Mark-recapture abundance estimate of undulate ray in the Bay of Biscay

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Summary

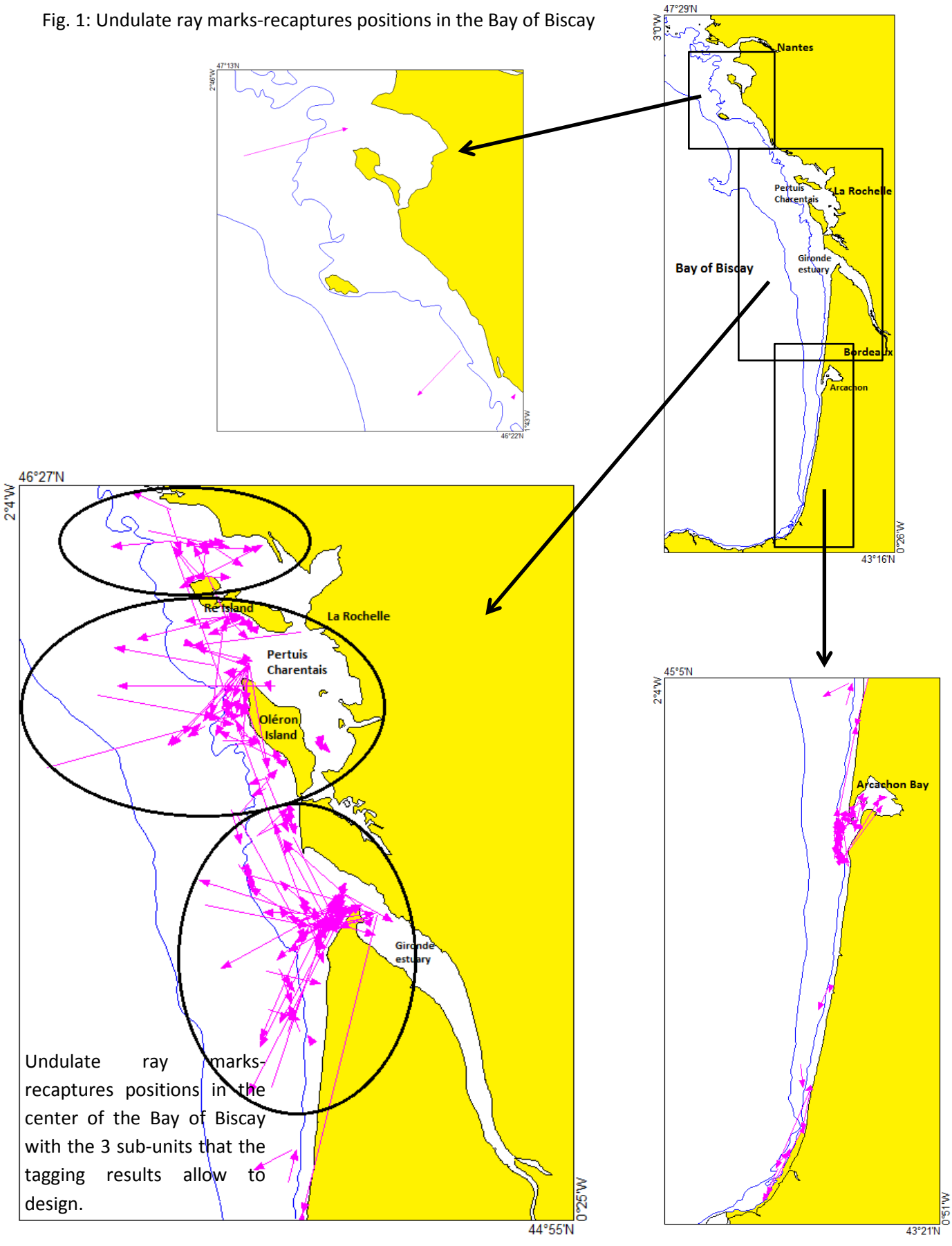
An undulate ray (*Raja undulata*) tagging survey was carried out from the end of 2011 to mid-2014 in the Bay of Biscay with the partnership of the fishing industry. It demonstrates that the undulate ray can be found all along the French coast from the Loire estuary to the Spanish boarder, forming several isolated units, the more important being likely in the central part of the Bay of Biscay (Pertuis Charentais – Gironde area). Even in this latter limited area, the population is structured in sub-units with a low exchange rate between them. This population structure allowed to estimate abundance by mark-recapture in the Gironde estuary, using a Petersen estimate. The conditions that must be respected for such closed population abundance estimate are analysed. The conclusions are that as long i) long-line catch of rays longer than 65 cm are used to the be sure to have an equal capture probability and no recruitment effect, ii) recaptures are within 4.5 month from the tagging date in winter to neglect tag losses and iii) number of tagged rays is corrected for emigration and mortality, an abundance estimate can be provided. The biomass of undulate rays longer than 65 cm in the inner Gironde estuary can thus be estimated to range from 51 to 70 t in the 2013-2014 winter (95% confidence interval is 30-124 t). This first trial allows to have some guidelines for future mark-recapture estimates of the abundance of a species for which the use of other methods may be difficult.

Introduction

As presented at the 2013 WGEF (Delamare *et al*., 2013), an undulate ray (*Raja undulata*) tagging survey was launched by the end of 2011 in the Bay of Biscay. This project was carried out up to 2014, gathering scientists of several organizations (Ifremer, CREAA, Apecs and Aglia) and fishermen. Is was supported by all the regional fishermen organizations from Loire estuary to the Spanish boarder, which is the part of the French coast along which extend the main fishing grounds of the undulate ray in the Bay of Biscay (Moreau, 1880). The aim was first to investigate the stock structure of this species of which the distribution is known as being patchy (Ellis *et al*., 2012).

The evidence of an isolated unit in the central part of the Bay of Biscay (Pertuis Charentais – Gironde area) was demonstrated by the preliminary results of this tagging survey which were presented at the 2013 WGEF. It was showed by 98 recaptures on 1700 tags deployed from November 2011 to May 2013. The increase in recaptures up to 265 as well as in that of deployed tags to 2858, from the beginning of the project to May 2014, confirms this stock structure, even if there is one observed trip from the Gironde estuary to the mouth of the Arcachon Bay (Fig. 1). Furthermore, additional tags deployed north and south of the Pertuis Charentais – Gironde area confirm the likely low exchange rate between units.

Fig. 1: Undulate ray marks-recaptures positions in the Bay of Biscay



Undulate ray marks-recaptures positions in the center of the Bay of Biscay with the 3 sub-units that the tagging results allow to design.

The split of the Pertuis Charentais – Gironde unit in three sub-units is also confirmed (Fig. 1) even if, here again, there is one exception with an observed trip from the northern mouth of the Pertuis Charentais to south of the Gironde estuary. This distribution in closed units gave the opportunity to carry out a mark-recapture abundance estimate as discussed in the WD presented at the 2013 WGEF.

The mark-recapture survey

Originally, the aim was to carry out a recapture survey by planning fifteen fishing days in autumn 2013 on chartered vessels with the following spatial repartition: 1 fishing day in the North of the Ré Island, 7 in the North and West of the Oléron Island, 7 in the Gironde estuary mouth.

But, despite the fact that 912 undulate rays were caught, no recapture was observed. The catch rate was obviously too low as well as the fishing effort likely not enough largely distributed. However, because these chartered trips were also used to tag 286 rays and because a partnership with the fishing industry was possible to get the recapture observations in the beginning of 2014, both gave a classical mark-recapture survey in two occasions separated by 4-5 months.

Fishermen were requested to report (by fishing day): date, position and number of rays, split by individual weight over and below 2kg and information on tagged rays, if any. The choice to split catch between less and more 2 kg was to sort rays by a criteria easy to be implemented by fishermen. According to available weight-length relationship (Dorel, 1986), it fits with a split between rays shorter and longer than 65 cm in total length. An abundance estimate should consequently be possible for rays at a size above which selectivity and recruitment bias are limited (Delamare *et al*, 2013).

This partnership allowed to get 175 fishing days with undulate ray catch information, but most of them in the Gironde area and in March-April 2014 (Table 1).

Table 1: Number of fishing days with undulate ray catch information got from the industry partnership in 2014

Area	Jan.	Feb.	March	April	May	Total
North of the Ré Island	0	0	0	0	0	0
North and West of the Oléron Island	1	5	14	33	2	55
Gironde estuary mouth	17	0	30	67	6	120
Total	18	5	44	100	8	175

This higher sampling effort for recapture in the Gironde area was also preceded by a higher number of tagged rays in this area in October-November, mainly at a length longer than 65 cm (table 2). Not surprisingly with such gaps between area and length group numbers, the recaptures were observed nearly all in the Gironde area. Their number reached 14 and all of them were rays longer than 65 cm. Consequently, **the Gironde area is the sole area for which undulate ray abundance can be estimated by mark-recapture. Furthermore, this abundance estimate must be restricted to the rays longer than 65 cm** to correspond to the recapture lengths.

Table 2: Number of tagged undulate rays in October-December 2014 (285 out of 286 during the chartered trips)

Area	Number<65cm	Number≥65cm	Total
North of the Ré Island	0	9	9
North and West of the Oléron Island	6	61	67
Gironde estuary mouth	28	183	211
Total	34	252	286

The tagging data

Three important conditions are necessary to estimate abundance by the simplest mark-recapture method, using the Petersen estimator (Pine *et al.*, 2003):

1. The capture probability is equal among all animals in each sample,
2. The marks are not lost or overlooked,
3. The population is closed to additions (recruitment or immigration) or deletions (deaths or emigration).

Capture probability

The fish length is likely the main factor that might have an effect on the capture probability if the gear is selective. The recapture survey and the partnership with the fishing industry were both mainly carried out on long liners as recommended by the 2013 WD (Delamare *et al*., 2013). Indeed, the long line is the most appropriate gear to catch larger fish as it has been confirmed by the November 2013 catch during the chartered trips (Fig. 2). Furthermore, the selectivity effect is likely small for this gear when fish are longer than 65 cm according to the comparison of its length distribution to the large mesh net one (Delamare *et al*., 2013). Consequently, **the capture probability during the recapture survey is likely little affected by the length of the fish as long the long line is used and the length above 65 cm**. It can also be thus assumed that that the long-line catches provide a fairly good representation of the length distribution in the local population above 65 cm.

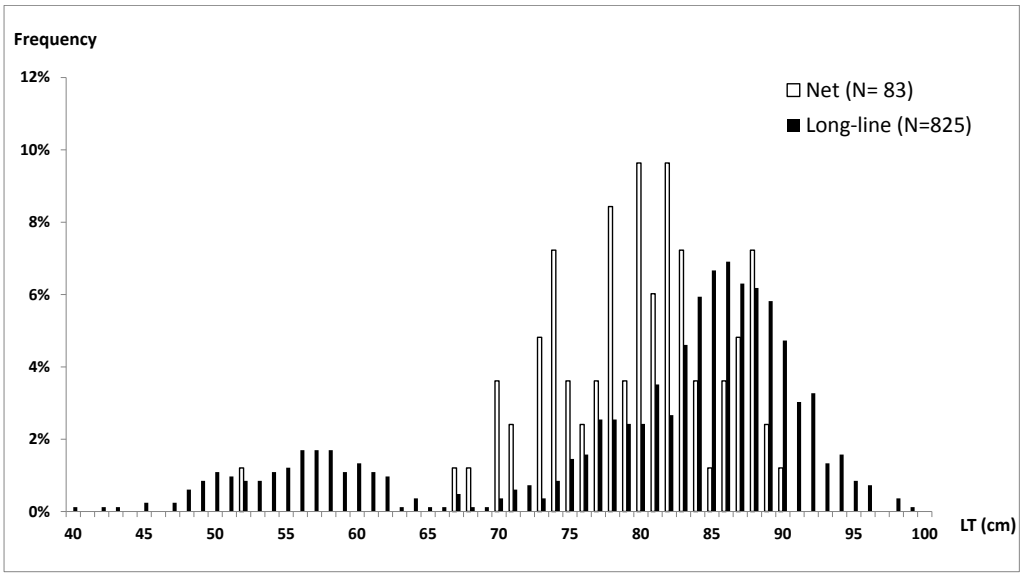


Fig. 2: Total Length (LT) frequency in undulate ray catch by gear in November 2013 (chartered trip).

The distribution of the tagged rays by length in the population can then be estimated by the ratio of the tagged frequency to the long-liners catch frequency by length. From 76 to 94 cm, this index ranges between 0.23 and 0.46 with no trend, the mean being 0.34 (Fig. 3). Lower values are observed below 75 cm and higher ones above 94 cm, but given that the abundance estimate must be limited to individuals longer than 65 cm, this two extreme sides of the length distribution contribute respectively only for 5 % and 4 % of the long-line catch. Assuming that the population length distribution is close to the long-line one above 65 cm, the tagged ratio in the population varies consequently slightly with the length for more than 90% of the population. **The capture probability of tagged fish can be thus considered to be likely little affected by the length of the fish, as long this latter is above 65 cm and the long-line is the gear.**

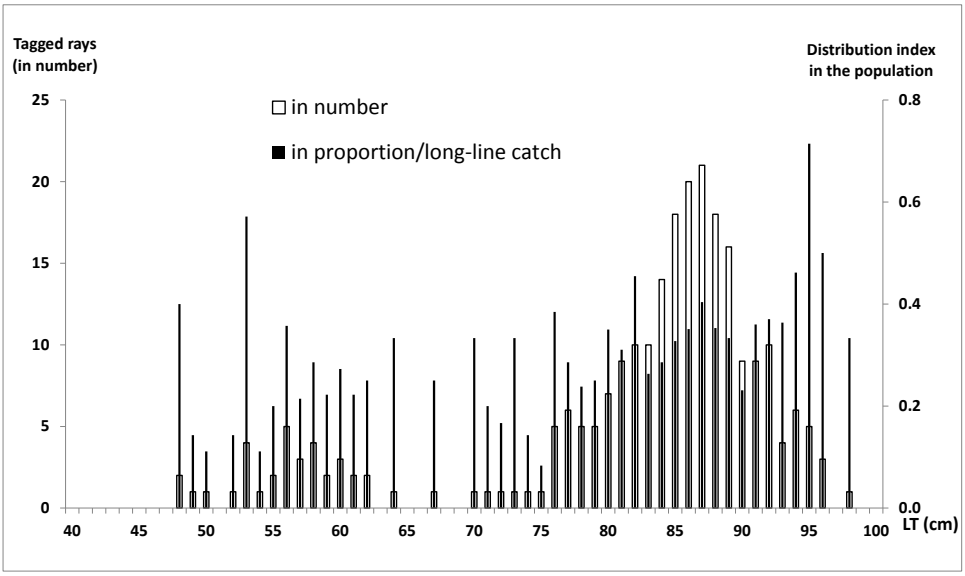


Fig. 3: Length (LT) distribution of the undulate ray tagged in November 2013 (absolute number) and their proportions in the long line catches (chartered trips).

Tag loss

There were several reports of ray caught by the tag in a net and, in one occasion, a tag was found alone in a net. Some fishermen reported that some individuals had been caught with an injury corresponding to the usual place of Petersen disk or with only one of the two plastic disks forming the tag. There is consequently no doubt that tag losses occur and they are likely principally due to a catch by a fixed net.

An attempt to estimate the tag loss percentage was planned by tagging 292 rays with a spaghetti tag and a Petersen disk in May-June 2013. 24 of them have been caught again latter but only 3 after more than 5 months. The other recaptures were before or near 2 months at liberty (1.5 and 2 months for 17 out of 24). None of these rays has lost its Petersen tag before 2 months but one of the rays at liberty more than 5 months has lost it.

It is difficult to draw out conclusions from this limited number of recaptures, except that there is likely a low risk to have tag losses before 2 months, during the period and in the area of this double tagging. This one was carried out in May-June. In this period the fixed nets are set much more frequently in the coastal area than in winter. This observation let hope that the risk of tag loss is low when a mark-recapture survey is 4.5 months after the tagging survey and mainly in winter and in spring first half. Consequently, tag loss will be **neglected** for the population estimate that this mark-recapture survey may allow.

Closed population conditions

a) Recruitment

The length distribution in catches shows (Fig. 2) that age groups are likely different below and above 65 cm. The rays longer than 65 cm form a group which is likely 6 years old and more, according to available growth-model parameters (Moura *et al*., 2007). This group should not be increased by any year class arrival or the body growth during a mark-recapture survey limited to less than 5 months, furthermore when this survey is carried out in winter when the growth must be low. Consequently, it can be assess that **the rays longer than 65 cm form a group which is closed regarding recruitment in winter**.

b) Immigration or emigration

Regarding immigration or emigration, the tags deployed in November-December and in the Gironde estuary from 2012 onwards show that the trips do not appear oriented in the months that follows the tagging. A large proportion is caught again in the Gironde mouth en April-May. In January-February, all the recaptures are outside the inner Gironde area but that is likely because these rays are caught by netters of the sole fishery which are fishing in more offshore waters in winter. Furthermore, one trip from the western part of the Gironde area to the inner Gironde mouth is observed among the few recaptures of tagged rays in the outer Gironde area. In percentage, from January to April 20 % is thus observed to move outside the inner Gironde area against 33 % to move inside. The moves appear so to be balanced between exits from the inner Gironde estuary and entrances in this area where the tagging and most of the recapture trips were carried out.

However, because the recapture observations are mainly less than 7 nautical miles far from the tagging positions, it makes sense to consider that the rays which move farer than 7 nautical miles have little chance to have been caught again during the recapture survey. To estimate the probability of such trips in the tagged ray population, the recapture numbers have been figured in relation to the distance from their tagging positions when the gears are the fixed net targeting sole or the trawl because the fishing effort of these gears is likely well spatially distributed over the undulate ray distribution area. The other reported gears are mainly used in the coastal area and consequently their use might give a biased figure of the ray mobility.

The time at liberty was fixed between 3 and 6 months, to be within the range of values observed during the recapture survey. Two cases were considered:

1) Selection of tags deployed only in the last quarter of the year and with a recapture from February to May, to be as close as possible to the mark-recapture survey period without limiting too much the number of observations,
2) No selection of the tagging or of the recapture period, assuming that trips have the same amplitude all along the year.

In the first case, when tagging and recapture periods are in accordance with the mark-recapture survey, 63 % of the observed distances are below 7 nautical miles (Fig. 4). This percentage increase to 79 % in case 2 when there is no selected period. The probability that tagged rays have remained in the area of the recapture survey from November to May will be assumed to be comprised between these two values. **This result allows to correct the number of tagged rays to estimate the size of the tagged ray group that**

remains in the inner Gironde estuary. The latter forms a group for which the closed condition is respected regarding immigration or emigration.

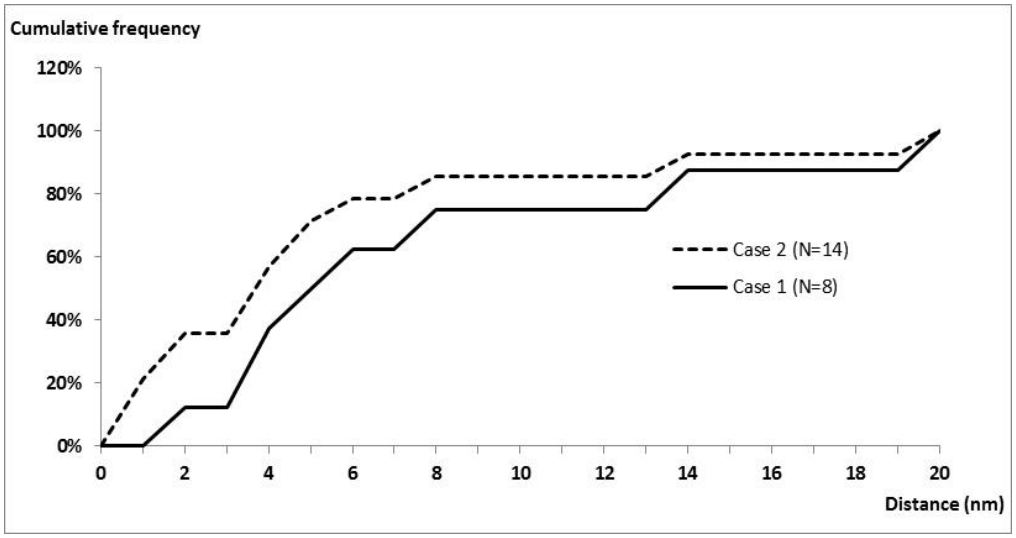


Fig. 4: Cumulative frequency (in %) of sole netter and trawler recaptures when the distance from the tagging position increases (Case 1 when tagging and recapture periods are in accordance with the mark-recapture survey; Case 2 when no selected period).

c) Mortality

Mortality should be limited to natural mortality because of the ban of landings. Coelho *et al.* (2002) estimated it to be about 0.2 for undulate ray of the southern Portugal. Serra-Pereira *et al*. (2013) estimate it a bit higher (0.24 to 0.27) in the northern and central part of Portugal. It corresponds to a 7% to 10% decrease of the population in 4.5 months, which is the mean time at liberty of the recapture rays (long-liners). The fishing mortality caused by accidental catch is likely low and will be neglected, considering the uncertainty on the natural mortality estimate.

However, a 6 % post-tagging mortality has been shown by a rearing experiment carried out in 2011 (Hennache, 2013). This value must be considered as indicative only, given the limited number of fishes on which it was estimated. A 3 to 9 % range will be assumed to be plausible.

Consequently, a 10 to 19 % range can be proposed for the removals by mortality of the tagged rays before their recapture. **This estimate allows to correct the number of tagged rays for mortality** and to get the number the tagged ray group that survives in the inner Gironde estuary up to the end of the recapture survey. **With this correction, this latter forms a group for which the closed condition is respected regarding mortality.**

Abundance estimates

Petersen estimates of the population were obtained using the unbiased estimator proposed by Bailey (1951) and Chapman (1951) (*in* Ricker, 1980).

$$N = \frac{(M+1)(C+1)}{R+1}$$

Where M = Number of individuals marked during the tagging period, corrected for emigration and mortality

C = Total number of individuals captured during the recapture period
R = Number of marked individuals caught during the recapture period

Confidence intervals for the Petersen estimates were calculated using the Poisson distribution as recommended by Ricker (1980).

Results

According to the preceding analysis, the abundance estimate of the undulate population is limited to the Gironde estuary and to the rays longer than 65 cm.

The following input values were used for the Petersen estimate:

M = 183, before the corrections for emigration and mortality (Table 2)

C = 1514, long-liner catch in number in the Gironde area (Fig. 5)

R = 13, number of tagged rays longer than 65 cm and caught during the recapture survey by long-liners (Fig. 5)

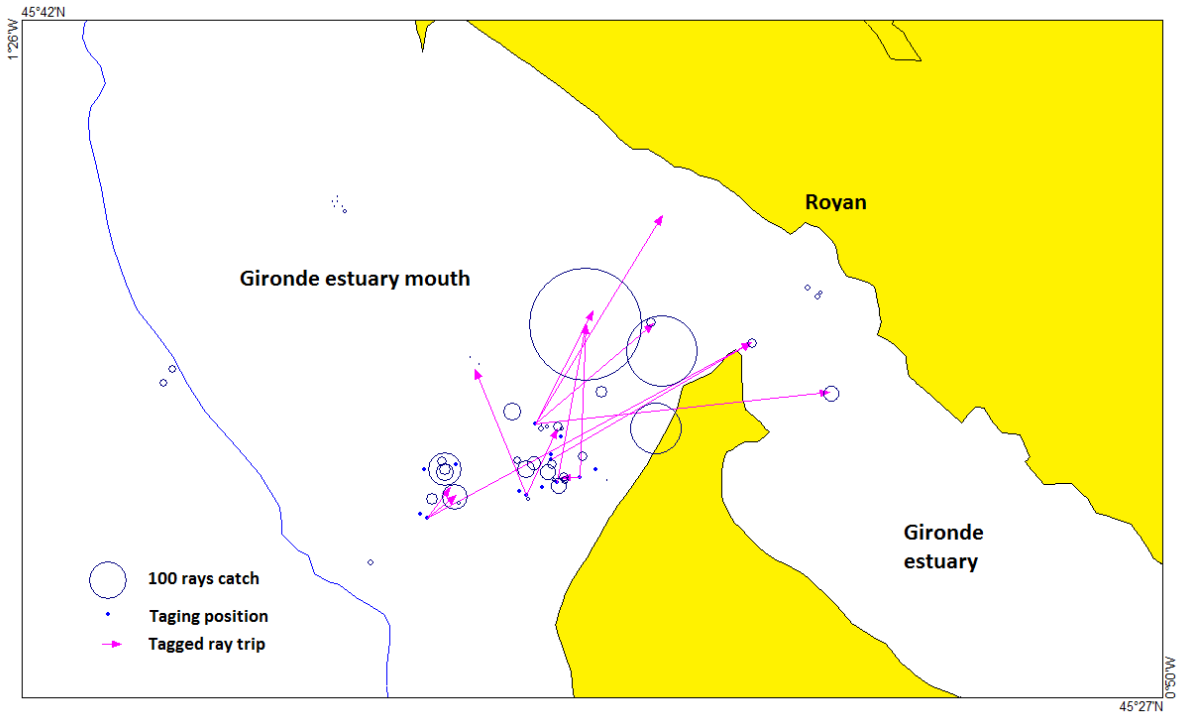


Fig. 5: Undulate ray tagging (Nov.-Dec. 2013), recaptures (April-March 2014) and long-liner catch (Jan.-May 2014) positions in the Gironde estuary

Two sets of results were obtained using the Petersen estimate for a probability to move less far than 7 nautical miles estimated to 0.63 and to 0.79 (Table 3). For each of this probability, the mortality removal was set at 10 % and 19 %. 95% confidence intervals are given. Population estimates in number are been converted to biomass using available weight-length relationship (Dorel, 1986).

Table 3: Population and biomass estimates in the inner Gironde estuary

Probability to move less far than 7 nm	**0.63**		**0.79**	
Mortality removal	**10%**	**19 %**	**10 %**	**19 %**
Abundance estimate (number)	11337	10214	14188	12780
Abundance estimate 95 % confidence intervals	6812-20090	6137-18100	8525-25144	7649-22649
Biomass estimate (t)	56	51	70	63
Biomass estimate 95 % confidence intervals	34-99	30-90	42-124	38-112

According to these results, the biomass of undulate ray longer than 65 cm could range from 51 t to 70 t in the inner Gironde estuary during the 2013-2014 winter. However, 95 % confidence intervals increase this range to 30-124 t.

Conclusion

This mark-recapture estimate of undulate ray abundance faced the difficulty to have a time-lag between the tagging and the recapture phase which must be extended to 5 months. Regarding the tag loss problem, a shorter time-lag must be preferred as the tag-losses, even if they are low, must increase with time. However, even if this time-lag may be shorter, it may be worth doing systematically a double tagging in areas where fixed nets are set.

However, the undulate ray does not move rapidly and furthermore sometimes by aggregated groups as shown by some recaptures. Consequently to shorter the time-lag to less than a month, to be more in line with the typical duration of such study (Pine *et al*, 2003), is likely not to be recommended. According to the observed mean trips in relation with time at liberty, 45 days seems a minimum time-lag to allow tagged undulate rays to mix with the rest of the population.

A second problem was that the recapture survey could not spread over the whole area that may be inhabited by the tagged individuals. The undulate ray may move farer than 7 nautical miles sometimes within less than a month. However, the trips are scarcely greater than 20 nautical miles. The budget limitation led to try to carry out a recapture survey in partnership with the fishing industry. The results are more than satisfactory and show that this solution should be considered whenever it is possible to increase the catch of the recapture phase in such project. Some additional chartered trips should have been useful, particularly between 7 and 20 nautical miles, but the problem may be less important when a project does not address to a species for which there is a landing ban.

This mark-recapture abundance estimate provides thus some guidelines that may allow to estimate undulate ray abundance on a larger scale in the Bay of Biscay. If may be an interesting help for assessing the abundance of a species for which the use of other methods have to cope with a variable and coastal distribution, the lack of fishing statistics series and ageing difficulties.

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