Collect. Vol. Sci. Pap. ICCAT, 81(4), SCRS/2024/048: 1-14 (2024)

ONGOING PROJECTS TO UNDERSTAND AND MITIGATE BYCATCH FROM THE LONGLINE BLUEFIN TUNA FISHERY IN THE FRENCH MEDITERRANEAN

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SUMMARY

Understanding and mitigating bycatch is a major issue for the management of interactions between fisheries and marine ecosystems. In a context of biodiversity loss and climate change that impact marine fauna, research actions are needed to provide solutions for a sustainable future. The French longline fishery for Atlantic Bluefin tuna in the Gulf of Lion reports bycatch for different species. In order to provide solutions, several initiatives in collaboration with professional fishermen have been carried out since the beginning of this fishery in 2011. In the present paper, the different projects and programs developed in the Gulf of Lion are listed and explained. Different observation approaches were designed to characterize the fishery, collect data on bycatch, study the ecology and the post-release survival of these species, while other projects focused on innovative mitigation solutions. Preliminary results and work perspectives are presented.

RÉSUMÉ

La compréhension et l'atténuation des prises accessoires constituent un enjeu majeur de la gestion des interactions entre les pêcheries et les écosystèmes marins. Dans un contexte de perte de biodiversité et de changement climatique ayant un impact sur la faune marine, des actions de recherche sont nécessaires pour fournir des solutions pour un avenir durable. La pêche palangrière française ciblant le thon rouge de l'Atlantique dans le golfe du Lion déclare des prises accessoires de différentes espèces. Afin d'apporter des solutions, plusieurs initiatives en collaboration avec les pêcheurs professionnels ont été menées depuis le début de cette pêcherie en 2011. Dans le présent document, les différents projets et programmes développés dans le golfe du Lion sont énumérés et expliqués. Différentes approches d'observation ont été conçues pour définir la pêcherie, collecter des données sur les prises accessoires, étudier l'écologie et la survie suivant la remise à l'eau de ces espèces, tandis que d'autres projets se sont concentrés sur des solutions d'atténuation innovantes. Les résultats préliminaires et les perspectives de travail sont présentés dans ce document.

RESUMEN

Entender y mitigar la captura fortuita es cuestión fundamental para la ordenación de las interacciones entre las pesquerías y los ecosistemas marinos. En un contexto de pérdida de biodiversidad y cambio climático que impacta en la fauna marina, se necesitan acciones de investigación para facilitar soluciones para un futuro sostenible. La pesquería de palangre francesa para el atún rojo del Atlántico en el golfo de León comunica captura fortuita de diferentes especies. Con el objetivo de aportar soluciones, desde el inicio de esta pesquería en 2011 se han llevado a cabo varias iniciativas en colaboración con pescadores profesionales. Este documento enumera y explica los diferentes proyectos y programas desarrollados en el golfo de León. Se diseñaron distintos enfoques de observación para caracterizar la pesquería, recopilar datos sobre captura fortuita, estudiar la ecología y la supervivencia posterior a la liberación de estas especies, mientras que otros proyectos se centraron en soluciones innovadoras de mitigación. Se presentan los resultados preliminares y las perspectivas de trabajo.

KEYWORDS

Bycatch, longline, mitigation, Gulf of Lion

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Introduction

Bycatch is a cause of marine biodiversity loss, and in the context of the current climate change, the habitat of many species is modified and can affect their interactions with fishing gears (Hoegh-Guldberg & Bruno, 2010; McCauley et al., 2015; Sydeman et al., 2015; Worm et al., 2006). In that context, understanding processes associated with bycatch is important to propose sustainable solutions for the protection and conservation of marine ecosystems.

Longline fisheries are generally considered as selective compared to other techniques but are nonetheless generating bycatch, which depend on factors such as fish distribution, fishing strategy or bait and hook characteristics (Huse et al., 2000; Løkkeborg & Bjordal, 1992). The french longline fishery for Atlantic Bluefin tuna in the Gulf of Lion (LL_BFT_GOL) started in 2011. In 2023, 149 units considered as "small artisanal fishing vessels" were using this technique. The SATHOAN producer organization manages 82 of these vessels, which represents 75% of the quota allocated to the small-scale fishery, with the majority of the activity concentrated in the Gulf of Lion (GOL). In 2014 the collective label, "Thon rouge de ligne, pêche artisanale" (bluefin tuna caught with hook and line, artisanal fishery) was created to promote selective fishing methods and to guarantee sustainable and responsible exploitation. SATHOAN obtained the french ecolabel "Pêche durable" (sustainable fishing) in 2019 and became the first MSC certified BFT tuna fishery in 2020. In 2023, over the 82 boats managed by SATHOAN, 42 were certified by the "Thon rouge de ligne, pêche artisanale" label, 54 were certified with both the "Pêche durable" and MSC labels. These labels strongly encourage more selective fishing to reduce fishing impacts on marine ecosystems. Numerous programs and projects bringing together scientists and fishermen have attempted to provide solutions to tackle the bycatch issue (https://www.bmis-bycatch.org/index.php/). In addition to simply monitoring and quantifying bycatch, different methods have been tested and implemented to mitigate them. For instance, circle hooks are increasingly used as they catch less sea turtles and facilitate the release of some bycatch species (Coelho et al., 2012; Sales et al., 2010). Another example are repellants methods or pingers that are installed on longlines to ward off or scare away seabirds and marine mammals (Gilman et al., 2006; Løkkeborg, 2011; Molina & Cooke, 2012).

In the GOL, BFT is caught alongside other species in the french longline fishery, such as the pelagic stingray (*Pteroplatytrygon violacea*), the blue shark (*Prionace glauca*), the ocean sunfish (*Mola mola*), seabirds species and others (SATHOAN pers. comm., 2024). Several projects, with an active participation of SATHOAN, have been carried out and continue to be developed in order to better understand the dynamics leading to bycatch and to mitigate them (**Figure 1**). The past and present projects are presented through 3 axes that focus on 1) characterizing bycatch from the fisheries through data collection, observations and analysis, 2) proposing tools and methods for bycatch mitigation and 3) estimating their post-release survival.

To tackle these aspects a digital platform (ECHOSEA) was developed for the declaration of catch and bycatch by fishermen. The SELPAL and POBLEU programs developed awareness-raising actions, spreading good-practice rules, and developed an observer program on the fishery to increase the small coverage by national programs. SHARKGUARD and SAVESHARK focused on setting up a repellent device for bycatch species. REPAST and RAYVIVAL are 2 projects that aimed at studying the ecology and behavior of pelagic stingrays and initiated fieldwork to estimate post-release survival. Current projects provide a continuation to these actions and develop innovative technologies. Following the POBLEU project, PROTECT-MED proposes several activities including data collection with an observer program, raising awareness of fishermen and spreading good practices, technological tests aiming at reducing bycatch and replacing baits (artificial baits) and electronic tagging for post-release survival of different bycatch species (ocean sunfish, blue shark, …). SMARTSNAP is an innovative project towards a solution to mitigate bycatch over a broad spectrum of species and the LIFE EMM program is focussing on the study of behavior and post-release survival of blue-shark. This document proposes a synoptic view of the different approaches developed in these projects and the first results obtained (**Figure 1**).

1. Materials and methods

1.1 Characterizing the bycatch from the fishery: data collection, observation and analysis

To understand the interactions between fishing activities and marine ecosystems, one of the fundamental steps is the monitoring of bycatch through basic data acquisition. However, such activity is not necessarily trivial, it classically relies on observer programs that can be both expensive and difficult to implement. Such programs are logistically demanding and can also be limited by fisherman acceptance. In the LL_BFT_GOL, most boats are below 15m and they do not fall within the mandatory category to embark observers. Bycatch data from observer programs are therefore scarce. In order to provide a solution to this, a project was built to develop a smartphone application allowing the fishermen themselves to report bycatch (ECHOSEA). However, such information can be biased, so in the POBLEU project an independent observer program was developed to provide a comparison to the ECHOSEA database. As part of the POBLEU project, 40 fishing operations of LL_BFT_GOL fishery were monitored by one onboard observer on a total of 1465 fishing operations between 2022 and 2023 (3% of cover rate). All the details of the sampling method are documented in *Villalba et al., 2023*. These observation mediums provide information about the gear used, the seasonal dynamics of the fishery as well as bycatch quantity. This permits quantifying the share of bycatch in the total catch. Moreover, the digital platform ECHOSEA and on-board observers were used to understand the seasonality and record the diversity of species visiting the waters of the GOL. However, this information is specific and depends on the fishery. In the PROTECT-MED and LIFE projects, electronic tags different from those of survival studies are deployed. These tags will make it possible to describe the habitat and ecology of the animal and to better understand its interactions with fishing activities. In the context of climate change, these interactions will probably evolve. The data then collected on the phenology of animals present in the study area will make it possible to anticipate the different changes.

1.2 Proposing tools and methods to mitigate bycatch

The initial step was to raise awareness among professional fishermen of the importance of species of no commercial interest in the ecosystem. In addition, a series of actions summarized in a "good practices guidelines" have been defined in agreement with the fishermen in the projects SELPAL and POBLEU. This ensures as much as possible the post-release success as well as the safety of the crew. During the SELPAL project, specific tools have been made available to fishermen to improve the fish release process: pliers, hook remover, personal protective equipment. Users have been asked to comment on the usefulness, practicality, technical aspects and security of these tools. These devices do not reduce bycatch but allow maximizing the survival of the animals.

Hooks are a key aspect for catch efficiency. The hooks must be effective and strong to catch and retain the target species, but doing so, they also substantially affect bycatch species. In that respect, hooks should also be easy to remove to avoid as much as possible that the animal leaves with it or with significant injuries. The choice of the adequate type of hook is therefore complex for professional fishermen. One of the activities of the POBLEU project was to study hook selectivity between circular and J hooks and how easy it was to remove each of these different types of hooks from the fish mouth. For that purpose, an experiment was carried out during 31 fishing trips. 20 trips using J hooks and 11 trips using circle hooks. The number and bycatch species per hook type used was monitored. This made it possible to observe whether a type of hook favored bycatch or not. Additional work on how fast hooks were shedding from pelagic stingrays was carried out in the projects SELPAL and REPAST. Pelagic stingrays were caught with both J and circle hooks and were placed in tanks in captivity conditions for 4 months. The time elapsed before hook shedding was recorded in order to investigate the relationship with hook type. Healing speed was also monitored.

One way to avoid bycatch is to deter non-target species from biting the hook. Many techniques and devices have been developed to keep unwanted species away from fishing gear, but they can sometimes be complex to deploy, too expensive and difficult to maintain (https://www.bmis-bycatch.org/index.php/). The acceptability of these devices by professional fishermen is a major problem for the development of these projects and their practical implementation within their routine activity. In the LL_BFT_GOL fishery, several devices were tested. Kites have been tested to repel birds while the longline is being deployed. Pingers were also developed in collaboration with a private company (FISHTEK) to deter sharks and rays from biting the hook. These devices have been specially developed to avoid selachian bycatch in the SHARKGUARD and SAVESHARK projects. Located just above the hook, they emit a strong electric field in a small perimeter around the hook (Doherty et al., 2022). Experimental tests took place over 12 fishing trips to study the efficiency of these electric pingers to reduce bycatch. Each longline was equipped with more than 500 control hooks (without pingers), more than 100 inactive devices and more than 400 active pingers. The catches of each hook were reported in order to see the effectiveness of the device.

In the SMARTSNAP project a different research avenue is investigated, where the catch is not avoided. An innovative system is being developed to mitigate bycatch for a broad range of species, while keeping a strong focus on fishermen acceptability. The SMARTSNAP device is a watertight housing with a motherboard connecting a battery and multiple sensors (**Figure 2**). The sensors are continuously sampling the activity of the line during the set. Based on these data, the objectives are to discriminate between species in order to inform in real-time the fishermen of their catch, automatically release non-target species and collect data on bycatch. A first experimental phase allowed the design of ~180 prototypes that were deployed during 9 sets from the LL_BFT_GOL (Nieblas et al., 2023a). These first experiments aimed to validate the functioning of the housing as well as the acquisition of behavioral data of the species captured. This data will subsequently be used to feed the analyses and the algorithm, which will discriminate the species by its behavior on the line. For this experimental stage, the release system hasn't been integrated. The prototypes were home-made using PVC for the housing and open source electronic prototyping platforms (**Figure 3**). Further details on the design of the device are explained in *Nieblas et al., 2023b*. Albeit home-made, the PVC housing was reinforced and tested to resist depths up to 300 m. The device is attached with a snap to the main line and connected with another to the leader with the hook (**Figure 2**). A section of the longline was chosen with the fisherman and the devices were deployed one after the other. At the end of the sets, the devices associated with the hook that made the catch were put aside and the catch characteristics were recorded (species, health conditions, size, sex). The data for all the devices, the one associated with the catch and also the others, were retrieved back on land by opening the case and connecting to the computer via USB.

1.3 Estimating post-release survival

For a given individual, the impact of being caught and released in terms of behavior and survival is difficult to assess. The healing of potential injuries caused by the fishing gear as well as the recovery period can be long and are therefore complex to observe. In the REPAST project, pelagic stingrays were placed in tanks right after being caught, in order to observe the behavior of the animal as well as its survival. During 4 months, the animals will be kept in captivity in order to study their recovery capacity. This also makes it possible to monitor the healing speed of wounds caused by the hook. However, these tests do not completely represent the natural environment that the individual experiences. When the animal is released, it is very difficult to predict whether it will survive based on visual assessment of its health condition onboard. Some studies use different physiological markers observed before releasing the animal to predict its survival, for instance the concentration of certain molecules in the individual's blood at the time he is onboard has been linked to his ability to survive (Moyes et al., 2006).

Electronic tagging is a method widely used in marine science to better understand animal behavior (Nielsen et al., 2009; Want et al., 1999). The different sensors installed on the tags record pressure, temperature and light intensity information at different resolutions depending on the type. Based on this data it is possible to estimate survival and to identify recovery behaviors. In order to do that, different types of electronic tags exist with distinct technical characteristics. Four commercial models were used. MRPats and sPats from Wildlife Computers, as well as PSATLife from Lotek and SeaTag-3D from Desert Star. This last model did not work and will not be described later. The MRPat tag is interesting due to its low cost and small size but provides limited data (daily min/max temperature and tilt). sPat and PSATLife tags are more expensive but provide more data in quantity and quality, temperature and pressure at 10 and 5 min resolution, respectively. These last two types of tags also permit studying the ecology and habitat of tagged animals. Pelagic stingray is the most common species into bycatch in GOL. In the IUCN red list, pelagic stingrays are listed as "Least Concern", while their post-release survival is very poorly documented in the LL_BFT_GOL fishery and elsewhere (Kyne et al., 2019; Rigby et al., 2019). 10 electronic tags were deployed as part of the REPAST project to assess the post-release survival of pelagic stingrays caught by LL_BFT_GOL fishery. The data transmitted by these tags made it possible to observe individual behavior after release. This made it possible to identify whether the animal died or not and therefore to calculate a post-release survival rate. Within the RAYVIVAL program, the objective was also to assess the post-release survival of pelagic stingrays, to that end 41 tags were deployed during different longline sets, over two years, and without selecting specific individuals. The individuals were handled similarly as they would have been otherwise by the crew, as in cutting the leader flushed to the hook. Once the information collected by the tags was recovered, time series of depth and temperature data were analyzed on programming and data processing software (R Core Team, 2024). In the context of the PROTECT-MED project, electronic tagging effort to estimate post-release survival will concern a diverse range of bycatch species from the LL_BFT_GOL fishery, such as ocean sunfish or small swordfish, whereas the LIFE-EMM project will put the emphasis on blue sharks.

2. Results

2.1 Characterizing the bycatch from the fishery: data collection, observation and analysis

Since the creation of the french longline fishery in the GOL in 2011, the total allowable catch (TAC) and the bluefin tuna quota for France has been increasing. In 2024, the TAC is 40570 tons and the french quota is 6693 tons. The longliners of the SATHOAN producers organization own 75% of the quota caught by the small-scale artisanal fishery. All 82 vessels managed by the SATHOAN producer organization use the ECHOSEA platform to report catches. The ECHOSEA and POBLEU observation programs both consistently showed that bluefin tuna is the most captured species by this fishery with 92% of weight according to ECHOSEA platform and 84% of weight according to on-board observation by POBLEU project (**Table 1**). The results of bycatch declarations by the digital platform and the observer program seem to agree. The species recorded also seem to be identical between the two methods. Bycatch in LL_BFT_GOL fishery represented 8% of the weight of total catches. 65% of the fishing operations monitored by observers program reported at least one bycatch. Pelagic stingray, blue shark and ocean sunfish are recorded as the three most important bycatch in number of individuals by ECHOSEA platform. Despite their individual weight being low, the pelagic stingray and the blue shark represent a significant part of the catches in number of individuals (**Table 2**). The recording of observations on the ECHOSEA virtual interface made it possible to identify the presence of more than 36 species (seabirds, marine mammals, sharks and rays) in the Gulf of Lion. The spatial distribution of these observations is concentrated in several areas. These areas also correspond to bluefin tuna catching points (**Figure 4**). The seasonality of catches begins from March with strong activity in the summer period. According to the results of the POBLEU program, pelagic stingray and blue shark catches are substantial between July and September. All the details and results of this project are documented in *Villalba et al., 2023*. Deployments of electronic tags as part of PROTECT-MED and LIFE EMM projects to study phenology and habitat of bycatch species are underway.

2.2 Proposing tools and methods to mitigate bycatch

The awareness-raising actions lead the fishermen to respect "good practices" as best they possibly can during their daily activity. In general, during the release process, the line is cut flush with the hook to avoid the drag phenomenon. The different tools that were proposed to the fishermen to improve safety of the crew and release process received mixed feedback. Their acceptability depends on the opinion of each professional fisherman regarding different factors: weight, robustness, effectiveness, practicality, cost, etc... The results of tests on these tools are mixed and none is unanimous among users.

The first results of the work carried out on J and circle hooks seem mixed. Results from the SELPAL project show that all the J hooks fell from the jaw after 7 days while circle hooks fell on average after 44,5 days. However, 64% of bycatch species were caught on J hooks during the POBLEU project onboard observations. Several studies show that circle hooks could reduce mortality of bycatch species. Nevertheless, circle hooks do not appear to reduce the capture rate of sensitive species.

Hooks fitted with SHARGUARD device significantly reduced catch rates of blue sharks and pelagic stingrays, decreasing standardized catch per unit effort (CPUE; individuals per 1000 hooks) by an average of 91.3% and 71.3%, respectively. However, data suggest a reduction of BFT catch of 41.9% on hooks fitted with SHARKGUARD pinger, but this was not statistically significant (Doherty et al., 2022).

To test the SMARTSNAP device, nine deployments were carried out in the Gulf of Lion, four in September of 2022 and five in April 2023. The species caught on hooks equipped with SMARTSNAP were bluefin tuna (n=9), blue shark (n=3), ocean sunfish (n=1), pelagic stingray (n=2) and mackerel (n=2). Six devices failed to record data. Over the 17 catches, only 2 individuals were found dead. As each sensor was set to sample at high frequency, they produced a large amount of data, which provided a lot of information on species behavior. In the present document, an example of the output from the pressure sensors of 2 different species, a bluefin tuna and a blue shark, caught during the same set (April of 2023 in the GOL) is presented (**Figure 5**). The bluefin tuna was found dead, whereas the blue shark was still alive. Several phases could be identified over the duration of the set. The moment of capture was clearly identifiable with a sudden change in pressure after 1h45 for the bluefin tuna and 3h30 for the blue shark. The two different species seemed to show very contrasted behaviors when caught by a longline. In the present case, it seemed that the bluefin tuna dived suddenly and struggled for a sustained period of time between 40 and 60 meters. During this period, vertical oscillations of a few meters could be observed. An hypothesis was that the individual died after 8 hours, but that determination is not trivial. In the case of the blue shark, the animal seemed to spend intermittent periods of time near the surface, with fewer vertical movements than the bluefin tuna.

2.3 Estimating post-release survival

During the SELPAL project, direct observation over 105 sets showed a blue shark mortality rate of 6%. For pelagic stingrays, the observed mortality rate was less than 2%. Within the REPAST project, 10 pelagic stingrays were placed in captive tanks after capture and the line was cut flush with the head of the hook. No mortality was observed after 4 months, and the hook had been lost for 60% of the individuals after one week. Further details and results of this project are documented in *Poisson et al., 2018.*

Tags were deployed within the REPAST and RAYVIVAL projects in order to study behavior and to estimate post-release survival. In the REPAST project, 2 electronics tags out of 7 deployed on pelagic stingrays caught by LL_BFT_GOL fishery seemed to show mortality behavior, which corresponds to a post-release survival rate of 72%. All the details and results of this project can be found in *Poisson et al., 2017.* More recently, the RAYVIVAL project focused on the post-release survival of pelagic stingrays caught by the LL_BFT_GOL fishery. 41 electronic tags (3 PSATLife, 3 sPats and 35 MRPats) were deployed between 2022 and 2023 during a total of 12 sea trips. 38 of the 41 tags deployed transmitted their data successfully (one sPats and two MRPats did not work). Tag retention times were very heterogeneous and the estimation of the post-release survival of each pelagic stingray was not trivial. 33 of the 38 tags were MRPats and provided only minimum and maximum temperature and tilt data per day. Preliminary results seemed to show that pelagic stingrays carried out significant movements in the water column after release. Some individuals showed complex behaviors, for instance an animal seemed to have swam between 0 and 250 m for more than one week (**Figure 6**). After that, a second phase displays a sudden and monotonic dive down to 750 m, which suddenly stopped during 8h and resumed afterwards, to reach depths substantially fluctuating around 1000 m. During one week, the animal performed significant vertical movements reaching a maximum depth of 1400 m. Survival analyzes are still in progress, but determining whether or not the individuals were still alive when the tag reported proved to be highly nontrivial.

3. Discussion

The LL_BFT_GOL fishery seems to have a substantial interaction with its ecosystem. Although longline is a selective gear for catching bluefin tuna (more than 80% of the total volume of the catch), other marine species are accidentally caught (Poisson et al., 2019). To better understand these bycatch and mitigate them, several initiatives and programs have been developed and implemented. The digital platform for recording bycatch and observations at sea by professional fishermen appears to be validated by on-board observers. The catch composition of the target species (bluefin tuna) is similar between ECHOSEA declaration and POBLEU observations. For the catch composition of bycatch species, ECHOSEA and POBLEU results also agree (**Table 1**). Therefore, the use of the ECHOSEA declaration interface makes it possible to build a very rich and rare database. This unique database provides a very good basis to characterize bycatch and monitor it. The characterization of the fishery and the quantification of bycatch seems to show that the marine species most affected by longline fisheries in the Gulf of Lion appear to be the pelagic stingray (*Pteroplatytrygon violacea*), the blue shark (*Prionace Glauca*) and the ocean sunfish (*Mola mola*). The pelagic stingray is captured in large quantities but its conservation interest is very low while the other two species are less impacted but their situation is more worrying (Kyne et al., 2018; Liu et al., 2011; Rigby et al., 2019). Moreover, the impact of the fishery on these 3 species is very poorly documented. It is therefore important to understand the consequences of fishing activities on these species in order to apply appropriate bycatch mitigation measures.

The methods and tools that were proposed to mitigate bycatch were found to have mixed results. Awareness-raising measures and guidelines allowed professionals to adopt good practices aiming at maximizing the survival of animals after release. The work on selectivity showed that J hooks remained on the animal for a shorter period of time than circle hooks, but several studies show that circular hooks reduce bycatch mortality (Ferrari & Kotas, 2013; Yokota et al., 2006). The devices tested on longlines to keep these sensitive species away were found to affect the catchability and to reduce the catch of the target species (Doherty et al., 2022). This therefore created an issue of acceptability among professional fishermen.

SMARTSNAP aims at providing a mitigation solution applicable to a broad range of species. Preliminary results show that for a given set the behavior of two distinct species can be discriminated using the depth sensor, even though it is not expected that species-specific behavioral differences will always be easy to distinguish, the addition of the data from the other sensors is expected to provide enough information to differentiate them (**Figure 4**). One important aspect to consider is that the behavior recorded on one device might propagate to the neighboring ones, which might complicate the determination of a catch event for a given hook. Once again, the fusion of data from different sensors might be able to provide enough information to overcome this. The amount of high resolution data acquired by these devices is already very significant and its analysis is underway. These data will be used to feed machine learning algorithms, in order to predict species caught on the line from their behavior. If it is a bycatch species, the future objective is that a release system will instantly be activated, reducing the time spent on the longline and maximizing survival probability. Other issues then emerge regarding the fate of the hook and the fishing line, which can remain on the individuals. Hooks can shed by themselves for some species, such as pelagic stingrays, but in other cases they may not. This is overall problematic, because it may affect the survival rate of the released individuals, but also because this will constitute a form of plastic pollution. To tackle this, several studies focus on using biodegradable fishing line, but their technical characteristics are currently not appropriate for commercial use in a longline fishery and require further developments (Cerbule et al., 2022; Deroiné et al., 2019). To inform the fisherman of its catch in real time, a communication medium between each device and the boat will have to be developed. This could provide information on fishing efficiency, spatio-temporal dynamics of the gear as well as information on aspects of the ecology and capturability of the species.

Ensuring the post-release survival of bycatch individuals is a general objective. The quality of the declarations from the ECHOSEA platform allow to characterize the interaction of the fisheries with different species, in space and time. Electronic tagging approaches are then used to provide behavioral data and post-release survival estimates. Preliminary results were obtained on post-release survival of pelagic stingrays but complementary data acquired from additional tag deployments in the RAYVIVAL project are being analyzed. The LIFE EMM project aims at completing tagging experiments on blue sharks, an important bycatch and a more sensitive species, to both provide an estimate of post-release survival and also data on its habitat and ecology that will serve to study its potential interaction with the fishery. The PROTECT-MED project will focus on tagging experiments for other species (ocean sunfish, mobula ray and other shark species). These electronic tagging operations are in process and will make it possible to better understand the potential recovery behavior of these species after being released. Individual tracking will be used with the spatio-temporal information from ECHOSEA to identify the phenology of each species and their specific fishery interaction. Nevertheless, the modification of habitats as a consequence of warming waters could affect this phenology. In a context of global climate change, the presence of marine species previously absent or little observed could increase (Duarte et al., 2020). This would intensify interactions between fisheries and marine ecosystems, for instance with species that are currently not much impacted. An ongoing and active line of research projects has been developed for more than 10 years in the french Mediterranean, through a tight collaboration between scientists and professional fishermen from the LL_BFT_GOL fishery, to ensure both the sustainable exploitation of target species and the protection of marine resources.

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Table 1. Catch composition (% of weight) from ECHOSEA platform and POBLEU project observations of French longliners in Gulf of Lion in 2022-2023.

	ECHOSEA	POBLEU
Bluefin tuna	92	84
Swordfish	3,6	7
Blue shark	1,5	4
Pelagic stingray	2,1	5

Table 2. Catch composition from ECHOSEA platform declaration of French longliners in Gulf of Lion in 2023.

	% of weight	% of number
Bluefin tuna	92	56,6
Pelagic stingray	2,1	30,4
Blue shark	1,5	4,2
Others	4,4	8,8

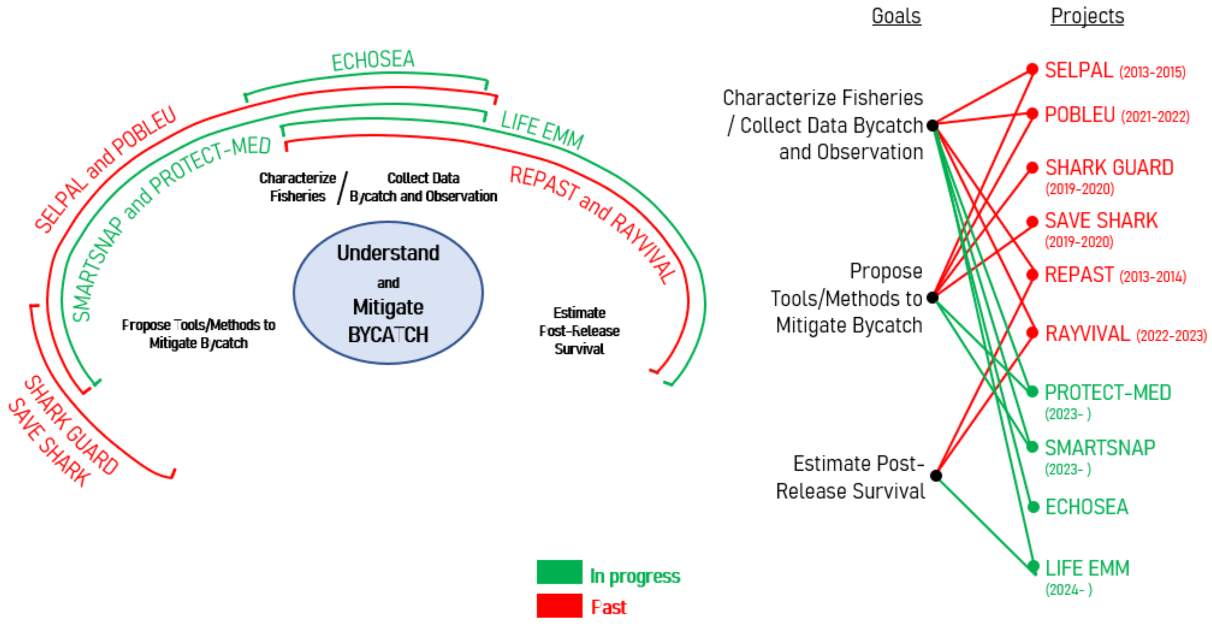

Figure 1. Conceptual diagram of the different projects and objectives developed around the bycatch of longline fisheries in the French Mediterranean.

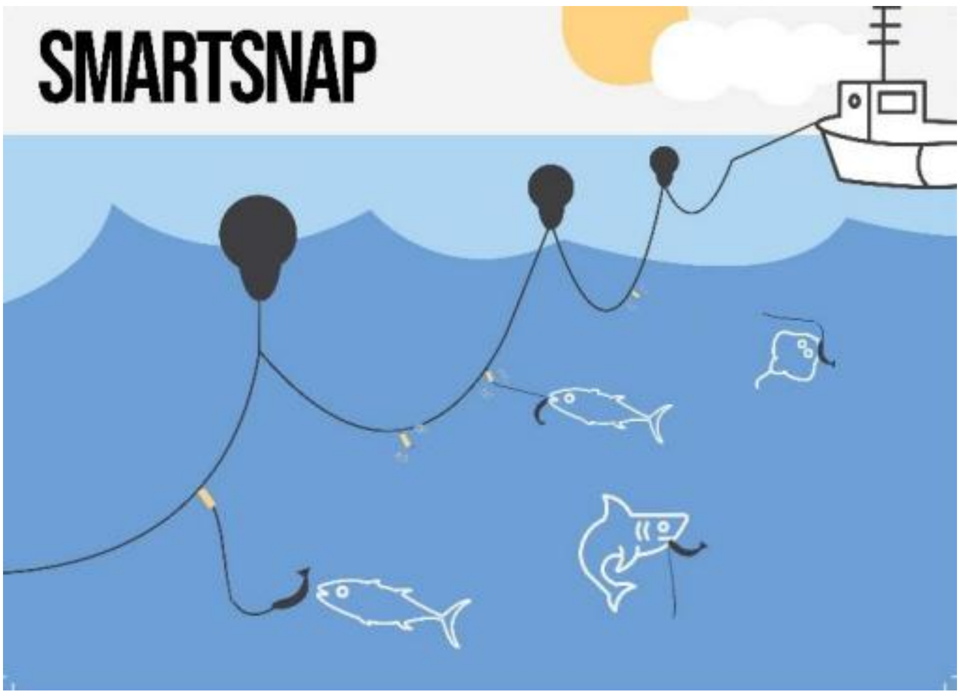

Figure 2. Schematic principle of the SMARTSNAP device.

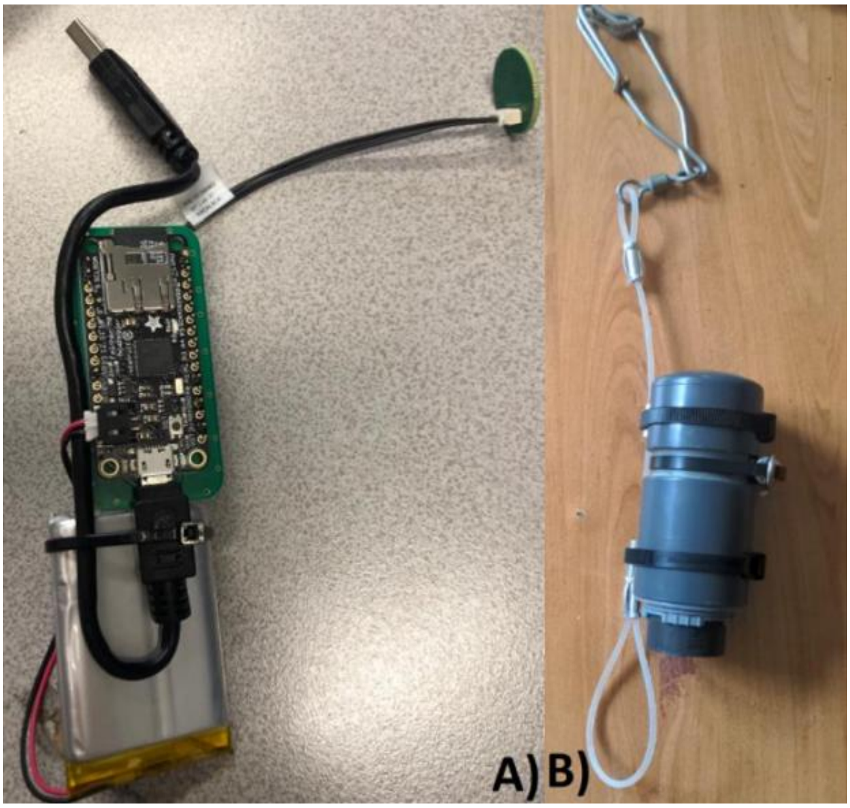

Figure 3. Manufactured prototype of the SMARTSNAP device. Intern part with electronic system and battery (A) and closed device with rigging system and snap ready to deploy (B).

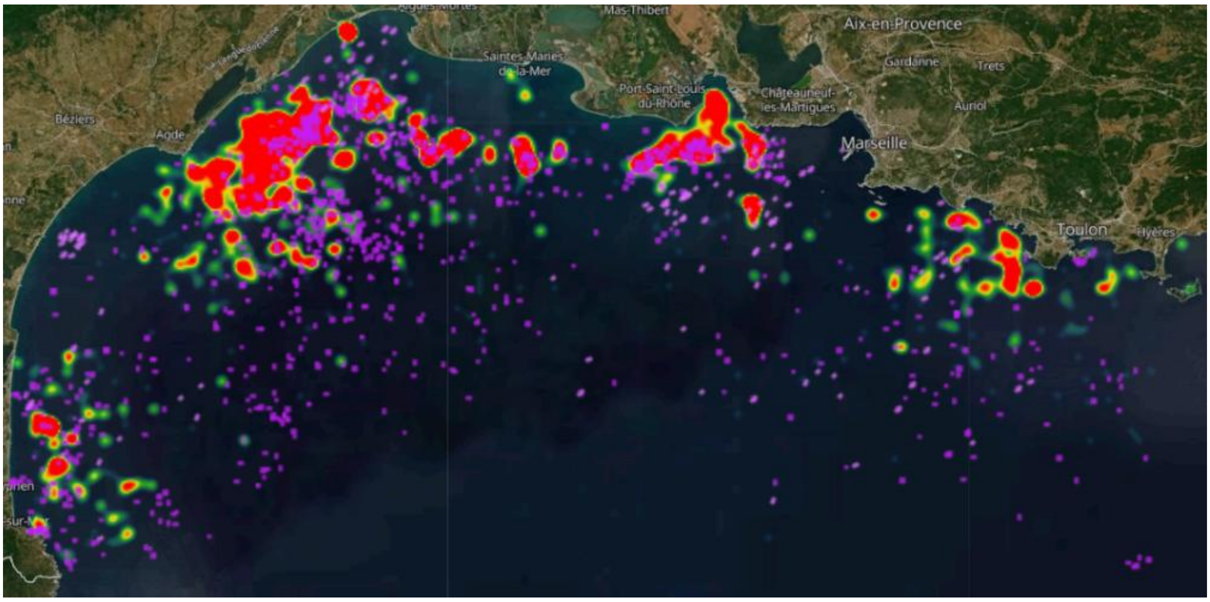

Figure 4. Map of presence gradient of observations by ECHOSEA platform and bluefin tuna catching locations (purple point) in 2023.

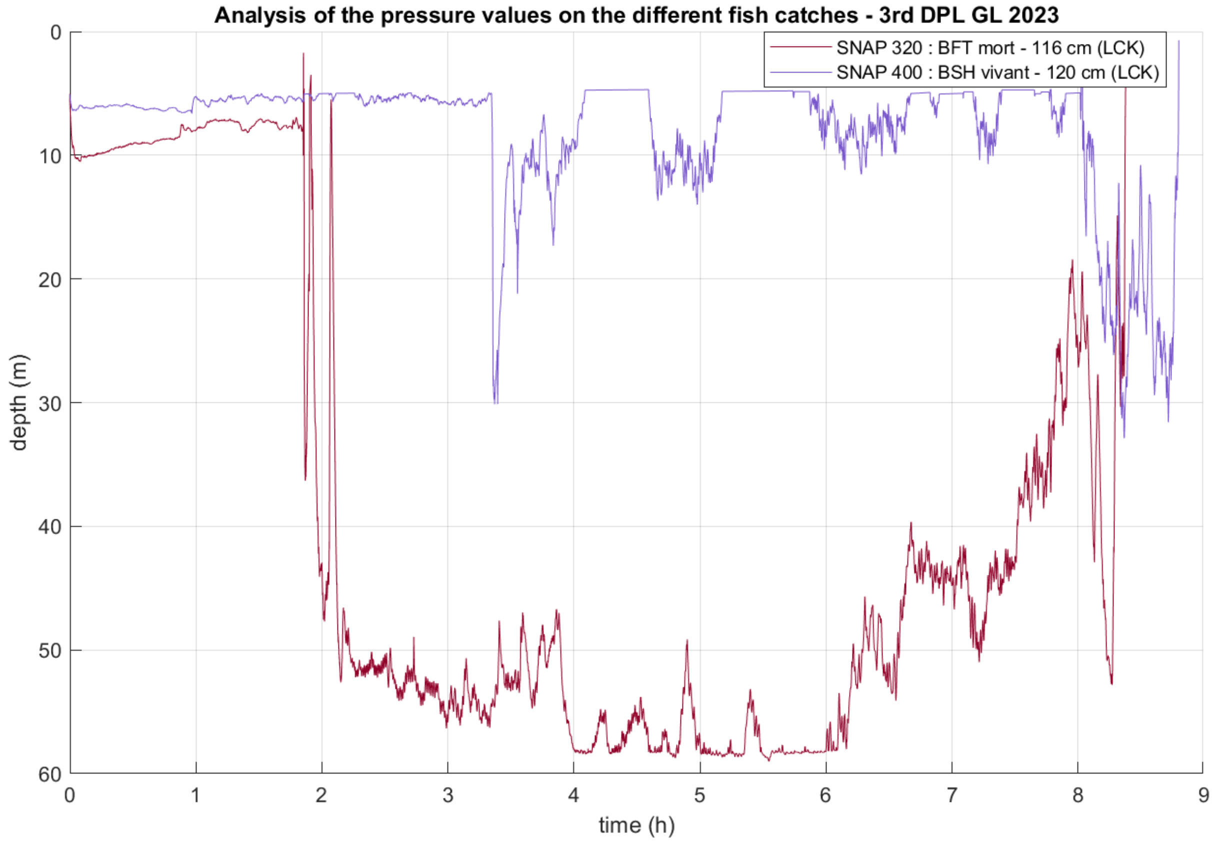

Figure 5. Depth time series for two SMARTSNAP devices deployed on a longline in the Gulf of Lion, which caught a blue shark that remained alive (purple line) and a bluefin tuna that died by the end of the set (red line).

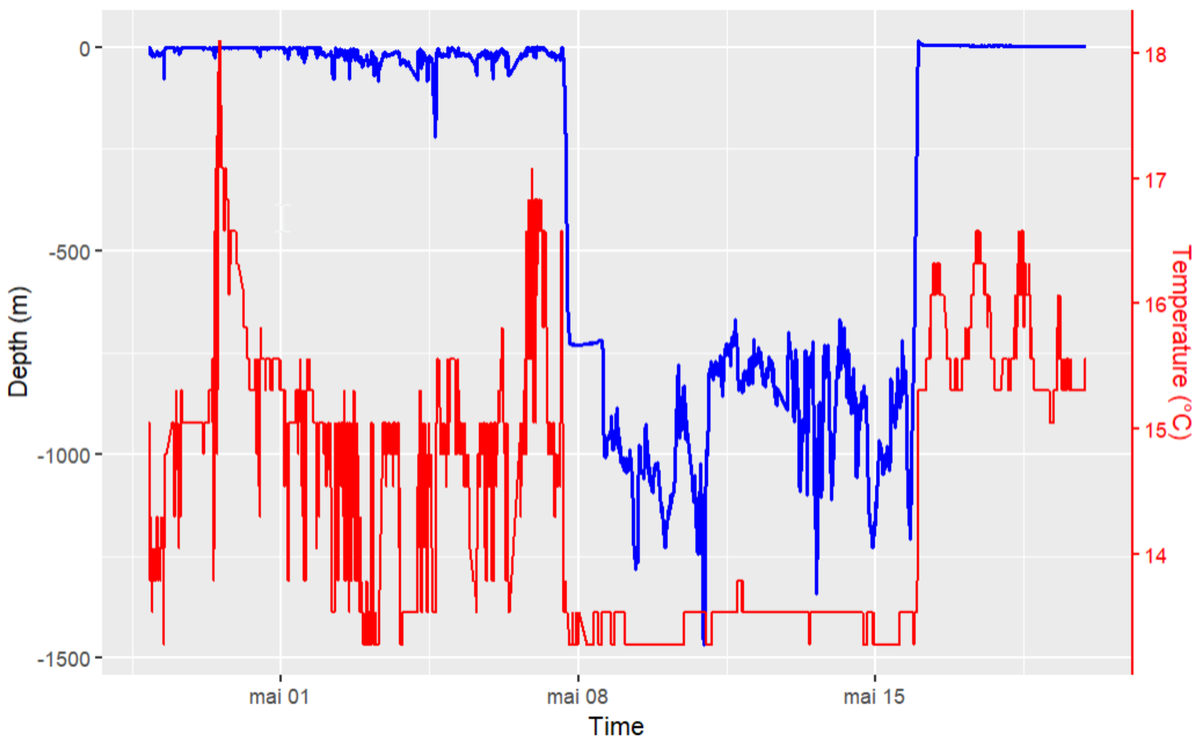

Figure 6. Depth and temperature profile (each 5 min) from a survival tag (PSATLife from Lotek) deployed on a pelagic stingray caught by a longliner.