure the maximum profit from the provided data.

Previous research studies carried out since the early ‘90s has indicated that the relationship between bathymetry, SST, salinity, surface chlorophyll concentration, eddy kinetic energy, and thermohaline stratification of the water column is critical for understanding tuna reproductive habitat (Teo et al., 2007; Alemany, et al., 2010; Reglero et al., 2012). These environmental variables define a spawning-habitat envelope that needs to be better described to facilitate identification of individual reproductive events. Spawning was observed to start at SST over 20.5ºC, with a preference for waters between 21.5ºC and 26.5ºC (Alemany, 2010) and in presence of a well-defined thermocline, preferably having a negative gradient of 3°C (Di Natale, 2010; Piccinetti et al., 2012). Additionally, reproductive tuna exhibit specific behaviors during spawning: a marked preference for permanency at depths of less than 40 m (Aranda et al., 2013); and a significantly more residential and highly sinuous movement paths (Teo et al. 2007). Moreover, adults in spawning areas present a particular diving behavior, characterized by repeated and brief oscillatory movements up and down through the mixed layer (Aranda, et al, 2013), which is consistent with low horizontal speed and high preference rate by surface waters.

The characterization of the bluefin tuna spawning habitat is essential to improve fisheries management. The strengthening of the management framework of the Eastern Atlantic bluefin tuna stock from 2006, after scientists and civil society calls due to the alarming state of the stock, has proven to give successful results in effectively increasing biomass abundance and recovering the stock. However, efforts to improve the understanding of the biology of the species and its fisheries management are taking place due to be considered essential to effectively sustain the health of the stock in the long term. In this context, the identification of bluefin tuna spawning areas has been considered a priority by ICCAT (Di Natale, 2011 and ICCAT Recommendations 08-05, 10-04, 12-03, 13-07 and 14-04). However, as recently suggested by Reglero et al. (2012) and Cermeño et al. (2015), bluefin tuna seem to be opportunistic spawners that follow environmental signals and adapt to variability. Taking into account ocean variability, likely amplified by the recent increased climate variability, makes even more important the characterization of the spawning environment in support to an adaptive management approach.

An accurate definition of the spawning habitat envelope would be extremely helpful in allowing: 1) An identification of reproductive or non-reproductive individuals relying on data from electronic tagging; 2) The identification of potential but still unknown spawning areas; 3) The prediction of both emergent and relocation of spawning areas due to environmental impacts such as climate change; and 3) A more adaptive and precautionary management framework for the species in Eastern Atlantic and Mediterranean.

In this study we incorporate biological knowledge of the species-habitat relationship to create a spawning habitat envelope that constrains the environmental variables and species responses as behaviors that match with tuna reproduction events. We propose a predictive model that accounts for the spatial limits of bluefin tuna spawning from electronic tagging data in the most well-known spawning ground, around the Balearic Islands. This approach, in turn, provides an objective methodology to predict and adapt those known limits, and to identify other potential but unknown, or even new, spawning areas and periods for the species.

METHODS

Electronic tagging methodology and data

A total of 27 electronic Pop-up Satellite Archival Transmitting (PSAT) tags that were deployed between 2011 and 2015, were used in the present work. These tags were deployed within the framework of a larger tagging program that has deployed 124 PSAT tags between 2008 and 2015. Nevertheless, for the specific analysis presented here, only those tags that were attached to the tuna during the spawning season and that were at liberty for at least 18 days were used.

Following the same protocol as the one described in Quílez-Badia et al. (*submitted*), Atlantic bluefin tuna were tagged with electronic tags in expeditions that occurred between 2008 and 2015 in locations along the eastern Spanish coast - Roses, Llançà and Garraf (NE Spain), Moraira (E Spain) and Algeciras (SE Spain) -; in the Balearic Islands - Port of Pollença (N Majorca, Spain)-; in the Adriatic Sea - in San Benedetto del Tronto and Porto Barricata, E and NE Italy, respectively -; and in Larache (E Morocco). The research presented in this manuscript involved no endangered or protected species and no harm to the animals. No special permission was required for the study in any of the locations as it was not required, however a special permit was granted by the Spanish Ministry "Agricultura, Alimentación y Medio Ambiente" for the 2011 tagging operations in Roses and Llançà.

The tagging was conducted with electronic tags (built by Wildlife Computers, Redmond Washington, using PAT Hardware version 2.0), which recorded pressure, light and water temperature every 60 seconds interval and were grouped in 6- or 24-hour binned histograms (for 2012 to 2015, and 2011 tags, respectively). Temperature layers were set at 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33 and over 33 ºC and depth layers at 0, 2, 10, 20, 50, 100, 150, 250, 300, 400, 500, and over 500 m. In addition to these histogram data, the minimum and maximum daily temperatures observed at different depths were also obtained. When all dives during a summary period were less than 400 m the tag defaulted to lowresolution profiles, meaning 8 different depths fitting into one message per summary period. Whereas when the tag ventured below 400 m it defaulted to high-resolution profiles, meaning 16 different depths fitting into two messages per summary period. For these vertical profiles of temperature, depth points were distributed between the minimum and maximum depths observed during each summary period.

All bluefin tuna trajectories were estimated by CLS (Collecte Localisation Satellites) applying the Kalman filtering of the light-based geolocations and using satellite obtained sea surface temperature (SST) and bathymetry as constraints (for more details see Cermeño et al., 2015).

Statistical analyses and modelling

A series of generalized linear models were fitted to analyze the relationship between individual reproductive state of tuna and a set of environmental and behavioral variables. Following a habitat envelop concept similar to the one developed by Walker (1991) and Zarnetske (2007) as an ecological representation of a species feature's observed distribution based on the spatial intersection of multiple attributes, we constructed a habitat envelope for 15 individuals passing through the Balearic Islands well known spawning area during the spawning season to obtain the binary dependent variable representing reproduction or non-reproduction for each individual. The area was approximated by an 85.5 km^2 polygon defined by 4 geographical coordinates (39.89N, 0.66E; 40.75N, 4.64E; 37.61N, 5.03E; 38.37N, 0.53E), and the season by a 78 days period, from JD 135 to JD 213 (14 or 15 May and 31 July or 1 August, depending on the year). The environmental variables used as habitat descriptors influencing tuna reproduction were: sea surface temperature (SST) and difference in temperature between 0 and 24 m (i.e., the vertical temperature gradient at the thermocline hereafter diff_ther). The behavioral variables used to complete the habitat envelope were: daily average of the percentage of time spent between 21 and 27 ºC (hereafter TAT 21-27 ºC); daily average of the percentage of time spent between 0 and 20 m (hereafter TAD 0-20 m); and tuna velocity (km/h). All five variables were extracted or calculated from electronic tagging data. We assume that spawning aggregation fine-tunes its precise location to match environmental conditions; and that each of these conditions prevail for at least 75% of the time adults remain in spawning areas.

Prior to statistical analysis, explanatory variables were scaled (mean = 0, standard deviation = 1) to approach normality and to reduce the influence of extreme values. Spearman rank correlations were computed between all pairs of explanatory variables in order to examine for the presence of collinearity. From each pair of highly correlated variables ($r > 0.7$), only the one demonstrating the stronger association with the response variable was retained for further analysis (Zar 1996).

The 15 tuna adults passing through the Balearic Islands spawning area were categorized as reproductive or non-reproductive if all explanatory variables have passed a defined set threshold value. To avoid subjective errors in determining the threshold value for each variable we obtained descriptive statistics for all set of predictive variables and we identified the quartiles, first or third depending on the variable, encompassing the 75% of data distribution.

We used logistic regressions through a generalized linear model (GLM) approach to determine whether reproduction was affected by spawning habitat characteristics and individual behavior. The dependent variable (reproduction/non-reproduction of tuna) was binomial, and we subsequently used the logit as the link function. Five predictive variables were used: (1) SST and (2) diff_ther, describing the habitat, and (3) TAT 21-27 ºC; (4) TAD 0-20 m; and (5) tuna velocity describing individual behavior. This technique converts binary data into probabilities values by fitting a binomial general linear model trough the observations that matched with the defined habitat envelope criteria for reproductive tuna. A stepwise procedure with both directions was performed to test the statistical significance of each variable in turn. The model selection was based on Akaike's information criterion (AIC). Those variables that contributed to the largest significant change in the deviance from the null model were selected as best predictors. Model fit was assessed by examining deviance and Pearson' χ^2 residuals.

We test the model's accuracy and its consistency with the data by comparing the reproductive state according to the habitat envelope criteria and the predicted reproductive state following the formula: 1 – (misclassification error). Additionally, we calculated the area under the Receiver Operating Characteristic ROC curve (true positive rate against the false positive rate). As a rule of thumb, a

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model with good predictive ability should have an area under the curve closer to 1 than to 0.5.

A synthetic model was then built using the best variables from all five sets of variables. Finally, the best model was used in a predictive mode to generate the binary response reproductive or non-reproductive state for tuna in the Mediterranean and the North East Atlantic (27 tags). All analysis and modelling was performed using R version 3.2.2 (2015-08-14), software (http://www.r-project.org/).

RESULTS

The historical spawning area of Balearic Islands is characterized by high sea surface temperatures (mean 22.210 ºC). Reproductive adults had a rate of permanency of 75% in areas with SST over 21.23 ºC and thermal difference between 24 m and surface below -2.292 (Table 1). The 75% of reproductive adults remained 41.53% and 69.14% of time between 21 to 27 ºC and 0 to 20 m depth, respectively. Swimming speed of bluefin tuna was lower in the Balearic Islands area (mean of 1.514 km/h, 0.019 min. and 9.267 max.) that in remaining areas (mean 2.007 km/h, 0.031 min. and 21.024 max.). Reproductive adults swam 75% of the time below 2.788 km/h in the Balearic Islands spawning area (Table 1).

An initial model with the five predictor variables showed an AIC = 97.494 and deviance explained = 54.99 %. Stepwise regression analysis removed the non-significant variables (z-statistic) and ultimately yielded the best combination of significant variables and their terms with the lowest AIC and the highest deviance explained values as compared to their individual and/or linear combinations of the previous steps (Table 2). For the optimal model, step-wise analyses revealed that the combination of four variables including two habitat descriptor (SST and diff_ther) and two tuna behaviors (TAD 0-20 m and velocity) were the best predictors of reproductive state (AIC = 96.372, deviance explained 54.528 %, Table 3).

The accuracy of the model (1-misclassification error) was high (92.843%) in the training set (i.e. using data from Balearic Islands spawning area). The area under the ROC curve was high also (97.145%). Both parameters indicate the good performance of the parsimonious model. Used in a predictive mode, the model generates the binary response “reproductive state” for all available tagged tuna.

Filtering the response of the model, we identified each day matching with the variables within the defined habitat envelope (reproductive event) for the 27 individuals (Tables 4, 5). 236 reproductive events from 3253 records corresponding to 17 of 27 bluefin tuna trajectories were predicted by the model within a wide range of probabilities of occurrence (Fig. 1a). Highest probabilities of reproductive events within the established habitat envelope (> 75%) which relates to 162 events corresponding to 16 tunas showed presumable spawning in 4 different areas within the Western and Central Mediterranean and in 3 areas in the Eastern Atlantic (Fig. 1b). The presumable spawning areas identified by the model within the Mediterranean are: a) the western Mediterranean from the Alboran Sea to Corsica and Sardinia Islands (111 events from 12 tunas), mostly in an area covering the well described spawning ground south of the Balearic Islands (44

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events from 11 tunas), expanded to the north to the Catalan Sea and reaching the Gulf of Lions (14 events from 2 tunas), to the east, to the Sardino-Balearic Plain (48 events from 4 tunas), and to the southwest, to the Algerian Basin (2 events from 2 tunas) and even the Alboran Sea (3 events from 2 tunas); b) the Tyrrhenian Sea (4 events from 1 tuna); c) an area covering from the southern Adriatic Sea to the south of Sicily including the Ionian Sea (29 events from 1 tuna); and d) the Gulf of Sirte (7 events from 1 tunas). The presumable spawning areas identified by the model in the Atlantic Ocean are the Bay of Biscay (6 events from 1 tuna), around Madeira Island (2 events from 2 tunas), and northeast of Lanzarote Island (2 events from 2 tunas).

The predicted reproductive events in the western Mediterranean from the Alboran Sea to Corsica and Sardinia Islands took place from late May to late September, i.e., from 25 May to 15 July in the south of the Balearic Islands during the 5 years, extending up to 22 August in the Mallorca channel and the Catalan Sea in 2011, and up to 23 September in the Catalan Sea reaching the Golf of Lions in 2015. The events in the Tyrrhenian Sea were predicted from 19 to 24 June in 2013. In the area covering from the southern Adriatic Sea to the south of Sicily, including the Ionian Sea, were predicted from 4 June to 16 September, and in the Gulf of Sirte from 20 to 27 June in 2012. The 10 events predicted in the Eastern Atlantic took place from 12 to 20 August 2013 in the Bay of Biscay, in June and July 2012 around Madeira Island, and in August and September 2012 in the northeast of Lanzarote Island.

Reproductive events of the same tuna in more than one of the mentioned areas were predicted for 3 different tunas (Fig. 2): one (tag ID 114007) in the south of the Balearic Islands (late May), in the Gulf of Sirte (late June), and in the northwest of Madeira Island (late July) on 2012; another one (tag ID 114006) in the south of the Balearic Islands and the Sardino-Balearic basin (June) and in the northeast of Lanzarote Island (mid August) in 2012; and the last one (tag ID 120446) in the south of the Balearic Islands (late June and early July) and in the Bay of Biscay (August) in 2013.

DISCUSSION

The model has predicted reproductive events in already well known spawning grounds in the western and central Mediterranean: around the Balearic Islands, in the Tyrrhenian Sea, and in the Gulf of Sirte (Druon, 2009 and references herein). Those areas have been identified in the past by both, the presence of larvae, and by the fishing activity of purse seine fleets which takes advantage of the spawning aggregations (Alemany 2008; Di Natale, 2011). Moreover, the model also predicts a high probability of reproductive events in areas in the Alboran Sea, the Catalan Sea, the Gulf of Lions, the Sardino-Balearic Plain and in an area covering from the southern Adriatic Sea to the waters around Malta, including the Ionian Sea. Bluefin tuna larvae were found in the Alboran Sea, off the Algerian coast and in the Ionian Sea (Rodriguez-Roda and Dicenta, 1981; Piccinetti et al., 1976, 1977a; Piccinetti et al., 1996a and b), corroborating the presumable spawning also in those areas. The previously known areas, likely due to the design of the sampling methodologies and the behavior of the tuna fleets, were usually represented as disconnected spawning grounds throughout the basin. Fig. 1a, however, suggest a continuous distribution area of reproductive events with high probability spots in certain places, matching the needed environmental conditions. This would confirm the results of previous studies (Reglero et al., 2012 and Cermeño et al., 2015) which suggest that bluefin tuna is an opportunistic spawner that reproduce only once favorable environmental conditions are met. The aerial surveys carried out by ICCAT's GBYP during 4 years, between 2010 and 2015, in potential spawning areas during the spawning season (mostly in June), have reported bluefin tuna sights in the eastern Alboran Sea, the Catalan Sea, the Sardino-Balearic Plain, and the area between the south of Sicily and around Malta (Di Natale et al., 2015), which could have been also related to spawning. On the other hand, the areas near the Strait of Gibraltar, the Gulf of Lions, and the southern Adriatic and northern Ionian Seas were not considered spawning areas by the project (Di Natale et al., 2015).

The model has also predicted 3 different presumable reproductive events in the Atlantic Ocean. Based on the presence of very small juveniles or of spawners, the possible presence of potential bluefin tuna spawning areas around Azores, the Canary Islands and Madeira was already suggested in the past (Di Natale et al., 2013 and references herein). However, potential reproduction of bluefin tuna in the Bay of Biscay has never been reported before. In addition, the reproductive events south of the Balearic Islands during the 5 years correspond to a typical spawning season for this area, from 25 May to 15 July. However, those in the Catalan Sea and in the Gulf of Lions, areas never reported as spawning grounds, have extended the spawning season until August and even September. It is noteworthy the case of one of the tunas which was in the south of the Balearic Islands during the typical spawning season (2-15 June) in 2015 but did not reproduce there, instead, it showed possible reproduction two and three months later in the Catalan Sea and the Gulf of Lions. The events predicted in the Gulf of Sirte in 2012 and in the Tyrrhenian Sea in 2013, both in late June, also match with the usual reproduction period (de la Serna and Alot, 1992; Medina et al., 2002). The predictions in the Atlantic Ocean, north east and north west of Madeira, correspond to events that would have taken place in June and July 2012 respectively. The ones observed north east of Lanzarote would have taken place also in 2012 but in Mid August and mid September. The events predicted in the Bay of Biscay would have taken place from mid August to mid September. It is interesting to notice that all three tunas showing reproductive events in both, the Atlantic Ocean and the Mediterranean Sea, have presumably reproduced before in the very well known spawning ground south of the Balearic Islands (Fig. 2) which still presents a higher number of reproductive events.

There is a broad body of evidence that climate change may strongly influence distribution and abundance of fish through changes in growth, survival, reproduction, or responses to changes at other trophic levels (Stebbing et al., 2002; Brander et al., 2003; Beaugrand et al., 2002; 2003; Perry et al., 2005; Poulard and Blanchard, 2005; Rose, 2005; Desaunay et al. 2006; Beare et al. 2004a, b; Mamie et al. 2007; Anadón, 2009; Heath et al., 2012; Petitgas *et al*., 2013). Lusitanian species, for example, have increased in recent decades (e.g. sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and horse mackerel (*Trachurus trachurus*)), especially at the northern limit of their distribution areas (Beare et al., 2004c; Rijnsdorp et al., 2009, 2010). Therefore, seasonal migrants that feed in the North Atlantic but spawn further south (e.g. bluefin tuna), may also be undergoing migration shifts due to the changes in their key forage fish (Rose, 2005). In addition, even though bluefin tuna possess a unique physiology that allows them to tolerate colder waters than other tuna, which has facilitated their expansion into feeding areas in the North Atlantic (Lutcavage et al., 2000), they also may be adversely affected by warm (>28–30ºC) waters (Blank et al., 2004). In fact, adult bluefin tuna target moderately warm waters to spawn. In the Mediterranean, spawning has been observed to start at SST over 20.5 ºC, with a preference for waters between 21.5 ºC and 26.5 ºC (Alemany, 2010). Thus, if the beginning of spawning requires a minimum water temperature and adult bluefin tuna cannot tolerate waters above a maximum temperature limit, a specific "thermal window" exists for spawning activity. It is therefore likely that variations in the water temperature of their spawning grounds will affect the spatial and/or the temporal distribution of bluefin tuna spawning effort (Muhgling et al., 2011). Moreover, larval growth rates are high in warm water (Brothers et al., 1983; Miyashita et al., 2000) and oligotrophic waters may present favorable feeding conditions for larvae with specialized diets (Bakun, 2006; Llopiz et al., 2010). Under climate change conditions, therefore, primary and secondary productivity regimes are being altered (Anadón, 2009; Brander, 2010; Rijnsdorp et al., 2009, 2010; Petitgas et al., 2012, 2013) and the current "match" between suitable water temperatures and low productivity in the spring (Muller-Karger et al., 1991) might not be maintained. If this is the case, then the survival rates of bluefin tuna larvae might be changing, as concentrations of planktonic prey and predators might also be changing. In addition, temperature increase can also modify water circulation, with clear consequences on larval dispersal and recruitment (Bianchi and Morri, 2004). Furthermore, we have to bear in mind that the actual location of spawning has to represent a balance between the requirements of the larvae and the physiological limitations of the adults (Rooker et al., 2007), which might not be met in a climate change scenario.

An example of the climate change effect in the north-western Mediterranean is the ornate wrasse, *Thalassoma pavo*, a warm water species that lives in rocky habitats, which is now commonly found on the Catalan Sea coast and the Gulf of Lion, while a few decades ago it was only found abundantly in more southern areas. The same is also the case for the pearly razorfish, *Xyrichtys novacula*, the bluefish, *Pomatomus saltatrix*, the bastard grunt, *Pomadasys incisus* and the dusky grouper, *Epinephelus marginatus* (Francour et al. 1994). In addition, in the Catalan cost, some warm water species that were not present in the past are now established and reproducing. This is the case for *Sardinella aurita* (Sabatés et al., 2006) and *Pomatomus saltatrix* (Sabatés et al. 2012 and Villegas-Hernández et al 2015). Similarly, in the Bay of Biscay the sea-surface temperature increase that has been observed in the past two decades (Palanque et al 2003; Anadón 2009) has directly and indirectly influenced fish stocks, and in particular the pelagic ones (e.g. sardine, anchovy, bonito). The Bay of Biscay is the subtropical boreal transition sub-province between the Atlantic boreal province and the northern subtropical sub-province, so life may respond rapidly to small shifts in climate (Blanchard and Vandermeirsch 2005). Anadón (2009) also observed how boreo-Atlantic species of the Cantabrian coast are suffering a “Mediterraneanisation”, thus, their populations are shrinking and are being replaced by warm water ones.

Regarding the genus *Thunnus*, we have recently observed how *T. alalunga* has not only extended its range from the south to the north of the western Mediterranean (Lloret et al 2015) but it also has changed its migratory route in the Bay of Biscay, shifting to the north. This is in association to the displacement of the 18 °C isotherm (Anadón 2009). Increasing water temperatures might, therefore, be affecting the spawning times and locations, larval growth, feeding, and survival of fish, including bluefin tuna, which might be what we are starting to observe in the present study.

CONCLUSION

The contribution of this work is twofold: (i) the creation of a reproductive habitat envelope combining environmental variables and bluefin tuna behavior, and a model which allows the prediction of reproductive events according to the defined habitat envelope from electronic tagging data; and (ii) the prediction of reproductive events associated with 17 tagged tuna, some of them matching with the already well known spawning grounds in the Mediterranean Sea (the area around the Balearic Islands, the Tyrrhenian Sea and the Gulf of Sirte) and supporting some other areas seldom or not at all mentioned in the bibliography in both, the Mediterranean and the Atlantic Ocean, such as the Alboran Sea, the Catalan Sea, the Gulf of Lions and the Bay of Biscay.

The authors believe that the implementation of the present methodology could be instrumental in supporting an adaptive management approach for Atlantic bluefin tuna by predicting areas suitable for spawning and identifying changes in spawning areas and season in the currently highly changing ocean and climate conditions. This, in turn, establishes a set of novel hypothesis that will be of great interest to the scientific community, and that might lead to a highly relevant discussion on the conservation and management of this highly valued fish species.

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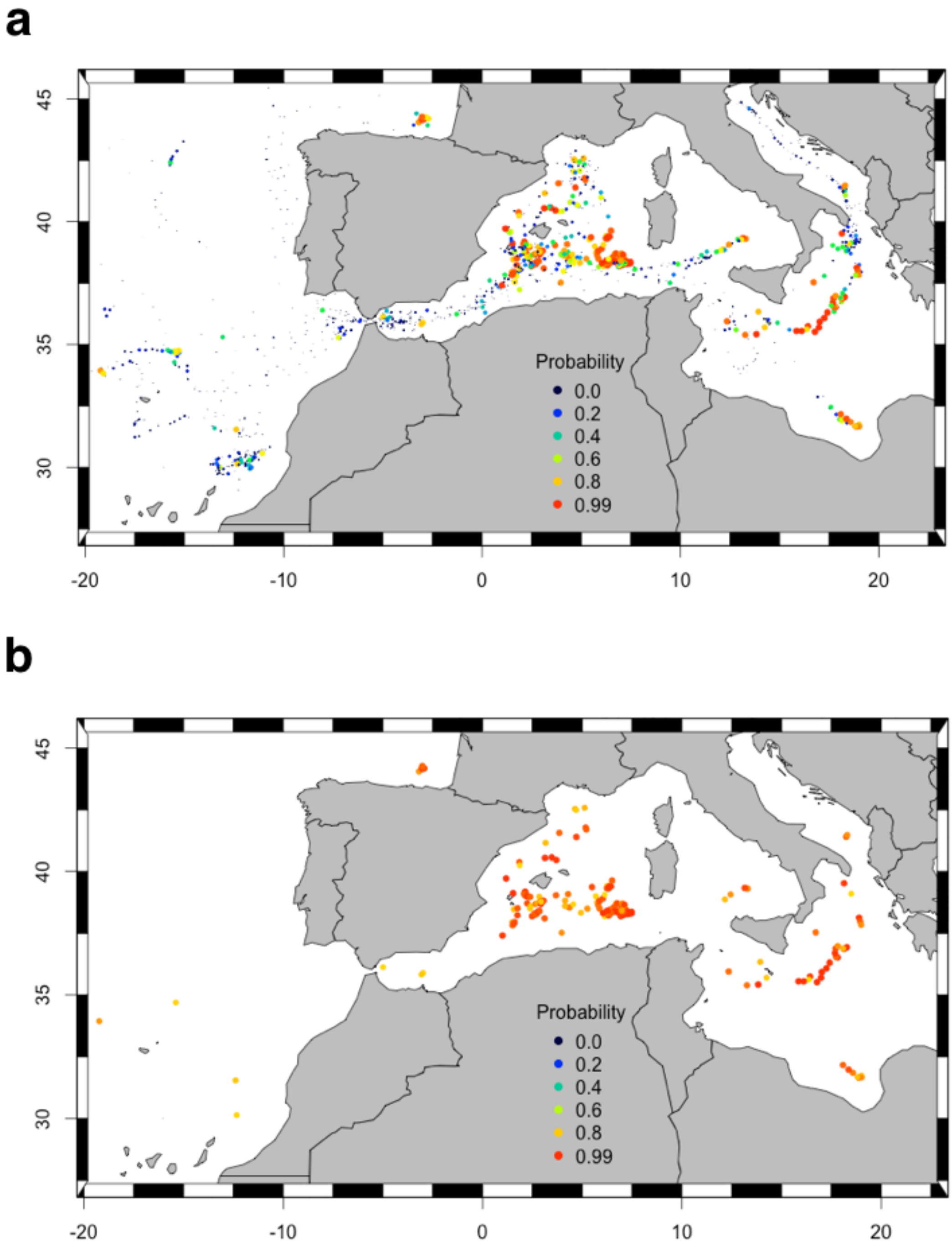

Figure 1. Best-fit reproductive state model predictions for tuna in their habitat envelope (Balearic Islands) and Mediterranean and East Atlantic Ocean. Model: Reproduction state ~ SST + diff_ther + TAD 0-20 m + velocity. AIC = 96.372 and total deviance explained of 54.53%: a) All reproductive events (236 of 3253

records) corresponding to 17 of 27 bluefin tuna trajectories predicted by the model and its respective probabilities of occurrence; b) Highest probabilities of reproductive events (> 75%) equivalent to 162 events from 16 tunas showing presumable spawning in 4 different areas within the Western and Central Mediterranean and in 3 areas in the Eastern Atlantic.

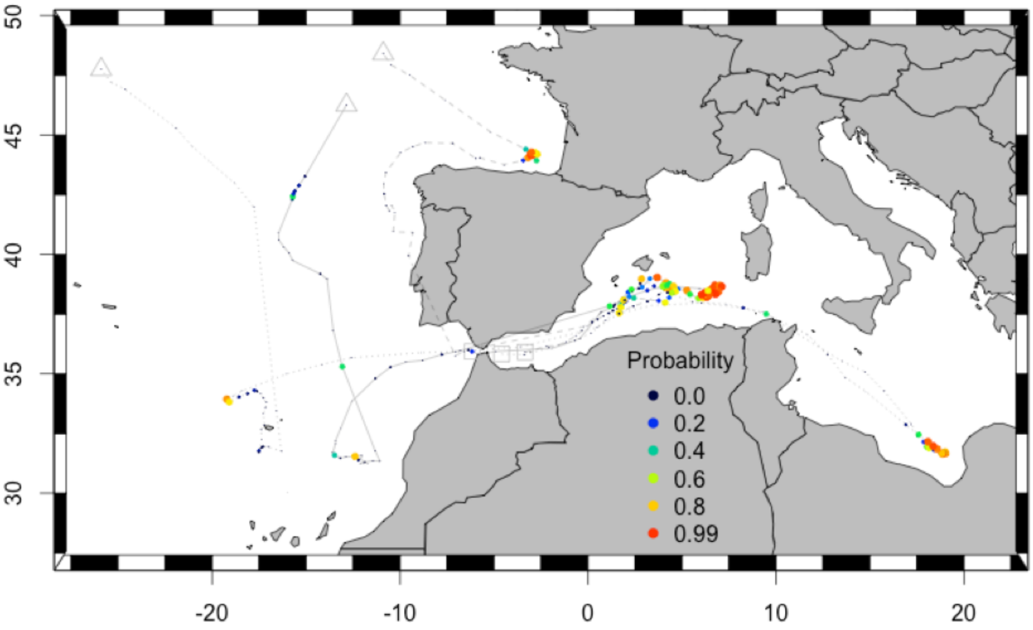

Figure 2. Reproductive events of the same tuna in more than one of the 4 different areas within the Western and Central Mediterranean or the 3 areas in the Eastern Atlantic. Highest probabilities of reproductive events (> 75%) for 3 different tunas are showed. See results section to a complete description of presumable reproduction events for these individuals.

TABLES

Table 1. Descriptive statistics of sea surface temperature, difference in temperature between 24 and 0 m (diff_ther), TAT 21-27 ºC, TAD 0-20 m and tuna velocity for individuals passing through the Balearic Islands spawning area.

	SST	diff_ther	TAT 21-27 ºC	TAD 0-20 m	velocity
Min.	18.510	-10.300	0.00	32.60	0.035
1st Qu.	21.180	-4.162	45.48	72.71	0.549
Median	22.010	-2.900	74.26	84.85	1.068
Mean	22.150	-3.350	62.26	80.51	1.548
3rd Qu.	23.020	-2.292	89.11	93.24	2.225
Max.	25.590	-0.167	97.10	99.22	9.267

Table 2. Model selection for the reproductive state of bluefin tuna from environmental and behavioral characteristics extracted from electronic satellite tag data. Df refers to degrees of freedom and AIC to the Akaike Information Criterion. The lowest AIC value is bolded and underlined.

model	**Df**	**Residual deviance**	**AIC**
rep. state ~ SST + diff_ther + TAT 21-27 ºC + TAD 0-20 m + velocity		85.494	97.494
rep. state ~ diff_ther + TAT 21-27 ºC + TAD 0-20 m + velocity	1	85.865	99.865
rep. state ~ SST + diff_ther + TAD 0-20 m + velocity	1	86.372	<u>**96.372**</u>
rep. state ~ SST + TAT 21-27 ºC + TAD 0-20 m + velocity	1	90.817	100.817
rep. state ~ SST + TAD 0-20 m + velocity	1	92.962	100.962
rep. state ~ diff_ther + TAD 0-20 m + velocity	1	98.759	106.759
rep. state ~ SST + diff_ther + TAT 21-27 ºC + TAD 0-20 m	1	114.979	124.979
rep. state ~ SST + diff_ther + TAD 0-20 m	1	125.774	133.774
rep. state ~ SST + diff_ther + TAT 21-27 ºC + velocity	1	125.851	135.851
rep. state ~ SST + diff_ther + velocity	1	140.122	148.122

Table 3. Deviance table for the parsimonious logistic regression model to predict individual reproductive state for tuna in their habitat envelope. Model: Reproduction state ~ SST + diff_ther + TAD 0-20 m + velocity. AIC = 96.372 and total deviance explained of 54.53%. Terms added sequentially (first to last).

	Df	Deviance Resid.	Df	Resid. Dev	Pr(>Chi)
NULL			139	189.947	
Velocity	1	42.322	138	147.626	7.743×10^{-11}
TAD 0-20 m	1	37.935	137	109.690	7.315×10^{-10}
SST	1	16.728	136	92.962	4.314×10^{-5}
diff_ther	1	6.590	135	86.372	0.010

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Table 4. Summary of reproductive events predicted with the most parsimonious model; mean, minimum and maximum of predictive variables and probability of reproductive state.

		SST			diff_therm			TAT 21-27 ºC			TAD 0-20 m			Velocity			Probability of reproduct state		
ID	repro. events	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	m
66697	39	26.243	21.680	28.618	-7.468	-10.956	-1.981	65.081	5.100	97.225	72.229	37.750	96.450	1.204	0.158	3.165	0.860	0.518	0
97462	5	24.627	23.085	25.742	-4.240	-5.100	-2.900	87.960	77.500	97.000	86.880	74.500	96.900	0.570	0.135	1.520	0.974	0.951	0
107360	40	24.371	21.000	35.650	-5.703	-12.600	-1.500	86.320	22.200	98.100	78.310	34.300	93.900	0.615	0.074	1.836	0.826	0.511	1
114006	24	23.079	20.232	25.455	-3.925	-6.700	0.050	81.798	0.000	98.000	89.723	67.650	96.975	0.673	0.083	1.835	0.869	0.521	0
114007	14	24.379	20.664	26.040	-2.276	-3.850	-1.050	86.541	12.625	98.750	80.802	69.425	98.025	0.561	0.122	1.388	0.790	0.551	0
114009	4	22.160	21.205	23.342	-0.917	-1.450	-0.050	41.115	0.000	88.900	90.652	84.775	97.000	0.618	0.406	0.844	0.643	0.506	0
118755	31	23.512	21.184	25.388	-4.564	-6.400	-2.775	82.646	32.700	95.567	92.277	80.550	97.967	0.720	0.051	1.953	0.925	0.625	0
118760	7	23.863	23.182	24.764	-2.348	-3.900	-1.167	73.830	19.425	98.000	84.724	78.750	91.867	0.737	0.106	1.423	0.773	0.511	0
120084	4	21.178	20.799	21.347	-1.827	-1.933	-1.775	16.606	0.250	32.100	93.206	91.025	95.375	0.395	0.245	0.536	0.725	0.694	0
120086	5	22.326	21.877	22.915	-3.420	-4.100	-2.700	78.888	51.800	96.175	80.695	74.200	86.725	0.365	0.095	0.677	0.626	0.523	0
120446	22	22.349	20.705	24.075	-2.997	-6.000	-1.500	77.342	1.000	97.500	90.539	78.750	98.950	0.646	0.075	2.057	0.782	0.564	0
130543	5	21.412	19.422	22.143	-2.990	-3.550	-1.600	67.710	0.000	94.925	98.008	96.375	99.367	0.709	0.147	2.141	0.810	0.540	0
137384	5	22.660	21.400	24.000	-2.943	-3.950	-2.300	86.415	74.700	93.850	86.290	71.500	92.625	0.527	0.035	0.867	0.750	0.596	0
137385	10	23.280	21.100	25.000	-3.690	-5.500	-2.100	84.318	0.000	97.050	93.570	85.333	98.667	1.256	0.409	2.568	0.878	0.613	0
147073	17	24.071	20.700	27.300	-3.578	-6.300	-0.800	77.767	13.300	96.500	82.997	65.600	94.900	0.926	0.094	2.401	0.798	0.532	0
118758B	2	19.994	19.827	20.162	-3.575	-3.750	-3.400	27.763	19.100	36.425	98.450	98.200	98.700	0.589	0.412	0.767	0.790	0.772	0
86238E	2	21.881	21.663	22.098	-3.975	-4.100	-3.850	27.113	22.500	31.725	81.788	79.975	83.600	0.714	0.695	0.734	0.513	0.504	0
Grand Total	**236**	**23.879**	**19.422**	**35.650**	**-4.496**	**-12.600**	**0.050**	**76.512**	**0.000**	**98.750**	**84.243**	**34.300**	**99.367**	**0.776**	**0.035**	**3.165**	**0.831**	**0.504**	**1**

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Table 5. Prediction of reproductive events with probabilities >75% showing reproductive areas and dates and means of predictive variables and probability of reproductive state.

ID	date Ini.	date final	consecutive days in repro.	days from last repro. window	mean SST	mean diff_ther	mean TAT 21-27 ºC	mean TAD 0-20 m	mean velocity	mean Lat.	mean Lon.	mean probability of reproductive state	Area
107360	10-Jun-11	10-Jun-11	0	NA	21.2816	-3.8000	97.1000	91.1000	0.5547	38.5960	2.4100	0.7937	Southwest from Mallorca, Southeast from Ibiza, Balearic Isl
107360	13-Jun-11	19-Jun-11	6	3	22.9815	-6.4286	95.7429	86.8286	0.4121	38.7340	2.8809	0.9272	South from Minorca, Balearic Isl
107360	29-Jun-11	11-Jul-11	12	10	24.3607	-3.2923	97.0846	89.0077	0.8318	39.1517	6.0648	0.9158	Sardino-Balearic plain, West from Sar
107360	22-Jul-11	22-Jul-11	0	11	24.5518	-9.4000	97.0000	80.5000	0.6964	40.4600	3.6990	0.9918	Magonis valley, Northeast from Mallorca Is
107360	24-Jul-11	24-Jul-11	0	2	24.1322	-6.5000	97.0000	90.7000	0.5018	40.5670	3.4660	0.9945	Off Mataro canyon head, Northeast from Mallorca Is
107360	27-Jul-11	27-Jul-11	0	3	24.1661	-7.9000	97.0000	90.8000	0.4827	40.5460	3.1300	0.9974	Off Mataro canyon head, Northeast from Mallorca Is
107360	05-Aug-11	05-Aug-11	0	9	25.8000	-5.4000	77.6000	70.1000	0.2517	38.9700	2.3870	0.9504	Mallorca Channel, West from Mallorca, Balearic Isl
107360	16-Aug-11	16-Aug-11	0	11	35.6500	-11.3000	50.0000	35.4000	0.6973	39.1160	1.5300	0.9996	Off Ibiza North coast, Balearic Isl
107360	22-Aug-11	22-Aug-11	0	6	26.3764	-12.6000	22.2000	79.2000	0.8538	39.7140	1.1790	0.9994	Off Valencia, Southeast from Columbretes Islands, North from
97462	20-Jun-11	20-Jun-11	0	NA	23.0850	-4.1000	97.0000	96.9000	0.3056	37.4020	0.9970	0.9897	Off Algiers, Algerian I
97462	28-Jun-11	28-Jun-11	0	8	24.2650	-2.9000	84.8000	87.3000	0.5466	37.8160	1.5080	0.9512	Algerian basin, South from Ibiza, Balearic Isl
97462	07-Jul-11	07-Jul-11	0	9	24.8873	-4.3000	89.7000	87.8000	0.3409	38.3800	2.7910	0.9902	Southwest from Mallorca, Southeast from Ibiza, Balearic Isl
97462	10-Jul-11	10-Jul-11	0	3	25.1564	-5.1000	77.5000	74.5000	0.1351	38.3980	2.8570	0.9611	Southwest from Mallorca, Southeast from Ibiza, Balearic Isl
97462	15-Jul-11	15-Jul-11	0	5	25.7424	-4.8000	90.8000	87.9000	1.5201	37.9010	1.5650	0.9755	Algerian basin, South from Ibiza, Balearic Isl
118755	31-May-12	08-Jun-12	8	NA	22.1549	-3.8185	75.4417	95.3037	0.3733	39.0703	2.1566	0.9477	Mallorca Channel, West from Mallorca, Balearic Isl
118755	14-Jun-12	14-Jun-12	0	6	21.9436	-2.7750	76.8500	96.3500	1.1249	38.3280	4.9340	0.8115	Mallorca Channel, West from Mallorca, Balearic Isl
118755	20-Jun-12	07-Jul-12	17	6	24.5564	-5.2009	89.3338	90.4662	0.7617	38.3688	7.0212	0.9638	Sardino-Balearic plain, Southwest from Sar
114007	29-May-12	29-May-12	0	NA	20.6638	-2.5750	12.6250	98.0250	0.5327	38.9740	2.8460	0.8155	South from Mallorca, Balearic Isl
114007	20-Jun-12	21-Jun-12	1	22	24.5561	-1.0750	94.4500	83.5000	0.3539	31.6580	19.0170	0.8840	Gulf of Sidra, I
114007	23-Jun-12	27-Jun-12	4	2	25.6116	-2.8683	93.8750	80.9900	0.8108	31.8616	18.5402	0.9178	Gulf of Sidra, I
114007	25-Jul-12	25-Jul-12	0	28	23.2241	-2.1333	93.9250	87.7250	0.4065	33.9360	-19.2320	0.8786	Northwest from Madeira Island, Atlantic O
114006	02-Jun-12	02-Jun-12	0	NA	22.2199	-4.4500	76.9500	96.9750	0.9549	39.0340	3.6790	0.9469	South from Mallorca, Southwest from Minorca, Balearic Isl
114006	04-Jun-12	04-Jun-12	0	2	21.9855	-4.4000	56.1250	92.3750	0.9935	38.8160	4.1420	0.8536	Southeast from Mallorca, Southwest from Minorca, Balearic Isl
114006	08-Jun-12	08-Jun-12	0	4	21.8809	-3.6667	93.8667	94.5667	0.7720	38.4880	5.2560	0.8894	Sardino-Balearic plain, Southwest from Sar
114006	11-Jun-12	13-Jun-12	2	3	22.3319	-3.5500	87.7056	91.7250	0.6023	38.2063	6.2567	0.8729	Sardino-Balearic plain, Southwest from Sar
114006	17-Jun-12	17-Jun-12	0	4	22.6773	-3.6000	90.7500	88.8500	0.2888	38.4930	6.5070	0.9283	Sardino-Balearic plain, Southwest from Sar

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ID	date Ini.	date final	consecutive days in repro.	days from last repro. window	mean SST	mean diff_ther	mean TAT 21-27 ºC	mean TAD 0-20 m	mean velocity	mean Lat.	mean Lon.	mean probability of reproductive state	Area
114006	18-Jun-12	18-Jun-12	0	1	22.8166	-3.8500	91.2667	92.4667	0.5316	38.5680	6.6180	0.9545	Sardino-Balearic plain, Southwest from Sar
114006	20-Jun-12	22-Jun-12	2	2	23.0649	-3.8361	91.1722	93.1722	0.5921	38.6863	6.9570	0.9521	Sardino-Balearic plain, Southwest from Sar
114006	24-Jun-12	30-Jun-12	6	2	24.6358	-5.3738	81.9357	87.1750	0.7458	38.3577	6.4694	0.9648	Sardino-Balearic plain, Southwest from Sar
114006	12-Aug-12	12-Aug-12	0	43	21.8261	0.0500	98.0000	95.4000	0.1865	31.5380	-12.3970	0.8065	Off Morroco, Northeast form Lanzarote Island, Atlantic O
66697	04-Jun-12	04-Jun-12	0	NA	21.6800	-3.2500	5.1000	93.1500	0.9189	39.0960	18.4930	0.7710	Ionia
66697	12-Jun-12	14-Jun-12	2	8	23.6521	-4.3104	94.5083	93.2167	1.0558	37.9747	18.9423	0.9466	Ionia
66697	21-Jun-12	21-Jun-12	0	7	24.9477	-5.9417	96.9750	89.3250	0.8194	36.5150	17.8160	0.9927	Ionia
66697	24-Jun-12	26-Jun-12	2	3	26.1672	-6.0653	86.1333	82.3000	1.3578	36.8900	18.1667	0.9389	Ionia
66697	01-Jul-12	04-Jul-12	3	5	27.3294	-6.3646	87.3938	76.4938	1.8105	36.7705	17.7355	0.9473	Ionia
66697	06-Jul-12	14-Jul-12	8	2	27.7920	-10.3229	28.9861	70.2111	1.1373	35.7739	16.6877	0.9697	East from Malta, South from Sicily, Ionia
66697	18-Jul-12	20-Jul-12	2	4	26.2957	-10.6208	70.9500	63.6583	1.0480	35.5003	13.7787	0.9087	Southwest from
66697	27-Jul-12	27-Jul-12	0	7	25.9353	-10.2625	69.5500	70.0750	1.8535	35.9420	12.3450	0.9356	West from
66697	31-Jul-12	31-Jul-12	0	4	25.8962	-7.0875	69.5750	67.7250	1.3760	36.3330	13.9270	0.8232	Northwest from Malta, South from
66697	04-Aug-12	04-Aug-12	0	4	27.5913	-8.4063	60.7000	59.5000	1.1484	37.5290	16.7120	0.9310	Off Calabria, Ionia
66697	17-Aug-12	17-Aug-12	0	13	27.3867	-7.9813	67.2000	67.1000	0.6813	39.5190	18.1340	0.9872	Off Apulia, Ionia
66697	15-Sep-12	16-Sep-12	1	29	24.2427	-4.9344	87.7375	84.2250	1.0155	41.4370	18.2695	0.9235	Adriatic plain, Adriati
120084	08-Jun-12	08-Jun-12	0	NA	21.3469	-1.7750	20.6250	95.3750	0.5358	34.6920	-15.3930	0.7786	South from Lion Seamount, North from Madeira Island, Atlant
120086	18-Jun-12	18-Jun-12	0	NA	22.9149	-2.7000	96.1750	86.7250	0.3832	38.4120	6.9820	0.8609	Sardino-Balearic plain, Southwest from Sar
114009	13-Sep-12	13-Sep-12	0	NA	23.3419	-1.4500	44.9250	84.7750	0.4064	30.1330	-12.3410	0.7762	Off Morroco, Northeast form Lanzarote Island, Atlantic O
118758B	16-Jun-13	17-Jun-13	1	NA	19.9944	-3.5750	27.7625	98.4500	0.5893	35.8580	-3.0245	0.7897	South from Alborán Island, Albora
118760	19-Jun-13	20-Jun-13	1	NA	24.0513	-2.7500	36.9250	85.5375	0.9097	38.9655	12.3015	0.8541	Northwest from Ustica Island, Tyrrhenia
118760	23-Jun-13	24-Jun-13	1	3	24.4869	-3.5000	77.5292	89.3208	0.9917	39.3165	13.2225	0.9452	North from Ustica Island, Tyrrhenia
130543	22-Jun-13	24-Jun-13	2	NA	22.0264	-3.2667	93.3583	97.4083	0.3730	38.2453	2.5793	0.9578	Southwest from Mallorca, Southeast from Ibiza, Balearic Isl
120446	24-Jun-13	26-Jun-13	2	NA	21.9801	-2.8111	74.2917	93.0667	0.4607	38.5640	4.2790	0.8789	Southeast from Mallorca, South from Minorca, Balearic Isl
120446	02-Jul-13	02-Jul-13	0	6	22.3378	-1.5750	92.9000	94.3500	0.8994	38.6680	4.5460	0.7820	Southeast from Mallorca, South from Minorca, Balearic Isl
120446	12-Aug-13	16-Aug-13	4	41	22.4455	-3.9900	96.1600	96.9933	0.4789	44.1486	-3.0324	0.9608	Landes plateau, Bay of Biscay, Atlantic O
120446	20-Aug-13	20-Aug-13	0	4	22.8294	-2.4000	97.0500	96.4500	0.6814	44.2710	-3.0250	0.9449	Landes plateau, Bay of Biscay, Atlantic O
137384	10-Jun-14	10-Jun-14	0	NA	22.2000	-2.9000	84.1750	84.5000	0.0355	38.5010	2.3800	0.8098	Southwest from Mallorca, Southeast from Ibiza, Balearic Isl
137384	14-Jun-14	14-Jun-14	0	4	24.0000	-3.9500	90.3000	90.2500	0.6812	38.7030	2.2380	0.9713	Southwest from Mallorca, Southeast from Ibiza, Balearic Isl

ID	date Ini.	date final	consecutive days in repro.	days from last repro. window	mean SST	mean diff_ther	mean TAT 21-27 ºC	mean TAD 0-20 m	mean velocity	mean Lat.	mean Lon.	mean probability of reproductive state	Area
137385	12-Jun-14	13-Jun-14	1	NA	23.2500	-4.8500	92.6500	93.3500	1.5702	38.4860	1.6590	0.8897	Southeast from Ibiza, Balearic Isl
137385	15-Jun-14	15-Jun-14	0	2	23.2000	-2.8000	97.0000	98.0000	0.5984	38.2250	1.7470	0.9776	Southeast from Ibiza, Balearic Isl
137385	17-Jun-14	17-Jun-14	0	2	22.8000	-3.1000	97.0000	98.0000	0.4089	37.9430	1.5990	0.9795	Prunes seamount, South from Ibiza, Balearic Isl
137385	21-Jun-14	21-Jun-14	0	4	22.9000	-4.2000	87.9000	88.8000	1.0168	37.9430	1.4960	0.8612	Prunes seamount, South from Ibiza, Balearic Isl
137385	26-Jun-14	26-Jun-14	0	5	23.4000	-4.1000	94.5000	94.9500	1.3657	38.2920	2.7240	0.9397	South from Mallorca, Southeast from Ibiza, Balearic Isl
137385	29-Jun-14	29-Jun-14	0	3	23.7000	-4.7000	90.4333	85.3333	0.4202	38.0980	3.1090	0.9591	South from Mallorca, Southeast from Ibiza, Balearic Isl
137385	16-Jul-14	16-Jul-14	0	17	25.0000	-2.3000	94.0000	90.8000	1.6810	37.5190	3.9640	0.8909	Off Algiers, Algerian
137385	07-Sep-14	07-Sep-14	0	53	21.1000	-3.9000	0.0000	98.6667	1.3623	36.1220	-4.9920	0.7749	Gibraltar valley, East from Strait of Gibr
147073	13-Jun-15	13-Jun-15	0	NA	22.3000	-4.7000	87.6500	91.8500	0.7065	39.0780	4.2850	0.9289	Southeast from Mallorca, South from Minorca, Balearic Isl
147073	19-Jul-15	19-Jul-15	0	36	25.5000	-2.6000	96.5000	92.3000	1.1042	41.3920	4.7030	0.9805	Off Palamos canyon head, South from the Gulf of
147073	05-Aug-15	05-Aug-15	0	17	23.3000	-6.0000	83.0000	85.6000	1.5191	42.5740	5.1160	0.8350	Off Grand Rh[one canyon, Gulf of
147073	08-Aug-15	08-Aug-15	0	3	25.2000	-2.9000	85.6000	83.7000	0.7435	41.5600	3.8480	0.9454	Palamos canyon head, Catala
147073	13-Aug-15	13-Aug-15	0	5	27.3000	-6.1000	28.9000	65.6000	0.6811	40.3750	1.8430	0.9580	Off Catalonia, Northwest of Mallorca Is
147073	17-Aug-15	17-Aug-15	0	4	25.4000	-0.8000	88.9000	82.4500	0.9155	41.1530	3.1600	0.8249	Blanes canyon head, Catala
147073	24-Aug-15	25-Aug-15	1	7	23.8500	-3.3500	83.6500	85.0000	0.1632	41.7350	5.1880	0.9535	La Renaixença hills, South from Gulf of
147073	31-Aug-15	31-Aug-15	0	6	23.2000	-6.3000	68.0000	77.0667	0.6296	42.5300	4.6360	0.8359	Off Montpellier canyon head, Gulf of
147073	02-Sep-15	02-Sep-15	0	2	23.1000	-3.5000	93.9000	91.0000	1.4455	42.4870	4.6900	0.7960	Off Montpellier canyon head, Gulf of
147073	23-Sep-15	23-Sep-15	0	21	24.1000	-2.6000	84.7000	82.8000	0.9598	40.2390	1.8610	0.7679	Off Catalonia, Northwest of Mallorca Is

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