Tagging Atlantic bluefin tuna from a Mediterranean spawning ground using a purse seiner

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1 TAGGING ATLANTIC BLUEFIN TUNA FROM A MEDITERRANEAN SPAWNING GROUND USING A

2 PURSE SEINER

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18 ABSTRACT

19

20 Atlantic bluefin tuna, *Thunnus thynnus*, is as an emblematic and commercially valuable large pelagic

21 species. In the past ten years, the purse seiner fishery in the Mediterranean has been representing

22 more than 50% of the catch and dominates its exploitation. Nowadays, purse seiners target large fish

23 and operate during the spawning season in the spawning grounds. Electronic tagging has shed a

24 considerable amount of light on the ecology and behaviour of bluefin tuna over the past twenty years.

25 However, such technique has hardly been applied on large bluefin tunas caught by the Mediterranean

26 purse seine fishery despite its major importance. The logistical constraints related to this specific

27 fishery, combined with the timing of migration of the fish and the requirements related to the handling

28 of such large animals to enable tagging in good conditions have made tagging from purse seines

29 complex. Here we detail such an operation, designed to bridge the knowledge gap on the migratory

30 behaviour of tunas targeted by the purse seine fishery. Three large bluefin tunas from the same school

31 were tagged during the fishing operation of a French purse seiner. The fish were tagged onboard in

32 less than 2 min and efficiently, avoiding any subsequent mortality. One fish migrated up to Ireland, one

33 was recaptured in the Alboran sea and the last one remained in Libyan waters. These results contrast

34 with those from tagging operations carried out in the Northwest Mediterranean, which underlies the

35 importance of tagging operations from purse seiners not only for understanding fundamental aspects

36 of the species behaviour, but also for accurately describing the movements of the eastern Atlantic

37 bluefin tuna stock in the context of its management.

38

1.INTRODUCTION

Atlantic Bluefin Tuna (*Thunnus thynnus*, thereafter referred as BFT) is an emblematic species, whose individuals can migrate across the Atlantic Ocean (Block et al., 2001; Fromentin and Powers, 2005; Rooker et al., 2007). BFT is currently managed as two-stocks, Western and Eastern, by the International Commission for the Conservation of Atlantic Tunas (ICCAT), but the two stocks display a substantial amount of mixing (Puncher et al., 2018). The Eastern stock is much larger than the Western one and Eastern catches represent about 90% of the total catch (ICCAT 2018 - task I). After a complex history of over-exploitation, successive stock assessments since 2008 have shown that the Eastern stock was recovering and increasing quotas were adopted (ICCAT, 2017). In 2017, the TAC for the Eastern stock was set to be 28000 tons in 2018, 32000 tons in 2019 and 36000 tons by 2020.

The Eastern stock is exploited by 25 countries and 11 different types of gears. Most of the catch, 66% in 2017, is made in the Mediterranean and is largely dominated by the purse seiners. Purse seine catches represent more than 90% of the Mediterranean catches and have been representing more than 50% of the overall Eastern stock catches over the past ten years (ICCAT 2018 - task I). They operate during a reduced season in space and time, mostly during June and concentrate on the spawning aggregations in the Balearic Islands, around Sicily and Malta, further south to Tunisia and off Turkey in the East, Libyan waters being now unexploited. This fishery has been managed by strict control measures since the enforcement of the Recovery Plan in the mid 2000s (ICCAT, 2017). The Croatian purse seiners in the Adriatic differ from the other purse seiners as they exploit substantially smaller fish (< 4 year-old). Over the past ten years, the largest purse seiner catch has been France, followed by Tunisia and Spain, representing 25%, 17% and 14% of the purse seine catch, respectively. The BFT caught by the purse seine fishery is predominantly transferred to farms, where the fish are caged and fattened until harvested.

Since the late 1990s, electronic tagging has shed a considerable amount of light on the ecology of BFT (Block et al., 2005; Fromentin and Lopuszanski, 2014; Teo et al., 2007). Electronic tags log temperature, pressure and light and transmit this information via the Argos satellite system after a pre-defined duration before release, often set between a few months and one year. This data allows scientists to reconstruct the trajectory of the tagged fish in time and space. A large number of tags have been deployed on BFT since this technique existed, covering various fleets and parts of the species' life cycle, with the aim of describing as accurately as possible its migratory routes and understanding the variability of these migrations (Abascal et al., 2016; Aranda et al., 2013; Arregui et al., 2018; Cermeño et al., 2015; Fromentin and Lopuszanski, 2014; Galuardi et al., 2010; Galuardi and Lutcavage, 2012). Tagging data are useful for management (Hays et al., 2019) and ICCAT has its own tagging program coordinated by the Atlantic-Wide Research Program for Bluefin Tuna (GBYP). The tracks obtained by tags deployed on BFT are used by the ICCAT Standing Committee on Research and Statistics (SCRS) working group not only to improve the understanding on the ecology of the species, but also to calibrate spatially explicit models, for instance in the context of the Management Strategy Evaluation process (ICCAT MSE). Since the start of the use of this technique, and owing to a larger research effort, substantially more tags have been deployed in the Western Atlantic than in the Eastern Atlantic and Mediterranean. This uneven tagging effort is the opposite to the catch intensity as the Western area only weighs about a tenth of the total catch.

Tagging BFT is not a trivial operation, specifically when the individual is large (e.g. > 70kg), as it requires a skilled crew, suitable boat and material to catch and appropriately handle these animals for tagging purpose (Rouyer et al., 2019). This constraints the ability of scientists to realize large-scale deployments of tags on large BFT and requires specific logistics. Rod and reel (recreative or professionnal) and traps are fishing gears that can provide fruitful opportunities for tagging BFT from the eastern stock. However this still leaves a deficiency of tagging in the main fishing segment, i. e. purse seined fish. Attempts for tagging purse seined BFT were made in the US coast (Wilson et al.,

93 2005), but tagging large fish from a purse seiner on the Mediterranean spawning grounds, the main

94 and key fishing segment of the eastern stock, has not been covered by tagging activities carried out by

95 the international scientific community.

96

97 The migratory behaviour of BFT is at the essence of the purse seine fishery, as it benefits from the

98 spawning behaviour of BFT, which aggregates for spawning in specific areas over a short amount of

99 time, typically mid-May to mid-July. In the northwestern Mediterranean BFT has been shown to display

100 strong residency (Cermeño et al., 2015; Fromentin and Lopuszanski, 2014), whereas Atlantic

101 individuals typically migrate within the Mediterranean in early spring and depart in July-August, often

102 seen as catches by the Morrocan and Portuguese traps (Fromentin and Powers, 2005; Rooker et al.,

103 2007). Catches of purse seiners are composed by fish gathering in the spawning grounds in the

104 Mediterranean. Understanding the migrations routes of the BFT targeted by the purse seiners is

105 therefore of importance for the fishery and the conservation of the species, specifically to assess the

106 relative importance of BFT exiting the Mediterranean after spawning.

107

108 Here we describe a tagging operation designed as a first step to address these aspects. After previous

109 work using farming cages to set-up a protocol to efficiently tag BFT (Rouyer et al., 2019), an attempt

110 was made to transfer the protocol to a purse seiner during the 2018 fishing season to assess the

111 feasibility of such an operation on larger fish. The French purse seiners operate in two main fishing

112 grounds, the Balearic Islands and Malta, which are both well documented spawning grounds in the

113 Mediterranean. Two French purse seiner operating off Malta were used for the operation. The tracks

114 obtained from the tagged BFT are then compared to tracks obtained from tagging operations in the

115 Gulf of Lions (french Mediterranean), which target a different component of the population in terms of

116 age and behaviour. As tag data serve as input for connectivity/migration matrices used in spatially

117 explicit models, it is critical to collect information about the migration patterns from large individuals

118 targeted by purse seiners in the Mediterranean Sea.

119 2.MATERIAL AND RMETHODS

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121 As tagging from a purse seiner involves complex logistics, the protocol has first been set-up in

122 cooperation with a Maltese fattening farm, MFF Ltd and has been described in Rouyer et al., 2019.

123 Tagging from a cage allowed to remove important constraints, such as the variability of the

124 meteorological conditions and the availability of fish, but also allowed to operate on fish with a lower

125 stress level as they are used to be held in a confined space. The following sections describe the

126 transposition of this protocol to a purse seiner.

127

128

129 2.1.Purse seine set

130

131 The French purse seine fishery operates mostly south of the Balearic Islands and south of Malta. The

132 purse seiner vessels that participated in this operation were the Saint Sophie François II (SSFII,

133 ICCAT serial number ATEUFRA00064) and the Saint Sophie François III (SSFIII, ICCAT serial number

134 ATEUFRA00065). The tagging team embarked on the purse seiner SSFIII from the harbour of

135 Birzebugga (Malta), on the 19th of June 2018, to rejoin the other vessels scouting the waters south of

136 Malta in search of BFT schools. The period was chosen late enough to avoid the bulk of the fishing

137 season associated with a higher probability of recapture, but early enough so that the post-spawning

138 migration was not at its highest and suitable meteorological conditions could be met. Flat sea and

139 sunny clear sky not only facilitate the operation, but also ensure that the fish remain as calm as

140 possible during the operation and would accept to be fed inside the purse seine for the tagging

141 operation. Such conditions were met the next day, on the 20th of June 2018 (Fig. 1). A school detected

142 in the early morning was captured by SSFII. A transfer cage was organised to transfer the fish the next

143 day, which left the whole day for the tagging trials. Dinghies were deployed around the purse seine to

144 maintain it opened until the transfer cage arrived.

145

146

147   2.2.Personnel and equipment

148

149   The purse-seiner SSFIII worked with his sistership SSFII and both crews, 13 people each, are

150   combined during the fishing and subsequent caging operations. Both ships have large decks and are

151   equipped with cranes. A piece of synthetic turf and a thick mattress were laid onto the free deck space,

152   so that the fish could be positioned appropriately for the tagging operation without hurting its lateral

153   line (Fig. 2). The location on the deck was also chosen so that the head of the fish could easily be

154   accessed by a sea water pump to supply the fish with oxygen while being held out of the water. One

155   crane was equipped with a stretcher specifically designed for such an operation, made of smooth

156   material to avoid scraping the fish skin and punctured with holes to let the water through. The stretcher

157   opening was equipped with a chain so that the fish could easily be maneuvered into it, whereas its

158   other end was closed with a rope, so that the fish would be held on the stretcher while being

159   maneuvered in the water and lifted onto the deck. The rope was designed to be easy to remove once

160   the fish needed to be released back into the sea. One crew member was tasked with operating the

161   handline. Two scientists were assigned the task to deploy the tags. One scientist was tasked with

162   covering the eyes and maintaining the water pipe into the mouth of the tuna and another one with

163   measuring the fish (curved forked length). Two crew members were tasked with removing the hook

164   with as much care as possible to avoid injuries. Three divers helped to maneuver the fish into the

165   stretcher placed into the water. One crew member operated the crane with the stretcher to move the

166   fish on the deck and in and out of the water as quickly and smoothly as possible. The ICCAT Regional

167   Observers on each of the fishing boat were present during the whole operation.

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170   2.3.Tagging

171

172   Wildlife Computers' minipats were used for the deployments. They were programmed to remain

173   attached on the fish over the course of one year. The tether was 15cm long and equipped with a large

174   Domeier anchor. A second anchor was added to reduce the lateral movements of the tag that could

175   hurt the fish and reduce deployment times (Fromentin and Lopuszanski, 2014). The main anchor of

176   the tags was inserted onto the base of the second dorsal fin. This location enables the anchor to get

177   tangled into hard bones, which increases the probability of long retention times (Cort et al., 2010). The

178   second anchor was directly inserted into the flesh. Chlorhexidine was used to treat all the material

179   before deployments.

180

181   The fish caught in the purse seine was fed with frozen sardine in order to induce feeding behaviour. A

182   long handline was prepared with hooks used by maltese longliners. A buoy was attached to the

183   mainline to help keeping the tuna at the surface. The hook was baited with frozen sardine and the line

184   was deployed in the purse seine. The purse seine was deployed to about 500m long and the fishing

185   boat was far from the center of the seine. Thus, the handline was deployed using a small boat placed

186   into the purse seine while baiting with frozen sardine, which concentrated the tunas and induced

187   feeding behaviour. The line was left sinking a few seconds and was towed back towards the purse

188   seiner. Once a tuna took the bait, the fish was towed back by the fishermen as quickly and smoothly

189   as possible to avoid exhaustion of the fish or to break the line. The school caught by the purse seiner

190   was composed of large fish, whose acceleration when taking the bait was so intense that the line often

191   broke. Once the fish was close enough to the purse seiner, the stretcher was deployed and the divers

192   maneuvered the fish into it. The stretcher was then lifted onto the mattress on the deck, where the

193   eyes of the tuna were immediately covered with a wet cloth and the water pipe inserted into its mouth.

194   While the hook was being removed, the tag was deployed onto the fish. The stretcher was then hauled

195   back into the water, outside of the purse seine, the rope of the stretcher opening was undone and the

196   fish was released.

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199   2.4.Comparison to tracks obtained from the Gulf of Lions

200

201   A dataset of 44 tracks obtained from deployments on BFT in the Gulf of Lions by a recreative rod and

202   reel fishery was used to compare to the tracks obtained from the present tagging operation with purse

203   seiners. This dataset was acquired through deployments made between 2007 and 2015 in

204   cooperation with recreational fishermen, off Marseille, after the spawning season, from August through

205   to November (Fig. 1). Full details about the methodology of the deployments are available in

206   (Fromentin and Lopuszanski, 2014). The tracks from the dataset were simply plotted next to the tracks

207   obtained from the present operation to highlight differences in their dynamics.

208   3.RESULTS

209

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211   3.1.Tagging operation

212

213   About 15 BFT were hooked on the 20th of June 2018. The handlines prepared were just about strong

214   enough to handle the large animals but most of the lines broke, the crimps used to tie the line slipped

215   and/or the hooks were bent open. Three BFT of 226 (BFT1), 189 (BFT2) and 206 cm (BFT3) straight

216   fork length were caught at 11h30, 14h30 and 15h30 respectively. The three fish did not fight more than

217   15 minutes each time and were towed smoothly towards the divers who could maneuver it into the

218   stretcher. Once a fish was hauled onto the deck, less than 2 minutes were needed to intubate it, cover

219   his eyes with a soft and wet cloth and remove the hook from its mouth as carefully as possible. The

220   fish was then measured and tagged before being released into the water. No tagging-induced mortality

221   was observed.

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224   3.2.Tracks

225

226   The retention times were 72 days, 62 days and 32 days for BFT1-3 respectively (Table 1). No

227   premature release was observed. Tags either indicated that the release pin broke or were recaptured.

228   BFT-2 appeared to have been recaptured by a fisherman in the Alboran sea as the tag moved onshore

229   following a straight line after it popped-up (Fig. 3). No tag was physically recovered. The GPE3 state-

230   space model algorithm from Wildlife computers was used to estimate the geolocation of the fish from

231   the tag data. BFT1 and BFT3 showed comparable dynamics as both fish reached the Alboran Sea in

232   about a month. They both went west of Sicily and south of Sardinia and via the Balearic Islands. BFT1

233   seemed to have passed more northern than BFT3 as it went via the island of Menorca before going

234 more south passing Majorca and south of Ibiza, whereas BFT3 went more directly south of Ibiza,

235 around where another major fishing ground is located. BFT1 reached the straight of Gilbraltar three to

236 four days before BFT3. Whereas BFT3 was recaptured at this point, BFT1 exited the Mediterranean

237 and followed the continental shelf along the Portuguese and Spanish coasts up to the Bay of Biscay

238 where it stayed for about three weeks from late July to the middle of August 2018. BFT1 then

239 continued its route towards Ireland where the release pin broke. BFT2 contrasted with these two

240 routes. The fish did not attempt any large scale movement, so whilst BFT1 and BFT3 were setting off

241 for the Atlantic, BFT2 went south into Libyan waters where it stayed two months until the tag popped-

242 off in late August.

243

244

245 3.3.Comparison to the Gulf of Lions dataset

246

247 The 44 tracks from tagging operations realized in the Gulf of Lions between 2007 and 2015 were

248 plotted next to the tracks obtained from the purse seiner deployment reported here. This dataset

249 spans fish of various sizes (up to 237cm) comparable to the ones tagged from the purse seiner and

250 exhibit times at liberty of up to a year. The fish were tagged after the spawning season, from late July

251 to November off the city of Marseille. Not one single fish from this dataset made its way out of the

252 Mediterranean. The closest attempt was a fish that just crossed the Straits of Gibraltar and

253 immediately after headed back to the Gulf of Lions, close to where it was tagged. This contrasted with

254 the present results that displayed one fish exiting the Mediterranean an another one that seemed to be

255 on its way to do so before it was captured.

256 4.DISCUSSION

257

258 The operation described here presents a successful tagging attempt of large BFT in one of their

259 Mediterranean spawning ground, during the spawning season. The tags deployed during this

260 operation document the migration of individuals targeted by the largest fishery segment operating on

261 BFT. A past operation using purse seiners in the US coast used harpoons to tag the animals (Wilson et

262 al., 2005). Our results show that tagging large individuals from the spawning grounds on the deck of

263 purse seiners is possible. The tracks obtained from these deployments contrast with the results

264 obtained by tagging operations performed in other areas, periods and gears. This manuscript

265 underlines the importance of such operations to fully grasp the migratory behaviour of BFT in the

266 Mediterranean.

267

268 Results obtained from other tagging operations in the northwest Mediterranean have displayed

269 relatively strong fidelity to the Mediterranean (Cermeño et al., 2015; Fromentin and Lopuszanski,

270 2014). In contrast, the results obtained in the present manuscript tend to suggest migrations outside of

271 the Mediterranean, but this will have to be confirmed by more tracks. These different patterns can be

272 explained by different factors, one being the period of the operation. Post-spawning tagging operations

273 are often favoured as tagging before the purse seine fishing season is increasing the likelihood of

274 early recaptures that reduces the probability of long tracks. In addition, a large number of tagging

275 operations in the Mediterranean are carried out in cooperation with recreative fisheries, which also

276 operate more easily in summer (Cermeño et al., 2015; Fromentin and Lopuszanski, 2014; Stokesbury

277 et al., 2007). This induces a bias on the migratory patterns captured by the tags deployed, as tagging

278 BFT after the spawning season targets fish that did not migrate outside the Mediterranean, such as

279 BFT2. In addition, recreative fisheries operate nearer to shore than professional ones where large

280 schools are less frequent. The group dynamics captured is thus likely to be different compared to the

281 group dynamics of individuals from the spawning grounds, where large aggregation of fish are

282   commonly encountered. Tags deployed from the spawning grounds and during the spawning season

283   therefore target individuals likely to have a different behaviour than the fish targeted by recreative

284   fisheries. One fish over the three released was recaptured, but not enough tags were deployed to

285   strictly assess whether a larger amount of early recaptures happened than during other periods.

286   Regarding deployment times, a salient aspect was the failure of the release system of the tag ("pin-

287   break") that impaired the retention times achieved by the tags deployed during the operation.

288

289   Given the right conditions and the right technique, tagging from a purse seiner can be an advantage in

290   terms of logistics, as purse seiners often catch a very large amount of BFT in less than a day. The first

291   attempt described in the present manuscript show that 3 fish could be tagged in less than an hour of

292   cumulative time, although the technique presented has also a lot of room for improvement, as only

293   three tunas were tagged when about 15 of them had actually been hooked. Compared to the

294   operation carried out in fattening cages (Rouyer et al., 2019), decking the tunas from the purse seine

295   proved to be much more complex. The main problematic aspect was the size and the strength of the

296   individuals captured that broke the handlines deployed. Improving the strength of the material used for

297   the handlines, shock-leader and hooks, should improve this aspect for future operations. Yet, the

298   technique still enabled the decking of a fish estimated to weigh 250kg (BFT1) in less than 15mn. The

299   rate at which the tunas were taking the baits suggested that 15 fish tagged during one day is not an

300   unrealistic target given that the right meteorological conditions are met. Such large scale deployments

301   repeated on different schools would provide a unique source of insights into BFT migratory behaviour.

302

303   Besides bridging a gap by describing the migratory behaviour of BFT targeted by the largest fishery

304   and being appropriate for large scale release and group dynamics studies, tagging BFT from the

305   spawning grounds is an opportunity to draw a clearer picture of BFT migrations. Spawning grounds,

306   where the purse seine fishery operates, are areas where BFT from different size classes and

307   potentially different behaviour mix (Fromentin and Powers, 2005; Mather et al., 1995; Rooker et al.,

308   2007). Tagging from such an area could therefore allow scientists to capture a large range of migratory

309   behaviours, which would draw a clearer picture of the relative importance between resident individuals

310   and individuals migrating outside of the Mediterranean. Our results illustrate this aspect, as it showed

311   that fish from the same school, and whose tagging conditions were as similar as possible, displayed

312   very different migratory patterns. The trajectory of BFT1 was consistent with observations of BFT

313   migrating to northern latitudes during the recent past years, as the fish went straight to Ireland after

314   spending some time in the Bay of Biscay. BFT3 seemed to also exit the Mediterranean, whereas BFT2

315   displayed a more residential behaviour in Libyan waters.

316

317   From a management point of view, and in the context of climate change, understanding the migratory

318   behaviour of BFT is of key importance. For instance, within ICCAT, the ongoing Management Strategy

319   Evaluation process uses spatially explicit model that requires migration rates between areas to

320   capture the movement of the stock. ICCAT therefore encourages tagging activities, as accurately

321   depicting migrations and exchange rates between areas from the major fisheries segments is of key

322   importance. The operation described here is thus an important step to enable the international

323   scientific community to move forward in that direction, providing information from the largest BFT

324   fishing segment.

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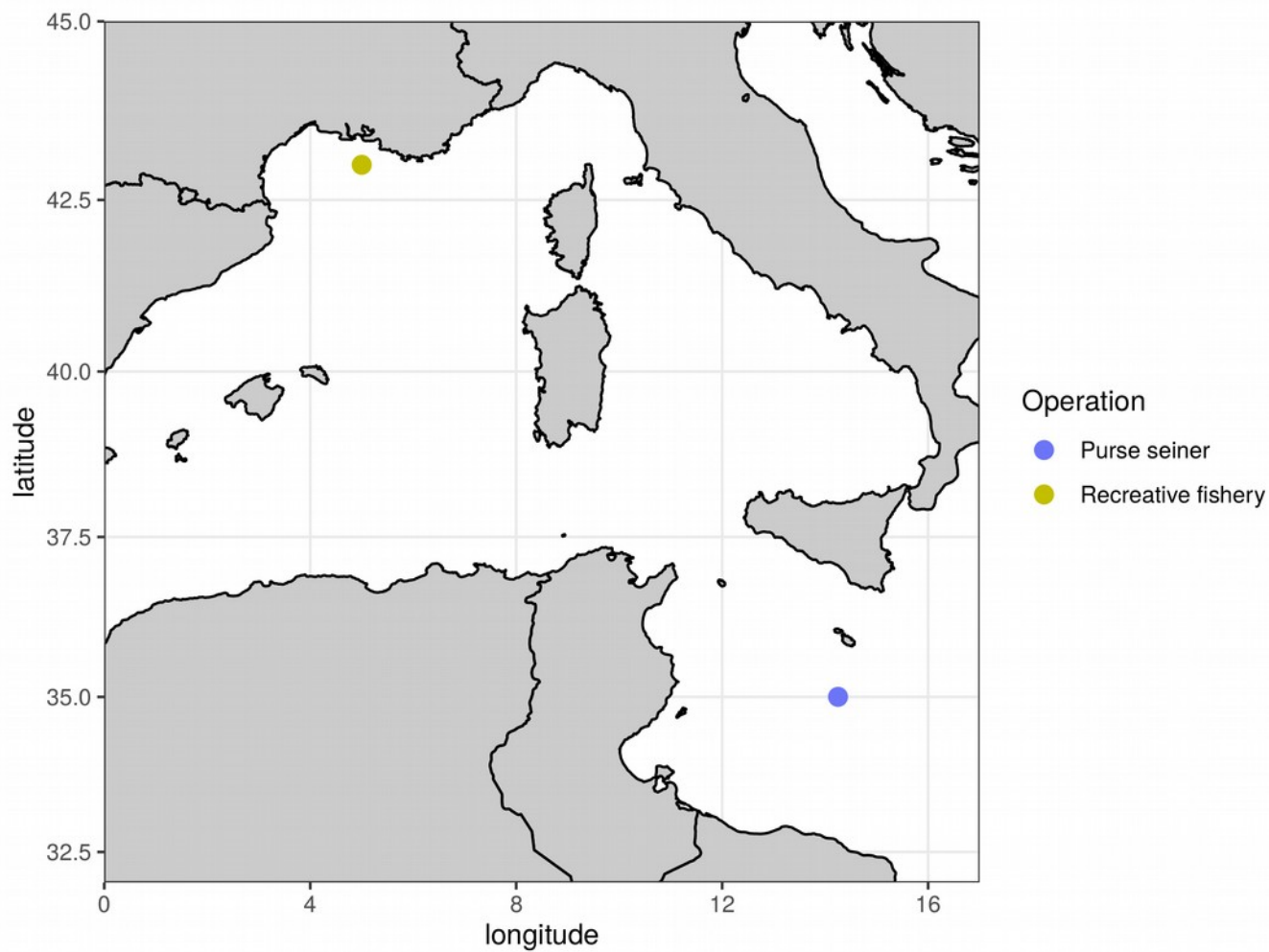
335 TABLE

336

337 Table 1: Information about the three tags deployed.

| Tag	Straight fork length (cm)	Time of tagging	Time at liberty (days)
BFT1	226	11h30	72
BFT2	189	14h30	62
BFT3	206	15h30	32

338

Figure 1: Location of purse seiner and recreative fishery tagging operations.

342

344 Figure 2: Main steps of the tagging operation. From top left to bottom right. A school of tunas

345 was captured by the purse seiner SSFII. The purse seine was maintained open while waiting

346 to transfer the fish into a cage. A dinghy was placed in the purse seine to deploy the baited

347 handline, which was left to sink a few seconds and then slowly towed from the vessel. Once a

348 tuna was hooked, it was towed in as fast and smoothly as possible. A clean space over the

349 deck was prepared with a mattress and a water pipe. Once the tuna was close enough to the

350 boat, three divers manoeuvered the fish inside a stretcher attached to a crane. The fish was

351 then hauled onto the deck and then tagged using a double anchorage. It was immediately

352 released outside of the purse seine.

353
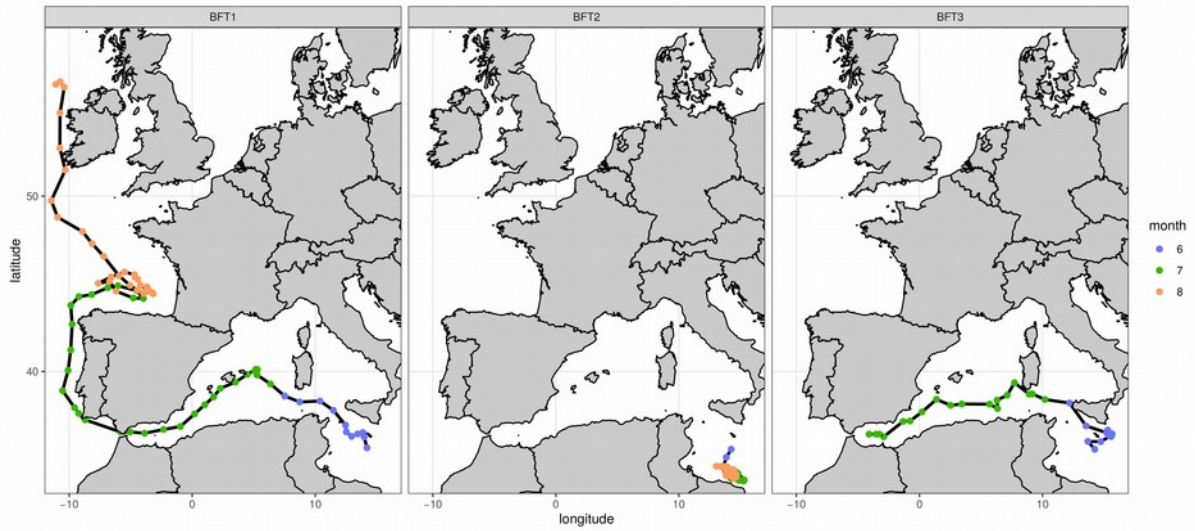
Figure 3: Tracks of the fish tagged during the operation obtained from Wildlife Computer's GPE3 algorithm.
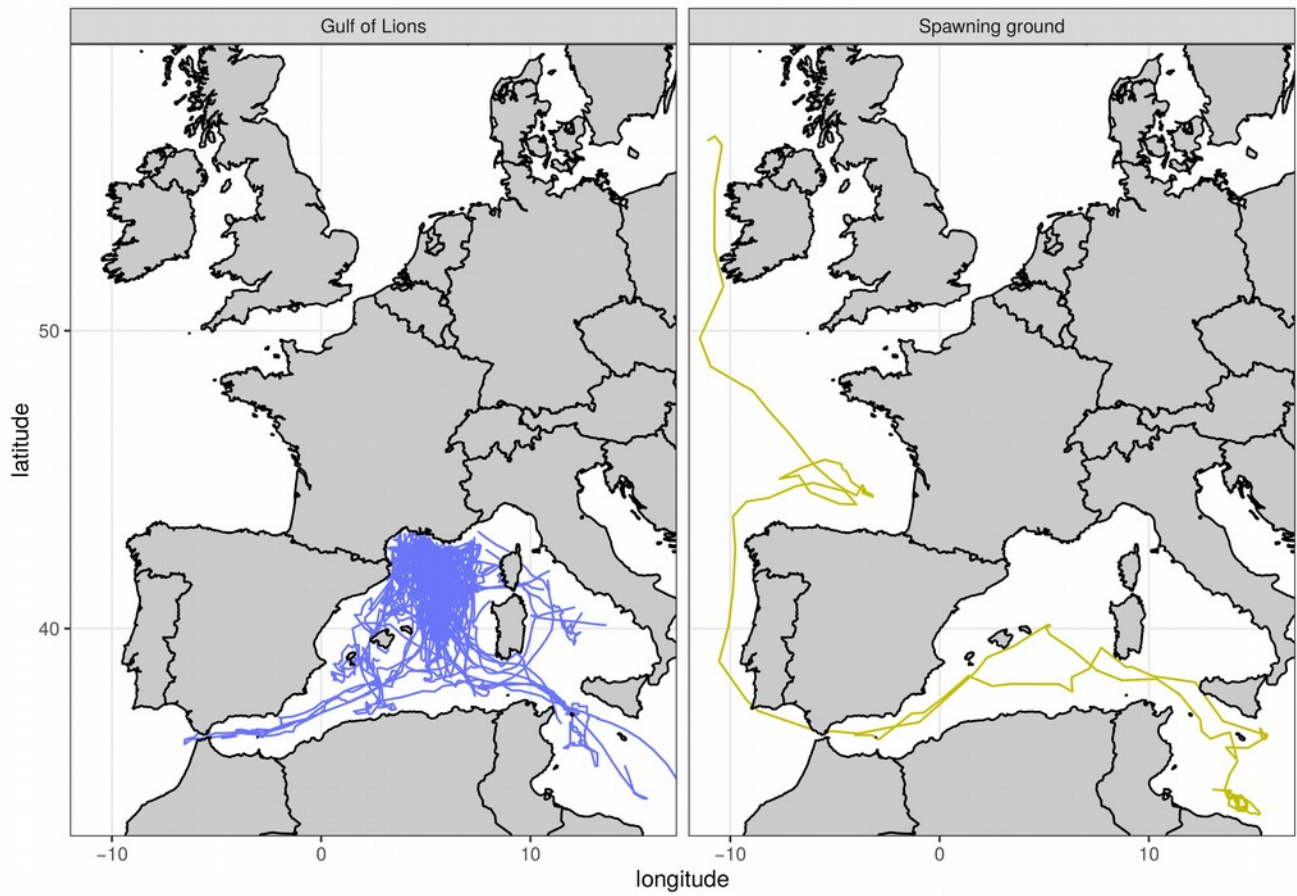
Figure 4: Comparison of the tracks obtained from the tagging operations in the Gulf of Lions and from the Purse Seiner.